Information Technology Systems Installation Methods Manual

Sixth Edition









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ITSIMM 6th Expanded to Address Continually Evolving ITS Industry

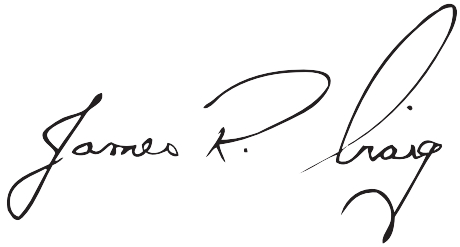
This sixth edition of BICSI's *Information Technology Systems Installation Methods Manual* (*ITSIMM*) has been greatly expanded to include three new chapters covering data centers, health care facilities, and enhanced safety procedures. Existing content in the *ITSIMM* 5th edition has also been thoroughly updated to reflect new installation technologies in the constantly evolving information technology systems (ITS) industry.

During the Editorial Review held in July 2010 at BICSI World Headquarters in Tampa, Florida, 16 of the ITS industry's finest cabling installation subject matter experts (SMEs) contributed to a complete reorganization of the existing chapters of the *ITSIMM* 5th edition, resulting in the production of a high-quality document providing installation personnel and planners throughout the world with BICSI best practices for ITS infrastructure in customer premises.

Special thanks to Robert Faber for undertaking the last-minute task of reviewing and updating the contents of Chapter 5: Copper Structured Cabling Systems. His expertise and dedication to all BICSI technical manuals and standards are very much appreciated.

Last, but certainly not least, I would like to thank all of the dedicated volunteers who gave so much of their time and talent to the development of this manual. BICSI and the ITS industry owe them a great debt of gratitude.

James R. (Ray) Craig, RCDD, NTS, ITS Technician, Certified Trainer



TI&M *ITSIMM* SME Team Leader

Thank you for ordering the *Information Technology Systems Installation Methods Manual,* 6th edition, 2010. Please place the chapter tabs and appendix tabs in front of the title page for each chapter and appendix.

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Information Technology Systems Installation Methods

M A N U A L

6th Edition



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Thank you for ordering the sixth edition of BICSI's *Information Technology Systems Installation Methods Manual* (*ITSIMM*). The officers and management of BICSI are pleased to provide an up-to-date reference manual that offers proven guidelines and methods accepted by the ITS industry. Volunteers outside the United States and Canada have provided valuable input to make the newest edition of the *ITSIMM* a valuable tool for an international audience.

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This technical reference manual is not a single source document but a compendium of many sources of ITS industry- related practices, processes, and procedures.

The information contained in this technical reference manual includes, but is not limited to, national and international codes, de jure and de facto standards, and industry- accepted best practices. All source information can be found in Appendix A: Codes, Standards, Regulations, and Organizations, and the Bibliography and Resources of this manual.

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Acknowledgments

BICSI's Technical Information and Methods (TI&M) Committee serves to coordinate the information within all of BICSI's technical publications. BICSI officers, membership, and Publications staff wish to thank the TI&M Committee and its many volunteer contributors who helped in the development of the sixth edition of BICSI's *Information Technology Systems Information Methods Manual* (*ITSIMM*).

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- In general, soft (approximate) conversions are used in this manual. Soft conversions are considered reasonable and practicable; they are not precise equivalents. In some instances, equivalents (hard conversions) may be used when it is a:
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  - Standard or code requirement.
  - Safety factor.
- For metric conversion practices, refer to SI 10-02 American Society for Testing and Materials (ASTM)/Institute of Electrical and Electronics Engineers® (IEEE®) SI 10, American National Standard for Use of the International System of Units (SI): The Modern Metric System.
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- In some instances (e.g., optical fiber media specifications), the physical dimensions and operating wavelengths are designated.
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Chapter number and name are indicated at the outside top of each page.

Chapters are divided into sections.

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Each chapter section is divided into multiple subheadings.

Part Heading

Part headings are used to discuss major areas of a topic.

- Bullet important terms and phrases.
  - Bullets are often followed by more detailed information.

Figures, examples, and tables are numbered sequentially in a given chapter. Each is followed by a brief descriptive title.

Figure 1.1
Title

Page numbers are shown at the bottom of the page. The chapter number precedes the page number.

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Chapter 1 Installation Foundations

Chapter 1 establishes the fundamentals of information technology systems (ITS) installation practices and recommends strategies for enhancing professionalism in the ITS workplace. This chapter provides ITS installers with information related to industry terminology, copper cable and optical fiber cabling media, and communications/customer relations best practices.

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Transmission Methods and Media

Introduction

This section discusses the transmission of information over various physical media. It also identifies the impact that information technology systems (ITS) cabling installation methods have on the transmission of information.

In the context of this manual, transmission is the movement of information in the form of electrical or optical signals from one point to another through a transport medium (e.g., air, balanced twisted-pairs, optical fiber strands). This section deals with the use of copper conductors and glass strands for the transmission of signals in analog or digital form.

Three transmission methods are:

- Simplex, which transmits signals in one direction only. A public address system is an example of simplex transmission. The signal, or the speaker's voice, is carried to a number of loudspeakers. The listener has no path to respond.
- Half-duplex, which can transmit signals in either direction but in only one direction at a time. This type of transmission typically requires agreement between stations and involves a "push to talk" switch arrangement on voice circuits or a signaling protocol on data circuits.
- Full duplex, which can transmit signals in both directions at the same time. All telephone circuits are full duplex, allowing both parties to talk simultaneously.

The choice of a specific transport medium is influenced by economics and technical considerations such as the:

- Physical diameter of the cable.
- Type of services to be provided (e.g., voice, data, video).
- Topology and size of the network.
- Transmission path distance.
- Transmission performance characteristics of the cabling.

In balanced twisted-pair cabling systems, when the adverse effects of electromagnetic interference (EMI) conditions cannot be remedied by shielded balanced twisted-pair cabling or by increasing the physical separation between the balanced twisted-pair cabling and the source of problematic EMI, optical fiber cabling may be useful in mitigating such problems.

Introduction, continued

All balanced twisted-pair and optical fiber media feature certain transmission characteristics that limit or define their respective performance capabilities. Media selection, therefore, may be based on specific network requirements when such network requirements are known.

For balanced twisted-pair cabling, the assignment of a category or classification performance rating (e.g., category 3/class C, category 5e/class D, category 6/class E, category 6_A/class E_A, category 7/class F, category 7_A/class F_A) provides a simple means to select cabling suitable for the ITS applications equipment that is intended to be supported.

Twisted-pair cable is called balanced cable because the physical construction of both conductors is at the same potential. Coaxial cable is unbalanced because the two conductors are at different potential.

Terminology

This section defines the major terms associated with signal transmission. The objective is to show the impact that improper cabling installation can have on media transmission characteristics.

Power, Current, and Voltage

True (real) power (P) measured in watts (W) has two variations also known as apparent or reactive power. When measured with a time element (e.g., seconds, hours), this type of power applies to the energy consumed by an electrical device (e.g., motor, amplifier, telephone transmitter). Power is derived from electrical pressure measured in volts (V) and electrical current measured in amperes (A). Using a water analogy, voltage may be thought of as the water pressure while current represents the quantity of water delivered. A power source having voltage without current flow will not provide any power and, therefore, will not energize a device to perform the desired function.

Apparent power is equal to the voltage (V) multiplied by the current (I) or P = VI. It is usually referenced in volt-amperes (VA). Apparent power is specified in alternating current (ac) circuits that have reactive components (inductors and capacitors).

Peak power (P_P or P) is shown as watt (W) but is actually V × current in amperes (A). Manufacturers of electronic devices usually show VA to signify apparent power. Reactive power represents the power stored by the reactive loads (inductors and capacitors) and is measured in volt-amperes reactive (VAR). Reactive power is only temporarily stored and not consumed and is sometimes called imaginary power.

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Terminology, continued

Peak power is a measure of electrical service consumption that a given device is designed to accept. It indicates the maximum power that is required for the device to operate under full load conditions. However, peak power is present only twice during a cycle. A better indication of power consumption is average power (P_A). Average power is the sustained power over 70 percent of the cycle and is shown in watts; it represents the usable portion of ac power.

$$P_A = 0.707 \times V \times A$$

EXAMPLE:

A device operating at maximum load under normal conditions uses 4.5 A at 120 V.

$$P = 4.5\ A \times 120\ V = 540\ VA$$

$$P_A = 0.707 \times 4.5 \times 120 = 382\ W$$

The amount of current flow in a telecommunications circuit is usually very small compared with that of a commercial electrical power line.

Electronic equipment and uninterruptible power supply (UPS) are generally rated in true power if shown as W and in apparent power if shown as VA.

Alternating Current (ac) and Direct Current (dc)

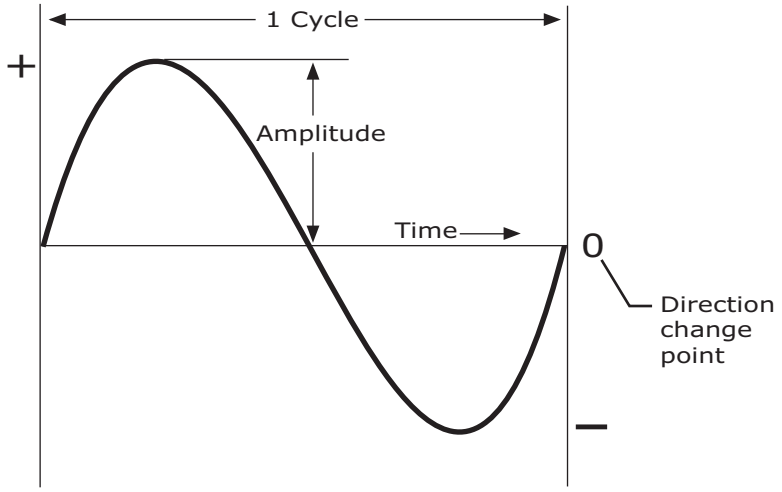
The standard commercial and residential main power frequency differs, depending on the region. The two standard frequencies are 60 hertz (Hz [cycles per second]) and 50 Hz. Generally, these can be attributed to North America (60 Hz) and many other regions of the world (50 Hz). Always confirm the standard frequency for the region with the authority having jurisdiction (AHJ).

For each sine wave in ac, the voltage begins at the zero level and increases to its maximum positive value before dropping back to the zero level where the voltage becomes negative. The voltage continues to track in the negative level to reach a maximum negative value; it then becomes less negative until it reaches the zero level again and completes the cycle (see Figure 1.1). Although the voltage has gone to zero twice in each cycle, the eyes cannot perceive the rapid increase and decrease of the voltage and the accompanying flicker of a lamp.

Direct current (dc) refers to a steady value that does not change the polarity of the voltage or the direction of the current. It rises to its maximum value when switched on and remains there until the circuit is interrupted. A battery is an example of a dc source.

Terminology, continued

Figure 1.1
Analog sine wave



Electromagnetics

All electrical activity produces electric and magnetic fields. Unwanted coupling of these fields can be minimized with proper cabling system component selection, cabling system design, and cabling system installation methods, including the associated cabling pathways selection and implementation, collectively known as telecommunications cabling and pathways infrastructure.

The subjects of EMI and radio frequency interference (RFI) are very complex. However, in most cases involving telecommunications cabling and pathways infrastructure, the adverse effects can easily be minimized with appropriate cabling system component selection, proper installation procedures, following power separation guidelines, and efficient and standards compliant bonding and grounding (earthing) methods where applicable.

Varying levels of EMI/RFI can cause problems, including signal corruption, component malfunction, equipment failure, property damage, injury to personnel, and loss of life in the case of extreme exposure. As a result, it has both technical service and safety issues. Nearly all undesirable circuit noise can be directly or indirectly traced to EMI or RFI sources:

- EMI is the random, unwanted energy that is coupled into a conductor or circuit from an external source. In ITS, that source could be external to the cable (e.g., other cables [alien crosstalk (AXT)], motors, fluorescent lighting, switching power supplies) or internal to the cable (e.g., from another pair within the sheath [crosstalk] or from the cable's shield, screen, or other metallic component that is improperly bonded and grounded).
- RFI is a disturbance in the reception of radio and other electromagnetic signals because of conflict with undesired signals.

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Terminology, continued

Any dc magnetic fields greater than 500 milligauss (mG) may create image distortion on a video display terminal (VDT). Sources that create strong dc magnetic fields include magnetic resonance imaging (MRI), dc arc furnaces, building elevators, and subway trains. VDTs may need to be properly shielded in order to reduce or eliminate distortion.

Image distortion on a VDT also can be caused by ac electromagnetic fields (EMFs) as low as 5 mG. Most ac image distortion on VDTs is the result of elevated magnetic fields from 50 Hz or 60 Hz power distribution equipment (e.g., overhead power lines, transformers, switch gear, busways, power cabling). Smaller, more isolated EMF sources (e.g., motors, office equipment, adjacent monitors) also can cause distortion when in close proximity to the victim VDT.

It is important to distinguish between EMFs caused by circuit conductors being unduly separated (high current) and fields caused by grounded conductors being unduly paralleled (net current). Although the fields from a high-current conductor are fundamentally indistinguishable from those from a net current wiring error, the available mitigation strategies are quite different. Net current fields weaken directly with distance, whereas transformer fields weaken with the cube of the distance (very fast). Shielding is ineffective for net current but is effective for a transformer. One way to clearly show the shape of the field and to identify the source is to take measurements with a gauss meter in a grid pattern throughout the equipment room (ER). Sources of the field typically are transformers or switching cabinets, busses, or incorrectly wired power circuits.

Electrical code violations can cause return current to travel on grounding (earthing) conductors throughout the building. In a typical telecommunications room (TR) or ER, many different pieces of electronic equipment are interconnected with telecommunications cabling and power cabling. It is important to minimize the chance of interference between the installed equipment, supporting infrastructure, and interconnecting cabling.

In the ER, EMI can couple itself onto telecommunications circuits and corrupt data packets being transmitted on that medium. This may cause corruption of the data that is being transmitted and stored. If the corrupt data is an address bit or part of a computer command, it can cause retransmissions of the data within a computer system or storage array, effectively reducing the transmission rates.

ITS installers, technicians, and designers must consider sources of EMI when designing or installing ITS equipment on walls, racks, or cabinets that share or separate telecommunications equipment and power equipment.

Terminology, continued

Frequency

Frequency is defined as the number of cycles a signal is repeated in a given time period. Typically, an ac signal is shown as a sine wave (see Figure 1.1). If the unit of time is equal to 1 second (s), the frequency is stated as 1 Hz.

The following are frequency unit sizes and names:

- 1 cycle in 1 s = 1 Hz
- 60 cycles in 1 s = 60 Hz
- 1000 cycles in 1 s = 1 kilohertz (kHz)
- 1 million (1,000,000) cycles in 1 s = 1 megahertz (MHz)
- 1 billion (1,000,000,000) cycles in 1 s = 1 gigahertz (GHz)
- 1 trillion (1,000,000,000,000) cycles in 1 s = 1 terahertz (THz)

Although humans can hear frequencies that range from 20 Hz to 20,000 Hz, typical voice-grade electrical transmission (e.g., telephony) is generally limited to 100 to 4000 Hz. Transmission of speech is generally limited to 300 Hz to 3400 Hz, which covers the majority of the spoken voice range under normal conversational conditions.

Bandwidth

Bandwidth is the information-carrying capacity of a system. The overall bandwidth of a telecommunications system is related to the respective bandwidths of its component parts. The bandwidth or capacity of a system will also vary depending on its length.

Signal

The information transmitted by a telecommunications system can originate in two fundamental forms—analog and digital. Analog data (e.g., speech waveform) is represented by the continuous variation of the message, whereas digital data is represented by a string of bits:

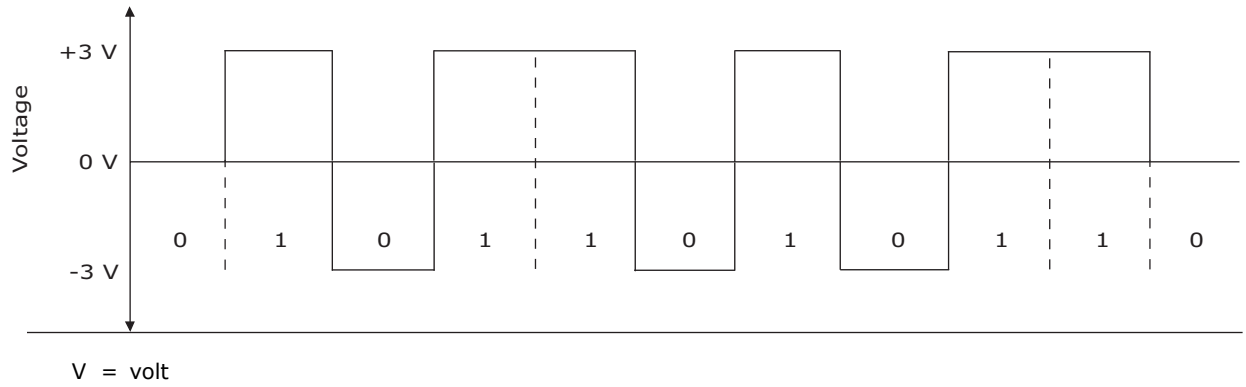
- Analog signal—Analog is derived from the term analogous, which means “similar to.” Analog transmission uses continuously varying electrical signals that directly follow or are similar to the changes in loudness (amplitude) and frequency (tone) of the input signal (e.g., human voice). For instance, the transmitter of a telephone converts sound waves to an analog electrical signal that varies in amplitude (signal strength) directly with the loudness of the voice and varies in frequency directly with the tone of the voice.

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Terminology, continued

- Digital signal—A digital signal is a discontinuous signal that changes from one state to another in a number of distinct steps within fixed bit framing time slots (see Figure 1.2). In its basic form, there are two states or signal levels—on and off where the "on" translates to to a one level corresponding to the digit one (1), and "off" translates to a zero level corresponding to the digit zero (0). Other means can be used to represent the two states (e.g., positive and negative voltage).

Figure 1.2
Digital signal



The digital message consists of a sequence of these digital pulses (bits) transmitted at regular and defined time intervals. These bits are usually rectangular in shape. Therefore, digitally transmitted information is an encoded representation of input unlike analog transmissions, which reproduce an analog input in both frequency and amplitude.

Digital Transmissions

The basic unit of digital information is a bit (a contraction of the term binary digit). It is used to indicate the existence of two (binary) states or conditions (on or off). In legacy electronic systems, current flow was controlled to indicate an on or off state.

In modern electronic systems, it is less complicated to change a voltage level (on/off state) of an existing current flow than to establish a new current flow each time a pulse is needed. This on/off state is accomplished with an electrical voltage pulse within a predefined time slot, which is greater than a continuous base or reference level (voltage) present during an entire message transmission.

NOTE: This base voltage is often shown on graphs as a zero reference voltage for simplicity, but it is actually a continuous current flow of a known and very stable voltage level (24 V and 48 V are common).

Terminology, continued

EXAMPLE:

> When a device first starts a transmission, it will employ a nominal base voltage of some level (e.g., 24 V). A pulse of + 3 V would indicate an on state, and the line voltage would rise from 24 V to 27 V. When the voltage level returns to the 24 V base, it would represent an off state.
>
> This example explains how a negative voltage pulse would work (unipolar nonreturn-to-zero [NRZ]). If a system were bipolar (+ 3 V and – 3 V), then – 3 V would indicate the change in base voltage from 24 V to 21 V and represent a negative pulse or on state. In this case, an on state will be either + 3 V (27 V) or – 3 V (21 V) while an off state would be 24 V.
>
> When a series of bits are grouped into a coded sequence (usually 4 or 8 bits), they make up basic building blocks that can convey information. The information that is conveyed depends on how a programmer references these building blocks to a table of information.

Modem

The transmission of digital data (from a computer) can be accomplished on a direct digital basis over a digital circuit, or it can be converted to an analog signal with a modulator/demodulator (modem). These modems convert the digital signal's 1s and 0s into two distinct analog frequencies, each representing a 1 or a 0. This analog signal is then transmitted over a standard telephone circuit. The process is reversed at the opposite end to recreate the original digital signal.

Codec

The transmission of analog data (from video devices) can be converted from analog format to digital with a coder/decoder (codec). These codecs convert the amplitude changes of various frequencies into a digital format for transmission over digital transmission media. The process is reversed at the opposite end to recreate the video images.

Analog to Digital Conversion

For analog inputs (e.g., voice), the conversion to a digital signal for transmission over a digital media involves a sampling process. An analog signal is sampled often enough that, when recreated, there is an acceptable facsimile of the original signal's data.

The most common process for voice conversion is called pulse code modulation (PCM). PCM samples the analog voice signal 8000 times per second to create a digital voice channel of 64,000 bits per second. All carriers use this method. However, other methods to compress the voice into smaller data streams are becoming popular because of voice over Internet protocol (VoIP), especially when used with wireless fidelity (Wi-Fi).

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Terminology, continued

Analog and Digital Subscriber Line (DSL) Convergence

Telecommunications signaling evolved from telephony systems. Information technology (IT) evolved from office computing machines. Distributed computing evolved from IT centers such as central offices and corporate data centers. The convergence of traditional telephony and distributed computing is now possible because both forms of IT can transmit over one set of transmission protocols (e.g., Ethernet).

The local loop of the public switched telephone network (PSTN) was initially designed to carry plain old telephone service (POTS) voice communication and signaling. The POTS signal range is transmitted between 300 and 3400 Hz, which is regarded as the range for human speech to be clearly audible. Commonly known as voiceband bandwidth, it is only a fraction of what can be transmitted on a single balanced twisted-pair cable. The local loop connecting the telephone exchange to most subscribers has the capability of carrying frequencies well beyond the 3.4 kHz upper limits of POTS.

Digital subscriber line (DSL) technology uses available bandwidth above the POTS range by creating 4312.5 Hz wide channels between 10 and 100 kHz, depending on how the system is configured. Allocation of channels continues at higher and higher frequencies (up to 1.1 MHz for asymmetric digital subscriber line [ADSL]) until new channels are deemed unusable. More usable channels equates to more available bandwidth. The pool of usable channels is then split into two different frequency bands for upstream and downstream traffic and is bonded together into virtual circuits, one in each direction. DSL transceivers constantly monitor the quality of each channel and will add or remove them from service depending on whether they are usable.

Traditional dial-up modems modulate signals in the 300–3400 Hz baseband. DSL modems modulate frequencies from 4000 Hz to as high as 4 MHz. This frequency band separation enables DSL service and POTS to coexist on the same balanced twisted-pair.

ADSL is one form of DSL technology, which allows faster data transmission over balanced twisted-pair cabling. Standard ADSL is full duplex, which uses 26,000 kHz to 137,825 kHz for upstream communication and 138 kHz to 1104 kHz for downstream communication. These frequency channels are sometimes referred to as bins. Each bin can carry a theoretical maximum of 15 bits of information. During initial synchronization (train-up), the ADSL modem tests each of the bins to establish the signal-to-noise ratio (SNR) at each bin frequency. The total maximum capacity derived from summing the bits-per-bins is reported by DSL modems and is sometimes termed the sync rate. Both downstream and upstream SNR rates are important when verifying the quality of a DSL circuit.

Transmission characteristics and testing procedures of each frequency range (e.g., voice, data) need to be understood by the ITS technician.

Terminology, continued

Megahertz (MHz) and Megabit (Mb)

It is important to understand the relationship between megahertz and megabits. Megahertz quantifies the bandwidth of a cabling system in a frequency range of interest (e.g., 1–1000 MHz category 7_A/class F_A cabling). This relates to the information-handling capability of the media (e.g., size of the highway).

Megabit (Mb) refers to the number of bits of information that can be transported over the media (e.g., vehicles on the highway). The number of bits that can be transported over the media is determined by the type of encoding scheme used in a system. With a simple encoding scheme (low efficiency), one bit may be transported by one cycle (a single vehicle). More complex encoding schemes (high efficiency) may have multiple bits of information transported in a single cycle (multiple vehicles on a car transporter).

Decibel (dB)

A measure of analog signal strength is a bel. This term is named in the honor of telephone pioneer Alexander Graham Bell. A bel is inappropriately large for ITS work, so a decibel (dB), or one tenth of a bel, is used. It is not an absolute value but a ratio of two signals, and it may be used for comparing power, current, or voltage.

System gain and attenuation are typically stated as decibel gain or decibel loss. For example, an amplifier may exhibit a power gain of 10 dB, or an optical fiber splice in a cabling system may exhibit a loss of 0.3 dB. Decibels express a ratio of two values, but the ratio is not linear.

The decibel is a logarithmic (as opposed to linear) function that allows large variations to be shown in very small increments. Increases or decreases of 3 dB will result in a doubling or halving of the power. Increases or decreases of 6 dB will cause a doubling or halving of the voltage.

Increases or decreases of 10 dB for power and 20 dB for voltage or current will cause an increase or decrease of 10 times the original value. This moves the decimal point one place forward or backward. For example, if the input power is equal to 1 W, a decrease of 10 dB will have a value of 0.1 W; however, an increase of 10 dB will have an output of 10 W.

The formula for computing dB is:

$$dB = 10 \log (P_1 / P_2)$$

Where P_1 is the device output power and P_2 is the input power.

A few examples of cabling system parameters that use decibel as a measurement of performance include:

- Crosstalk—The higher the decibel value, the better.
- Insertion loss (measured attenuation)—The lower the decibel value, the better.
- Return loss—The higher the decibel value, the better.

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Copper Cabling Media

Overview

With any copper cabling medium, a sufficient level of signal must be coupled through the medium from the transmitter to the receiver to drive the receiver.

The most effective and efficient transfer of a signal will occur at interfaces and connection points where all components share the same or similar characteristic impedance.

This section describes the electrical properties that make up characteristic impedance and how characteristic impedance can be impacted by hardware, design, and cabling installation methods or procedures.

American Wire Gauge (AWG)

Through usage and industrial standardization, the American wire gauge (AWG) sizing system has become generally accepted worldwide.

The AWG system is important because it provides a standard reference for comparing various physical dimensions of conductor materials.

Basis of the American Wire Gauge (AWG) Numbering System

Historically, the sizes in the AWG system roughly represent the number of steps that were involved in the process of wire drawing. Therefore, the AWG numbers and the size of the wires they represent have an inverse relationship.

In the AWG system:

- Smaller numbers denote larger wires (because there are fewer drawing steps involved).
- Larger numbers denote smaller wires (because there are more drawing steps involved).

Solid Conductor Diameters

The conductor diameters for the AWG system are based upon fixed diameters for the smallest size (36 AWG = 5 mil) and the largest size (4/0 = 460 mil), where 1 mil is equal to 0.0254 millimeters (mm [0.001 inches (in)]). The diameters for the intermediate sizes are derived from the largest size or the smallest size according to a geometric progression.

The AWG has become a standard for specifying and measuring conductor diameter. Smaller gauge numbers represent larger wire diameters:

- A gauge change of 3 approximately doubles or halves the conductor's cross-sectional area.
- A gauge change of 3 approximately doubles or halves the conductor's resistance.
- A gauge change of 6 approximately doubles or halves the conductor's diameter.

Resistance

For metallic cables, the electrical energy of the signals is typically transmitted over copper conductors. Copper is preferred because it offers less resistance to the flow of electrical energy and is relatively economical when compared with other metals.

Resistance is the property of a conductor to resist the flow of electricity through it. Resistance is expressed in ohms. One ohm of resistance will allow one ampere of current to flow when one volt of electrical pressure is applied. This is stated mathematically in Ohm's law (see Figure 1.3) as:

$$V = I \times R$$

or

$$R = V / I$$

or

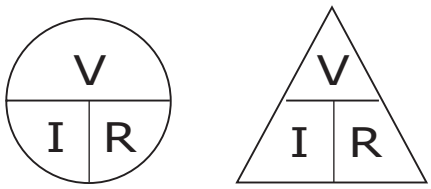
$$I = V / R$$

Where V is voltage in volts, I is current in amperes, and R is resistance in ohms.

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Resistance, continued

Figure 1.3
Ohm's law



V = Voltage in volts
I = Current in amperes
R = Resistance in ohms

Ohm's law values are easily solved. Place your finger over the I (in Figure 1.3), and you will see that V is divided by R. Place your finger over the R, and you will see that V is divided by I. Place your finger over the V, and you will see that I is multiplied by R.

Higher temperatures increase the conductor resistance by approximately two percent for each 5.5 degrees Celsius (ºC [10 degrees Fahrenheit (ºF)]) rise.

Resistance changes in proportion to length (e.g., doubling the length of the cable doubles its resistance).

The diameter of the conductors of a pair is maintained at a close tolerance to keep any resistance unbalance to a minimum. Such unbalance contributes to undesirable distortion of the signal.

Inductance

Inductance is a property of an electrical force field built around a conductor that opposes any changes in current flow in a circuit, both ac and varying dc. When dc flows through a conductor, the field is steady. An ac signal causes the lines of force to constantly build and collapse. The opposition to varying current results in energy loss, particularly for high-frequency signals.

Inductive coupling is the transfer of energy from one circuit to another (e.g., power lines on a utility pole can inductively couple a power surge onto telephone cables).

The basic unit of inductance is a henry (H).

Capacitance

Capacitance is a property of conductors that allows storage of electric charges when potential differences (voltages) exist between the conductors. Capacitance causes a voltage difference between two wires when separated by insulation. The insulation or dielectric (nonconductive material) separates the two wires, resulting in a buildup (or storage of electric charges) of capacitance between the wires.

Capacitance is measured in farads. Normally, capacitors are measured in microfarads (one millionth of a farad), nanofarads (one billionth of a farad), or picofarads (one trillionth of a farad).

Cable normally exhibits some level of capacitance. Typically, balanced twisted-pair cable will have a value of 56 to 66 picofarads per meter (pF/m [17 pF per foot (ft)]). Capacitance in cable must be minimized. Capacitance may be affected by improper cable installation. Because it is a very important element of the cable's characteristic impedance, changes in capacitance and inductance may degrade the quality of transmission through the cable.

In multiconductor cables, two capacitance factors are observed:

- Mutual capacitance—the capacitance between two conductors
- Unbalanced capacitance—the capacitance between a conductor and ground

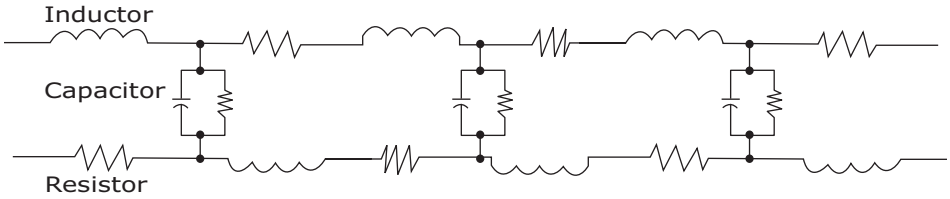
Impedance

In ac circuits, the total opposition to current flow is called impedance. This is the combined effects of resistance, inductance, and capacitance of the circuit.

Characteristic Impedance

Characteristic impedance is defined as the input impedance of a uniform analog transmission line of infinite length. An example of a transmission line is a balanced twisted-pair of wires. To a signal, a transmission line appears as a continuous configuration of resistors, capacitors, and inductors (see Figure 1.4).

Figure 1.4
Schematic of a transmission line



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Characteristic Impedance, continued

Every cable or transmission line has a characteristic impedance. The value of the characteristic impedance is determined by the:

- Metallic material and the diameter of the conductors.
- Distance between the conductors.
- Insulating value (dielectric constant) of the materials separating them.

Cables are designed to achieve constant characteristic impedance independent of the cable length. For example, if a 30 m (100 ft) length of cable has a characteristic impedance of 100 ohms, it will still be 100 ohms if the length is doubled or tripled for a given frequency.

All components of a system must reference the same value of input and output impedance for maximum signal (energy) transfer to occur at the interface point. Impedance matching becomes even more critical at higher frequencies. Impedance matching is a common problem when assembling audio components.

Most balanced twisted-pair cabling used for ITS exhibits a characteristic impedance of approximately 100 ohms ± 15 percent at 1 MHz at a temperature of 20 ºC (68 °F).

Insertion Loss (Attenuation)

Insertion loss (attenuation) is:

- The measure of signal loss resulting from the insertion of a component, link, or channel between a transmitter and receiver (often referred to as attenuation).
- The measure of how much a signal is reduced in amplitude (relative power) as it is transmitted over cable.
- Measured in decibels per unit length at a given frequency. As frequency or length increases, attenuation increases.
- A loss of usable signal to the load or receiver, the lower the decibel value, the better. Higher attenuation means less available signal.

There are times when attenuation is added so that the signal is not too strong at the receiver end. This is referred to as padding down the circuit. This also is done in laser-based optical transmission systems.

Return Loss

Return loss is a ratio expressed in decibels of the power of the outgoing signal to the power of the reflected signal. When the termination (load) impedance does not match (equal) the value of the characteristic impedance of the transmission line (e.g., 100 ohm impedance), some of the signal energy is reflected back toward the source and is not delivered to the load.

The amount of reflected energy is affected by the degree of impedance mismatch between the load and the line. The better the impedance match, the less energy is reflected. Reducing the level of the reflected signal increases the amount of power or signal level transferred to the load.

Return Loss, continued

For cabling systems, reflections result when impedance discontinuities exist along the line and at the end termination. Standards provide for component impedance (e.g., cable, connectors) of 100 ohm ± 15 percent. Impedance variations can result from the cable termination to the connector's installation variables (e.g., cable bends, stresses imposed on cables, mixed manufacturers components) as well as variations within and between cables and connectors. These variations can be measured and expressed in terms of return loss.

In systems where a single pair is used for bidirectional signaling (transmission from both ends of the pair at the same time), any reflected signal is seen by the transceiver as noise added to the transmitted signal.

Crosstalk

The unwanted transfer of a signal's electromagnetic energy from one or more circuits to other circuits is called crosstalk. This transfer may be between pairs in close proximity (e.g., pair-to-pair crosstalk) or between adjacent cables (e.g., AXT). Crosstalk is decreased by pair twists, cable lay, shielding, and physical pair separation, all of which are achieved during the cable manufacturing process.

The level of crosstalk increases when frequency or cable length increases although this increase is not directly proportional.

Three basic types of crosstalk are of interest for balanced twisted-pair cabling:

- Near-end crosstalk (NEXT)
- Far-end crosstalk (FEXT)
- Alien crosstalk (AXT)

Near-End Crosstalk (NEXT)

NEXT is a measure of the unwanted signal coupling from a transmitter at the near end into another pair measured at the near end. When NEXT measurements are made with field test equipment, there are six combinations of pair-to-pair NEXT associated with a 4-pair cabling link or channel:

- Pair 1–pair 2
- Pair 1–pair 3
- Pair 1–pair 4
- Pair 2–pair 3
- Pair 2–pair 4
- Pair 3–pair 4

Far-End Crosstalk (FEXT)

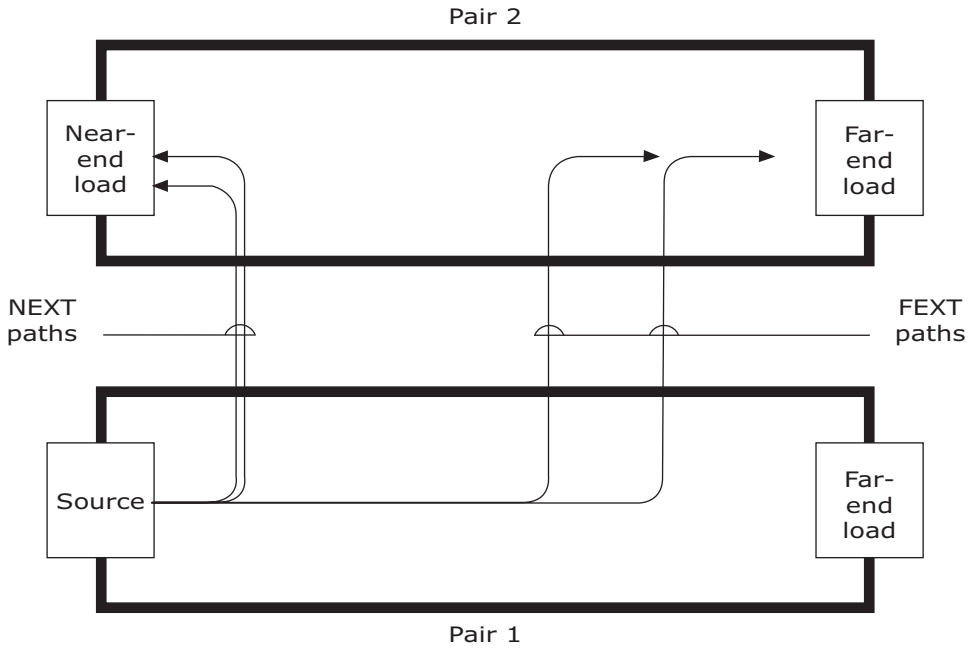
FEXT is a measure of the unwanted signal coupling from a transmitter at the near end into a neighboring pair measured at the far end. To measure FEXT, apply a disturbing signal on one pair at the near end, and measure the signal transfer level on the disturbed pair at the far end of the cable. FEXT is measured and expressed in decibels at the opposite end from which the source signal is transmitted.

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Crosstalk, continued

Figure 1.5 illustrates both NEXT and FEXT paths for two pairs. NEXT and FEXT are expressed in decibels.

Figure 1.5
Crosstalk paths



FEXT = Far-end crosstalk
NEXT = Near-end crosstalk

The lower the quantity of signal transferred between circuits, the smaller the received-to-transmitted signal ratio and the larger the decibel crosstalk loss value.

Attenuation-to-crosstalk ratio far-end (ACRF), formerly referred to as equal level far-end crosstalk (ELFEXT), is the measure of the unwanted signal transfer (coupling) that is assessed by applying a signal on one pair at the near end and measuring the signal transfer level on any disturbed pair at the receiving end of the cable. ACRF is measured and expressed in decibels at the opposite end from which the source signal is transmitted.

The value for ACRF varies, depending upon the length of the cable. In order to obtain consistent values for ACRF, regardless of cable length, insertion loss must be factored into the measurement. The insertion loss of the disturber pair is subtracted from the FEXT measurement and reported as ACRF.

Crosstalk, continued

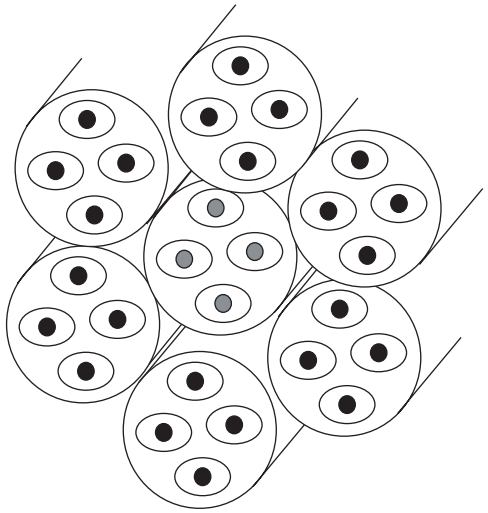
Alien Crosstalk (AXT)

AXT is the unwanted signal coupling from a disturbing pair of a 4-pair cable channel, permanent link, or component to a disturbed pair of another 4-pair channel, permanent link, or component.

There are several variants of AXT, including field test measurement orientation considerations as well as recommended test strategies for field testing as described in applicable standards and related amendments (e.g., ISO/IEC 11801, ANSI/TIA-1152, ANSI/TIA-568-C.2). Figure 1.6 depicts the six-around-one laboratory test methodology that is used to qualify cables for AXT compliance. These AXT measurements are made while the cables are placed in this configuration.

The cabling system manufacturer's laboratory tests are made to simulate typical field installation scenarios such as bundling and dressing cables in telecommunications pathways and spaces. To properly mitigate AXT, ITS installers should consult with the balanced twisted-pair cabling manufacturers to qualify maximum allowable cable bundling distances for their products.

Figure 1.6
Six-around-one alien crosstalk measurements configuration



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Crosstalk, continued

Installation Considerations Related to Alien Crosstalk (AXT) and Bundling of Cabling

Screened/shielded varieties (e.g., overall foil screened with unshielded twisted-pair [F/UTP], overall braid and foil screened with unshielded twisted-pair [S/FTP]) of category 6_A/class E_A and higher balanced twisted-pair cabling may be installed without installation restrictions related to bundling of different manufacturers' cables within the same pathway. There are no concerns related to screened/shielded cabling that the AXT requirements specified in applicable standards (e.g., ISO/IEC 11801, ANSI/TIA-1152, ANSI/TIA-568-C.2) will be exceeded.

Unshielded varieties (e.g., unshielded twisted-pair [UTP]) of category 6_A/class E_A and higher balanced twisted-pair cabling should not be installed in cable bundles composed of different manufacturers' cables within the same pathway. For additional guidance related to the installation of all forms of category 6_A/class E_A and higher balanced twisted-pair cabling, see Table 1.1.

Table 1.1
Cable bundling restrictions when cables are produced by different manufacturers

Cable Bundling Conditions within a Pathway (e.g., conduit, basket tray)	Category 6_A/Class E_A and Higher Balanced Twisted-Pair Screened/Shielded Cabling (e.g., F/UTP, S/FTP)	Category 6_A/Class E_A and Higher Balanced Twisted-Pair Unshielded Cabling (e.g., UTP)
Cables produced by different manufacturers that are bundled within the same pathway	Allowed	Not allowed
Cables produced by different manufacturers and bound in adjacent bundles within the same pathway	Allowed	Allowed
Cables produced by different manufacturers that are unbundled within the same pathway	Allowed	Allowed

F/UTP = Overall foil screened with unshielded twisted-pair
S/FTP = Overall braid screened with foil screened twisted-pair
UTP = Unshielded twisted-pair

For any of the allowed cable bundling configurations described in Table 1.1, there are no concerns that the AXT requirements specified in applicable standards (e.g., ISO/IEC 11801, ANSI/TIA-1152, ANSI/TIA-568-C.2) will be exceeded.

Crosstalk, continued

Mixing Category 6_A/class E_A and Higher Cabling with Lower Performing Cabling

Screened/shielded varieties (e.g., F/UTP, S/FTP) of category 6_A/class E_A and higher balanced twisted-pair cabling may be installed without installation restrictions related to mixing with lower category cables that are either bundled together or unbundled within the same pathway or grouped in adjacent bundles within the same pathway. There are no concerns related to shielded cabling that the AXT requirements specified in applicable standards (e.g., ISO/IEC 11801, ANSI/TIA-1152, ANSI/TIA-568-C.2) will be exceeded.

Unshielded varieties (e.g., UTP) of category 6_A/class E_A and higher balanced twisted-pair cabling should not be installed in cable bundles composed of category 6_A/class E_A and higher balanced twisted-pair cabling mixed with lower performing cabling within the same bundle within a pathway. For additional guidance related to the installation of all forms of category 6_A/class E_A and higher balanced twisted-pair cabling, see Table 1.2.

Table 1.2
Mixing category 6_A/class E_A and higher cabling with lower performing cabling

Cable Bundling Conditions within a Pathway (e.g., conduit, basket tray)	Category 6_A/Class E_A and Higher Balanced Twisted-Pair Screened/Shielded Cabling (e.g., F/UTP, S/FTP)	Category 6_A/Class E_A and Higher Balanced Twisted-Pair Unshielded Cabling (e.g., UTP)
Category 6_A/class E_A and higher cabling mixed with lower performing cabling that are bound within a bundle within the same pathway	Allowed	Not allowed
Category 6_A/class E_A and higher cabling mixed with lower performing cabling that are bound in adjacent bundles within the same pathway	Allowed	Allowed
Category 6_A/class E_A and higher cabling mixed with lower performing cabling that are not bundled within the same pathway	Allowed	Allowed

F/UTP = Overall foil screened with unshielded twisted-pair
S/FTP = Overall braid screened with foil screened twisted-pair
UTP = Unshielded twisted-pair

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Nominal Velocity of Propagation (NVP)

The nominal velocity of propagation (NVP) is a ratio of the speed of transmission along a cable relative to the speed of light in a vacuum. It is often stated in percentages. Certain test equipment uses NVP to determine the length of a cable.

Propagation Delay

Propagation delay is the time interval required for a signal to be transmitted from one end of a circuit to the other. For 100 ohm 4-pair cables, the maximum allowable propagation delay is measured at 10 MHz for all categories of cabling. The delay is expressed in nanoseconds.

Delay Skew

Delay skew is the difference in the propagation delay between the slowest and fastest pairs within the same cable sheath. For 100 ohm 4-pair cables, the maximum allowable propagation delay skew is measured at 10 MHz for all categories of cabling. This measurement is expressed in nanoseconds.

Insulation

Copper wires must be physically separated. In the case of a single pair of wires, contact of the two wires (short circuit) will prevent the signal from traveling down the transmission line. The selection of material to cover the wire involves economics as well as tradeoffs in characteristics desired for the application and installation environment.

An electrically efficient insulation is nearly always desired, but a tradeoff may be required (e.g., to obtain insulation capable of meeting plenum cable requirements). Similarly, less effective insulation may be used to secure more physically robust characteristics.

The insulation materials selected can affect the physical size of the cable assembly and determine two of the four primary electrical cable characteristics:

- Mutual capacitance of a pair
- Conductance

Mutual capacitance depends on the conductor's insulating material and the material's diameter (thickness).

NOTE: One primary performance indicator (in terms of bandwidth) of a cable is the mutual capacitance value of paired conductors. Typically, the lower the value, the higher the bandwidth.

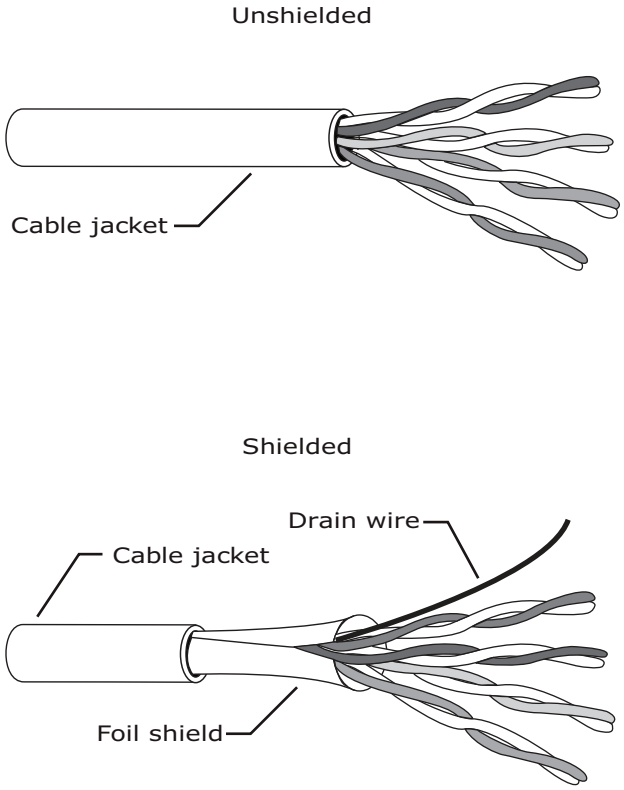
The conductance of a cable indicates the potential for current to leak through the insulation. Conductance is inversely related to resistance.

Pair Twist

To maintain consistent transmission quality in an ITS cabling system, the two wires of an insulated balanced twisted-pair cable are uniformly twisted together. The length of this twist (or pair lay or pitch) usually varies from approximately 6 mm (0.25 in) to 150 mm (6 in). The ITS cabling is manufactured so that no two pairs in a cable will have the same pair lay length. Because of the different twist rates in a multipair cable, the physical length of untwisted pairs is not equal. The effects of both capacitance unbalance and electromagnetic induction are improved by twisting the pairs.

Proper cable design and twisting of the pairs minimize detrimental crosstalk and noise. It is necessary that the ITS installer recognize the importance of each individual pair twist and maintain the same pair twist for each individual pair when terminating the conductors to the connecting hardware. Pair twist may vary from pair to pair within a given cable (see Figure 1.7). The objective is minimizing pair disturbance.

Figure 1.7
Typical balanced twisted-pair cable



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Shielding

Balanced twisted-pair cabling may or may not involve a metallic covering (shield) over the pairs (see Figures 1.8 and 1.9). Certain systems use shielded cables or shielded pairs. Backbone cables may use an overall shield.

The shield is used to:

- Reduce the level of the signal radiated from the cable.
- Minimize the effect of external EMI on the cable pairs.
- Provide physical protection.

The shielding material used and its thickness and relative coverage (limited number of perforations) determine the effectiveness of meeting the shield's goals. Types of shield include metallic foil, copper braids, solid tubing, drain wires, and coupled bonding conductors (CBCs).

The shield's characteristics are as follows:

- Foil will typically block higher frequencies (30 MHz and higher).

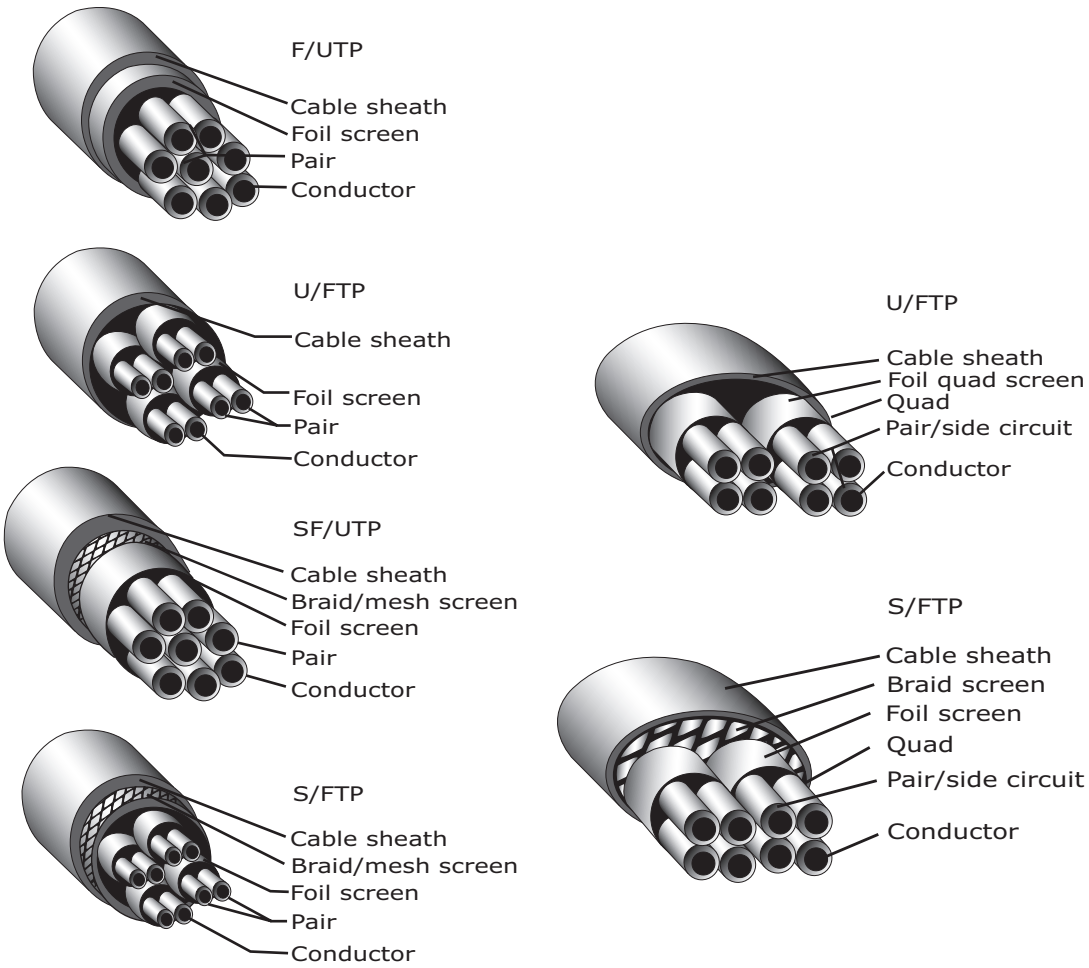
  NOTE: Drain wire will effectively drain the current on the shield.

- Copper braids will block lower frequencies.
- Solid tubing will block all frequencies.
- CBCs may help divert all induced frequencies from susceptible cables.

Shielding, continued

Cable designations define cable construction of the overall cable (e.g., F/) followed by the cable construction of the individual cable pairs (e.g., /FTP).

Figure 1.8
Examples of foil-screened and braid-screened cables

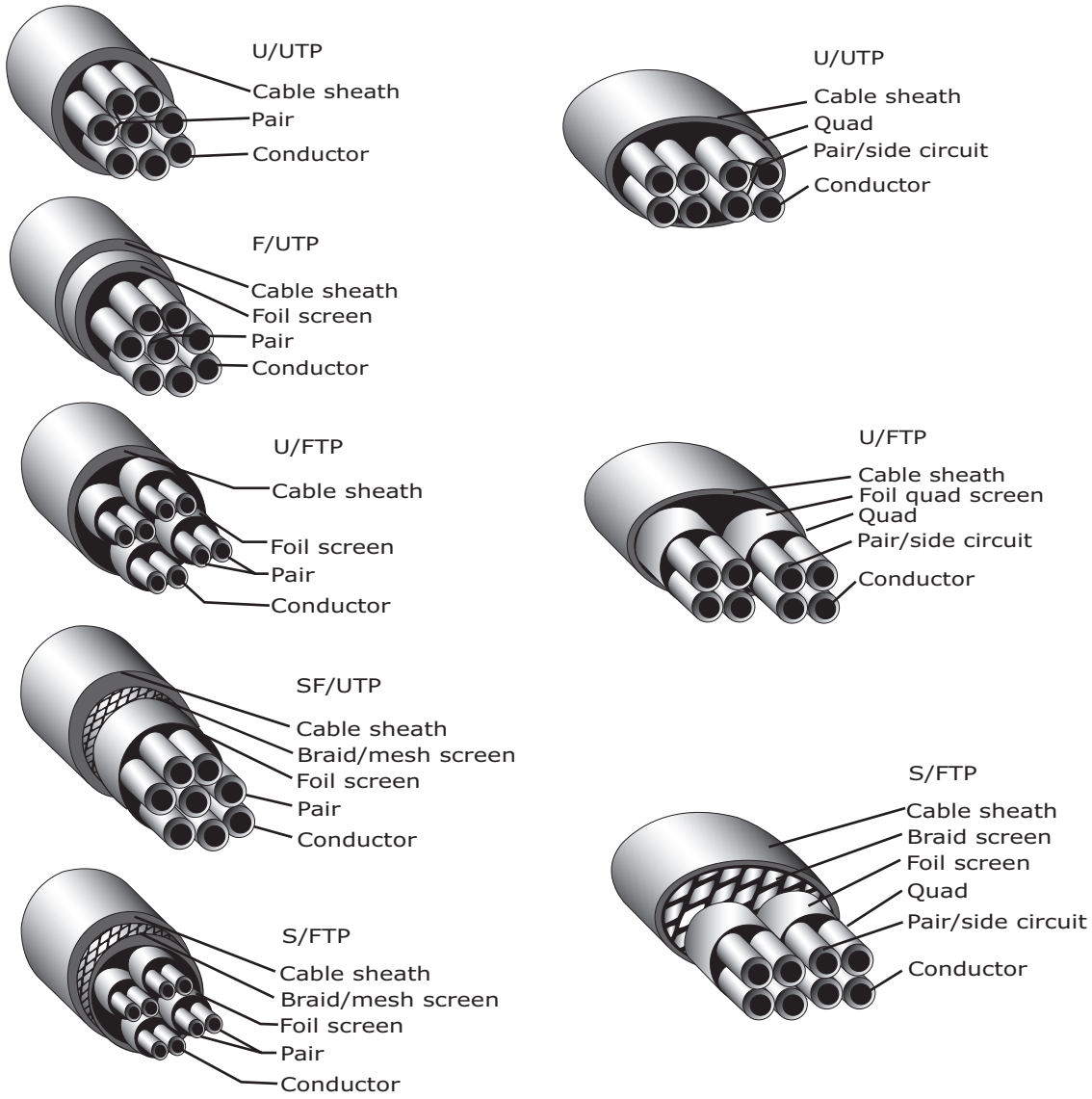


F/UTP = Overall foil screened with unshielded twisted-pair
S/FTP = Overall braid screened with foil screened twisted-pair
SF/UTP = Overall braid and foil screened with unshielded twisted-pair
U/FTP = Overall unshielded twisted-pair with foil screened twisted-pair

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Shielding, continued

Figure 1.9
Examples of screened and unscreened balanced twisted-pair cables



F/UTP = Overall foil screened with unshielded twisted-pair
S/FTP = Overall braid screened with foil screened twisted-pair
SF/UTP = Overall braid and foil screened with unshielded twisted-pair
U/FTP = Overall unshielded twisted-pair with foil screened twisted-pair
U/UTP = Overall unshielded twisted-pair with unshielded twisted-pair

Coaxial Cables

Coaxial cables derive their name from the fact that there is an insulated (centrally located) conductor surrounded by an overall metallic covering. The geometry of such a construction inherently provides reduced external interference and radiation protection; however, the metallic covering is not a shield—it is a conductor in the circuit.

Hardware

Although much of the information in the previous sections described the characteristics of balanced twisted-pair cable transmission media, attention also should be given to the connecting hardware used to establish the entire channel. Crosstalk, signal loss, and other detriments to the performance of the network also can be attributed to these devices.

All components within a link or channel (e.g., cable, telecommunications outlet/connectors, termination methods) must have matching electrical transmission performance characteristics for a circuit to support high-speed transmissions. The ITS installer must be aware of any specific requirements or limitations of the ITS equipment to be installed as well as the category and type of cabling required for a given project.

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Optical Fiber Cabling Media

Overview

Optical fiber cabling is used in backbone and horizontal distribution applications. When high-performance network cabling is required across cabling segments greater than 100 m (328 ft) or an all-dielectric construction is desirable, optical fiber cabling offers characteristics that can make it the media of choice. Transmission of information through optical fiber cables is not degraded by crosstalk, lightning, and most EMI problems. However, like copper cables, attenuation (loss of signal) and physical environmental considerations are of concern for optical fiber systems.

The primary difference between balanced twisted-pair and optical fiber cabling as a transmission medium is that pulses of light consisting of photons are injected into the optical fiber as opposed to the electron flow in balanced twisted-pair based cabling.

The inner portion of the glass optical fiber used for transporting the light pulse is called the core, and the surrounding glass layer is called the cladding. The purpose of the cladding is to confine the light within the core by creating a reflective boundary.

Optical fibers are classified as either singlemode or multimode. Singlemode optical fibers have a relatively small diameter, featuring a core of 8 to 11 micrometers (µm) and a cladding diameter equal to 125 µm. Laser transmitters have a narrow light beam and can focus 100 percent of the light beam down the core of the optical fiber. Multimode has a larger core diameter (e.g., 50 or 62.5 µm) with a cladding at 125 µm. The light is restricted to a single path or mode in singlemode optical fibers, whereas the larger diameter multimode has many paths or modes.

Current standards support both 50/125 µm and 62.5/125 µm as well as singlemode optical fiber cabling. While the 50/125 µm cable has a greater bandwidth, 62.5/125 µm cable has a significant installed base although most new network installations use laser optimized 50/125 µm.

Singlemode optical fiber systems are frequently used for long-haul transmission systems, data systems requiring high bandwidth, and many optical fiber-based video distribution systems.

The lasers used to drive the signal over singlemode are generally more expensive than the light-emitting diode (LED) and vertical cavity surface emitting laser (VCSEL) based multimode systems.

Two characteristics of particular importance in the transport of information over optical fiber media are bandwidth and attenuation. Bandwidth and attenuation relate to the transmission of light pulses over optical fiber cables.

Overview, continued

Tables 1.3 and 1.4 show the minimum bandwidth (capacity) and attenuation (insertion loss) per kilometer for each of the most commonly used optical fiber types.

Table 1.3
Optical fiber cable bandwidth performance parameters

	Multimode	850 nm OFL	850 nm RML	1300 nm	1310 nm	1550 nm
FDDI	62.5/125 µm	160 MHz•km	N/A	400 MHz•km	N/A	N/A
OM1	62.5/125 µm	200 MHz•km	N/A	500 MHz•km	N/A	N/A
OM2	50/125 µm	500 MHz•km	N/A	500 MHz•km	N/A	N/A
OM3	50/125 µm Laser optimized	1500 MHz•km	2000 MHz•km	500 MHz•km	N/A	N/A

µm = Micrometer
FDDI = Fiber distributed data interface
MHz•km = Megahertz kilometer
N/A = Not applicable
nm = Nanometer
OFL = Overfilled launch
OM = Optical multimode
RML = Restricted modal launch

NOTE: The terms overfilled launch (OFL) and restricted modal launch (RML) relate to the method of presenting the light into the optical fiber from the active equipment. This is explained in more detail in Chapter 6: Optical Fiber Structured Cabling Systems.

Table 1.4
Optical fiber cable attenuation performance parameters

	Multimode	850 nm	1300 nm	1310 nm	1550 nm
OM1	62.5/125 µm	3.5 dB/km	1.5 dB/km	N/A	N/A
OM2	50/125 µm	3.5 dB/km	1.5 dB/km	N/A	N/A
OM3	50/125 µm Laser optimized	3.5 dB/km	1.5 dB/km	N/A	N/A
OM4	50/125 µm Laser optimized	3.5 dB/km	1.5 dB/km	N/A	N/A

µm = Micrometer
dB = Decibel
km = Kilometer
N/A = Not applicable
nm = Nanometer
OM = Optical multimode

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Bandwidth

The modal bandwidth of an optical fiber provides a measure of the amount of information an optical fiber is capable of transporting. Modal bandwidth is described in terms of megahertz•kilometer (MHz•km).

Increasing either the length of the cable or the wavelength of the light source decreases the modal bandwidth and therefore the information-carrying capacity of the transmission path.

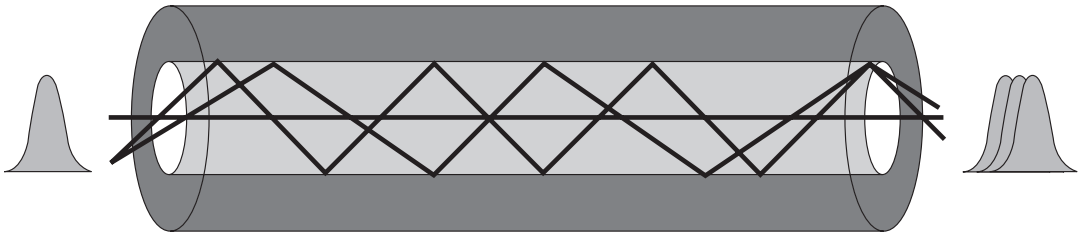
Dispersion

Dispersion is the widening or spreading out of the modes in a light pulse as it progresses along the optical fiber. If the pulse widens too much, it can overlap at the receiver and make it impossible to distinguish one pulse from another. As errors occur in the reading of pulses (bits), the bit error rate (BER) increases. Bandwidth is therefore limited by total dispersion that is the sum of modal dispersion and chromatic dispersion.

Modal Dispersion

Modal dispersion results from the different optical path lengths in a multimode fiber (see Figure 1.10). It is also called modal distortion. It is characteristic of the transmission in an optical fiber that results from different lengths of the light paths taken by the many modes of light as they travel down the fiber from the source to the receiver.

Figure 1.10
Modal dispersion



Dispersion, continued

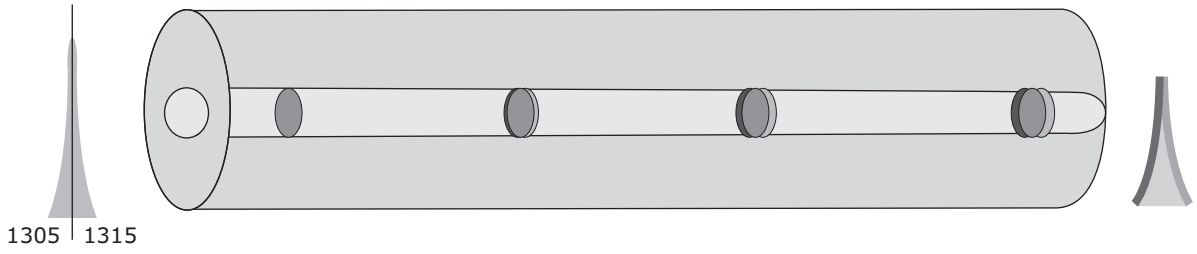
Chromatic Dispersion

Chromatic dispersion begins at the light source (see Figure 1.11). The sources utilized to create the light pulses are either a laser, VCSEL, or LED and do not furnish a perfectly monochromatic (single wavelength) light. Thus, the light injected into the optical fiber media contains a number of slightly differing wavelengths.

Because the index of refraction of the glass optical fiber is not the same for different wavelengths, each travels through the optical fiber at a slightly different speed.

Modal dispersion tends to further broaden these pulses. Together, these dispersion factors increase the BER and lower the effective bandwidth. Through the use of graded index optical fiber, the effects of modal dispersion are reduced but are not eliminated.

Figure 1.11
Chromatic dispersion



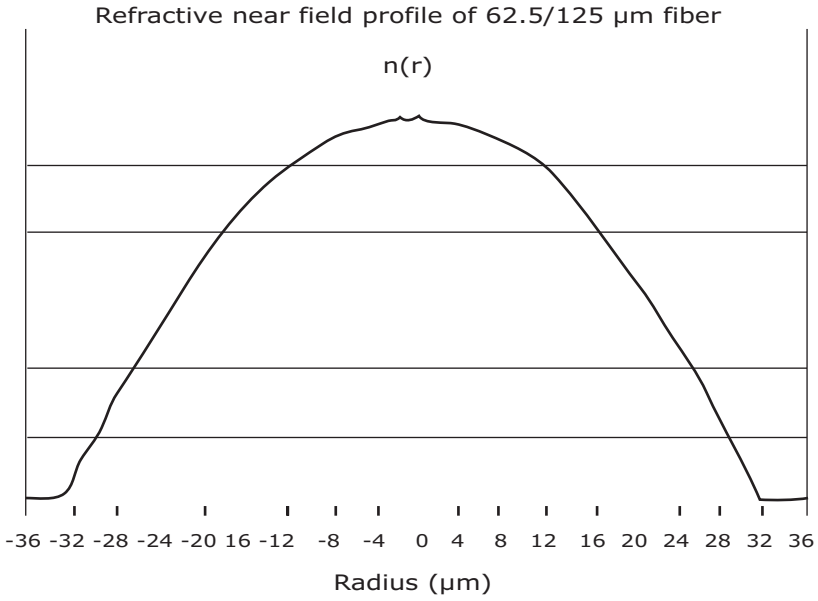
µm = Micrometer

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Differential Mode Delay (DMD)

Figure 1.12 illustrates the profile of a graded index core for 62.5 µm optical fiber. The curve for a 50 µm would look similar. Although a perfect curve is the objective, sometimes imperfections occur as shown at the top of this graph. These little imperfections are the cause of differential mode delay (DMD).

Figure 1.12
Core profile—laser-certified optical fiber



µm = Micrometer
n = Refractive index
r = Radius

Modal dispersion/modal bandwidth and DMD are associated with the optical fiber properties. When using a VCSEL transmitter, a better transmission path must be provided to ensure that the information arrives at the destination in an intelligible manner. Since an LED cannot be modulated fast enough to provide gigabit speeds, it becomes necessary to use lasers or VCSELs. VCSEL is a usual choice for LAN environments because of its lower cost.

When using a VCSEL transmitter, multimode glass, and a detector, the information pulse starts out as acceptable. However, as the light pulse travels down the length of the optical fiber, the pulse starts to spread because of modal dispersion and any present DMD problems in the optical fiber. At some point along the optical fiber, the pulse becomes too spread out. When this happens, the information becomes unintelligible. This is common with conventional multimode, either 62.5 or 50 µm. The 50 µm laser-optimized optical fiber glass reduces the effects of DMD and is in widespread use in enterprise networks.

Attenuation

Light pulses in optical fiber cables are subjected to a loss in the power as the light pulses travel along the optical fiber. This attenuation occurs as a result of absorption of power by impurities within the glass itself and scattering of the light.

Losses because of scattering are caused by such factors as:

- Dopants and impurities in the glass material.
- Core size variations (different manufacturers may have slight variations in core diameters).
- Variations in the interface between the core and cladding.
- Macrobends and microbends in the strands.
- Concentricity (relationship of core and cladding that make up the optical fiber).

Optical fiber attenuation is referenced in decibels per kilometer. It is proportional to length and is affected by the wavelength of the light contained in the pulse.

The mishandling or improper termination of optical fiber cable is frequently the cause of most unexpected attenuation. To provide a fully functional optical fiber transmission system:

- Maintain adequate bend radii (per manufacture's or standards specifications).
- Use cable designed for the environment.

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Professionalism

Overview

The ITS installer works in a world that is constantly changing and developing. For this reason, the ITS installer is required to work with different types of people—on both small and large installations—offering the same quality, professionalism, and acceptable costs.

Technical Expertise

The technical nature of the project requires the ITS installer to be highly qualified and capable of maintaining the system as designed.

Requirements of the industry demand that the ITS installer be a highly skilled professional, a team member, and an ongoing learner.

The ITS installer's role is affected by:

- Current and future technology.
- Complex equipment.
- Advanced tools.
- Constant refinement of standards.
- International, national, regional, and local codes.
- Intricate and evolving designs.

Project Objectives

Information should be provided about the job location and work area, customer requirements, project schedule, materials, safety issues, and code requirements.

The ITS installer is responsible for knowing the:

- Background of the project and project relationships.
- Project milestones.
- Specific roles within the project.
- Specific tasks expected to be performed.
- Challenges and issues unique to the project.
- Methods and techniques planned to be used.
- Applicable standards (e.g., local, state, national, company, customer).
- Security requirements.
- Safety requirements.
- Evaluation of work process.
- Recordkeeping process and requirements.
- Status and monitoring processes of both the company and the customer.
- Required meetings.

Project Team Members

An ITS installer is part of a team. The full team consists of their company and organization as well as the people and organizations for whom and with whom they work.

An ITS installer may be required to talk and work with many different people:

- Consultants
- Supervisors
- Project managers
- Coworkers
- Customers
- Manufacturers
- Vendors
- Suppliers
- Administrative and clerical staff
- Regulatory and government staff
- Other trades

Team Member Responsibilities

Team membership has its own set of requirements. The ITS installer must take responsibility to know, understand, and communicate all aspects of the job.

This involves getting and receiving information and asking the right questions such as:

- What is expected?
- What is the project environment?
- What is the expected schedule?
- What are the critical time frames and why?
- What other projects are being installed simultaneously during the project that may impact this project?
- Why was a particular ITS installer chosen for this job?
- Is the ITS installer expected to contribute a particular skill, knowledge, or task?
- What new skills might the ITS installer acquire?
- Is the ITS installer expected to provide training?
- What is the most efficient way to execute the project and see it through to delivery?

The items listed above are important when dealing with both large and small projects. On a small project, the ITS installer must possess high technical and interpersonal skills because there is more interaction with the customer in a shorter period of time.

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Interpersonal Skills and Communication Requirements

The ability to plan, organize, work in a team environment, and communicate effectively is just as important as the actual cabling installation performance.

Effective Communication Skills

The ITS installer's role is impacted by the effectiveness of the communications received and the communications delivered, whether verbal or written.

As an effective communicator, the ITS installer should:

- Listen attentively, and take notes as appropriate.
- Provide complete information about the project.
- Respect the values, traditions, and beliefs of others.
- Always find at least one positive thing to say.
- Praise in public, but correct in private.
- Seek the understanding of others.

Each person involved in the project expects all communications to be:

- Timely.
- Clear.
- Concise.
- Unbiased.
- Truthful.
- Free from unacceptable language.

Interpersonal Skills and Communication Requirements, continued

Table 1.5 lists the possible members of a project team and describes the types of procedures and issues the ITS installer may need to communicate to each member.

Table 1.5
Project communications

Position	Required Communications
Consultants	Design and product specification issues
Supervisors and coworkers	Safety issues, pull methods and techniques, cable tests, and work responsibility clarification
Customers and project managers	Project schedules, test results, safety and security issues, progress reports, and potential problems or delays (e.g., cutover issues, access requirements, clarification of requirements)
Contractors	Coordination of schedules, blueprints, building access, storage, and required meetings
Manufacturers, vendors, and suppliers	Project supplies, delivery schedules, verification of specifications, tools, materials, and equipment requirements
Administrative	Job location, ordering and delivery of clerical staff materials, and work schedule
Other trades	Work area arrangements, schedules, safety issues, and work coordination (e.g., grounding [earthing], space in closets, shared pathway spaces)
Regulatory and government staff	Permits and inspections, regulations, and codes clarification

A portion of an ITS contractor's base can be lost because of:

- A move, discontinuation of business, or merger with another company.
- Discontinuation of supplier relationship for an extended period of time for various reasons.
- Intentional customer abandonment by the ITS installation company.

Customers are not dependent on ITS installers; however, cabling installation companies are dependent on customers.

NOTE: Because of the technical language used in the ITS industry, exercise care to use communication the customer will understand.

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Interpersonal Skills and Communication Requirements, continued

Customer Relations

Customers are in an advantageous position because they do not depend on one installation firm. Most client loss occurs because of the lack of attention to the customer's needs. Customer requirements and expectations must be recognized and addressed in a timely manner.

The professionalism of the ITS installer is a major factor in being selected. Customers usually are willing to provide return business to companies who they know and trust. Clients typically judge this by their overall experience with any given company. It is all company employees' responsibilities to perform their particular tasks in order to differentiate themselves from their competition.

If the installation is conducted by a professional, there is a good probability that the customer will call that company back for return business. If the ITS installer has developed a working relationship with that particular customer, there is a high probability that the client will be asking the company for that particular ITS installer again.

It is worth attending an interpersonal relationships course in order to develop these skills. An ITS installer who does professional hands-on work with good interpersonal relationship skills will provide tremendous value and insight to a company and the end users.

Customer Perception

As the on-site representative of an employer, each employee carries certain responsibilities regarding the relationship between the employer and the customer.

Either positive or negative, an impression is formed within the first 10 to 15 seconds of a first meeting. Therefore, it is in the employee's best interest to do everything possible to ensure a positive first impression.

Because of this, it is important to:

- Make a powerful and positive first impression.
- Maintain a professional image at all times.

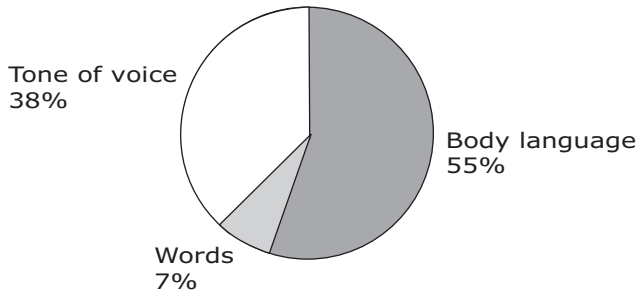
The way in which others perceive an employee can be divided into three distinct areas:

- Body language
- Tone of voice
- Choice of words

Interpersonal Skills and Communication Requirements, continued

Figure 1.13 illustrates how communications perceptions are broken down in a face-to-face meeting with the customer. Body language makes the biggest impression followed by the tone of voice and choice of words.

Figure 1.13
Communications perceptions



When talking with the customer on the telephone, the tone of voice and choice of words become much more critical. When communicating with the customer in writing, the only perception the customer obtains is through the choice of words and how those words are presented. Spelling, handwriting, and grammar become important in presenting a professional image.

It is important to understand the technical level of the person you are talking with, so from a psychological point of view, it is possible to create a positive relationship and not an adverse situation.

Feedback and Follow-Through

Feedback and follow-through are key to effective customer and coworker relationships. The customer must be kept informed. Any potential problems or concerns must be reported to the ITS installer's supervisor immediately.

This is especially true when it comes to project meetings. It is important to prepare for the meeting, create and follow an organized agenda, and distribute copies of the presentation to all attendees.

When changes are made, record and acknowledge the changes with the customer and the ITS installer's organization. The ITS installer's follow-through is the bond that promotes trust, protects reputation, and helps to ensure that time and resource commitments are met.

Professional Appearance

The ITS installer's appearance presents to the customer, coworkers, and supervisors an attitude about the quality of the work to be performed. Appearance must be appropriate for the task to be performed.

The ITS installer must recognize that appearance is a form of communication that can establish positive or negative expectations. An organized, neat appearance, free from offensive or distracting items, is a benefit to ITS installers and their organization. Having and using appropriate safety equipment is part of that image.

NOTE: Refer to Chapter 2: Safety Procedures for information on the available equipment and safety considerations.

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Appendix: Conductor Size

Table 1.6 is based on precise AWG calculations.

Table 1.6
Conductor size

AWG	1 Mil of an Inch	Conductor Size/mm Diameter	Conductor Size/in Diameter	CSA mm^2	Standard Conductor Sizes mm^2	dc Resistance (ohms per 305 m [1000 ft])	dc Resistance (ohms per 1 m [39 in])
4/0	460.000	11.684	0.46	107.22	120	0.05	0.000164042
3/0	409.642	10.405	0.41	85.03	95	0.06	0.00019685
2/0	364.797	9.266	0.365	67.43	70	0.08	0.000262467
1/0	324.861	8.251	0.325	53.48	70	0.10	0.000328084
1	289.297	7.348	0.289	42.41	50	0.13	0.000426509
2	257.626	6.544	0.258	33.63	35	0.16	0.000524934
3	229.423	5.827	0.229	26.67	35	0.20	0.000656168
4	204.307	5.189	0.2045	21.15	25	0.25	0.00082021
5	181.941	4.621	0.182	16.77	25	0.30	0.000984252
6	162.023	4.115	0.162	13.30	16	0.4	0.001312336
7	144.285	3.665	0.144	10.55	16	0.5	0.00164042
8	128.490	3.264	0.128	8.37	10	0.6	0.001968504
9	114.424	2.906	0.114	6.63	10	0.8	0.002624672
10	101.897	2.588	0.102	5.26	6	1.0	0.00328084
11	90.742	2.305	0.091	4.17	6	1.3	0.004265092
12	80.808	2.053	0.081	3.31	4	1.6	0.005249344
13	71.962	1.828	0.072	2.62	4	2.0	0.00656168
14	64.084	1.628	0.064	2.08	2.5	2.5	0.0082021
15	57.068	1.450	0.057	1.65	2.5	3.2	0.010498688
16	50.821	1.291	0.051	1.31	1.5	4.0	0.01312336
17	45.257	1.150	0.045	1.04	1.5	5.0	0.016404199
18	40.303	1.024	0.0403	0.82	1	6.4	0.020997375
19	35.891	0.912	0.0359	0.65	1	8.1	0.026574803

Conductor size, continued

Table 1.6, continued
Conductor size

AWG	Standard 1 Mil of an Inch	Conductor Size/mm Diameter	Conductor Size/in Diameter	CSA mm^2	Conductor Sizes mm^2	dc Resistance (ohms per 305 m [1000 ft])	dc Resistance (ohms per 1 m [39 in])
20	31.961	0.812	0.032	0.52	1	10.1	0.033136483
21	28.462	0.723	0.0285	0.41	0.5	12.8	0.041994751
22	25.347	0.644	0.0253	0.33	See Notes	16.2	0.053149606
23	22.572	0.573	0.0226	0.26	See Notes	20.3	0.06660105
24	20.101	0.511	0.0201	0.20	See Notes	25.7	0.084317585
25	17.900	0.455	0.0179	0.16	See Notes	32.4	0.106299213
26	15.941	0.405	0.0159	0.13	See Notes	41.0	0.134514436
27	14.196	0.361	0.0142	0.10	See Notes	51.4	0.168635171

AWG = American wire gauge
CSA = Cross-sectional area
dc = Direct current
ft = Foot
in = Inch
m = Meter
mil = Millionth
mm = Millimeter
mm^2 = Square millimeter

NOTE: Power cables generally do not have sizes below 0.5 mm^2. Control cables generally do have sizes below 0.5 mm^2.

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Chapter 2
Safety Procedures

Chapter 2 describes important safety practices and procedures for information technology systems (ITS) installers and work sites. Included in this chapter are guidelines for the personal safety of the ITS installer as well as for maintaining equipment and work areas.

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Common Safety Practices

Overview

It is every organization's responsibility to provide safety training for its employees and to ensure that safety procedures are strictly followed. Safety training should be given on a regularly scheduled basis and not as a result of an injury.

Because of the daily hazards to which information technology systems (ITS) cabling installers are exposed, it is vital that all ITS installers have a complete understanding of rescue and first aid procedures.

ITS installers must know their company's safety policies and practices, and they must follow them while working. Be aware of any site-specific safety issues that affect a task. Pay close attention, and ask questions during company and work site safety meetings.

Each employee should ensure that workplace safety is part of the job. Do not depend only on others' efforts to ensure job safety.

When working, consider the possible effects of every action. This is especially important for actions that could have consequences in remote locations (e.g., turning the power on or off, activating distant machinery).

This section is not intended to provide complete coverage of the issue of workplace safety. It is the ITS installer's responsibility to be aware of regulations, standards, and local policies and to play a primary role in practicing safety.

Most countries have national and, often, local requirements that must be followed as a minimum. In all instances, the ITS installer should seek guidance from the authority having jurisdiction (AHJ) on the minimum requirements for safe work and employee health at work. On most projects, a site-specific safety practice must be followed.

Safety Awareness

The rules regarding the size of a company that must provide a specific type of safety program or training vary by state and, at times, by city.

However, the common themes for safety are:

- Common sense.
- Training.
- Caution.
- Awareness.
- Cooperation.
- Participation.

Safety Awareness, continued

Workplace safety is not simply remembering to wear a hard hat or knowing how to secure a heavy load. It includes a full range of health-related issues as well as physical safety aspects.

Information about safety in the workplace is available for individual workers and companies of all sizes. In addition to local and national safety requirements, most industry trade organizations and labor unions offer extensive resources on safety and safety planning.

This section provides a limited overview of some common health and safety issues related to the ITS field. It is up to individuals to seek additional information from their company, trade organization, or regulating body.

First Aid

All ITS installers should take courses in, and be capable of, providing:

- Basic first aid.
- Cardiopulmonary resuscitation (CPR).

The Red Cross and other nongovernmental organizations (NGOs) offer local courses in standard first aid and community CPR around the world.

First aid is the emergency aid or treatment given before medical services can be obtained. Training in first aid prepares individuals to act properly and to help to save lives in the event of an emergency.

CPR is the emergency procedure used on a person who is not breathing and whose heart has stopped beating (cardiac arrest).

First Aid, Cardiopulmonary Resuscitation (CPR), and the Law

Depending upon your location, the AHJ may have laws that govern how to approach and assist an injured person.

First aid and CPR certifications should be kept current. Certification cards have expiration dates, and they require refresher courses to renew certification.

First Aid Kits

First aid kits and portable eye wash stations must be part of the equipment for every job. Portable eye wash stations can provide fresh water to rinse debris or toxins from eyes when fresh water may not otherwise be available during certain construction periods.

Ensure that the first aid kits are restocked after each use. Ensure that eye wash stations have not passed their expiration dates. Promptly report any use of supplies from the first aid kit to the appropriate supervisor.

NOTE: Many companies keep additional first aid kits. At the end of each month, kits that have been used on the job are swapped with fully stocked kits. The used kits may then be restocked and prepared for reuse.

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First Aid, continued

First aid kits and eye wash stations should be accessible to all personnel at the work site. Use precautions to ensure that eye wash stations and any liquids used for first aid services are protected from freezing temperatures.

Written copies of the first aid procedures for exposure to a hazardous substance (e.g., material safety data sheet [MSDS]) shall be brought to any job where ITS installers might be exposed to that substance. It is the assigned individual's responsibility to request these documents if they are missing, lost, or mutilated. Review these procedures before work begins.

Emergency Rescue

Emergencies allow no time for asking questions or learning from mistakes. There may be only one chance to save a life. An untrained rescuer often becomes an injured person of the situation that caused the emergency. For example, if a rescuer attempts to assist an unconscious injured person who is lying across an energized electrical circuit, the rescuer can become part of the circuit with the injured person. In addition, an untrained individual can inadvertently cause additional harm or injuries to the injured person.

Training in emergency rescue and first aid is often provided in one comprehensive course.

There are six basic steps to safely assist others without endangering yourself:

- Survey the scene—Check for fire, toxic fumes, heavy vehicle traffic, live electrical wires, ladders, or swift-moving water. If the injured person is conscious, ask questions to get information.
- Notify someone—It is imperative to let someone know that assistance is required and where the assistance is required, especially when you elect to stay behind to attend to an injured individual in an emergency or life-threatening situation. If a person attempts the rescue alone and becomes overwhelmed by smoke, electrocution, or unseen gases, additional help is needed.
- Secure the area—Make the area safe for the rescuer and the injured person. Locate and secure the power to the energized circuits, and turn off the gas or water mains if necessary. Move the injured person to a safe area only if doing so would not further complicate the person's medical condition or if the person is in an immediate life-threatening situation.

  NOTE: Do not move someone with a neck or back injury unless it is a life-threatening situation.

- Complete a primary survey of the injured person—Check the injured person's ABCs:
  - A is for airway. Open the injured person's airway. This is the most important action for a successful resuscitation.
  - B is for breathing.
  - C is for circulation.

Emergency Rescue, continued

- Phone emergency medical services (EMS)—Direct someone to call EMS, and relay all the information collected in the initial survey.
- Complete a secondary survey of the injured person—Perform CPR as needed, and check for secondary minor injuries that may have been previously overlooked.

IMPORTANT: The rescue techniques outlined are basic and should only be used after receiving the proper training. Some rescues require specialized training and equipment.

Communication

Communication is an important part of any safety program. Attend and pay close attention to all safety meetings and safety equipment training. Ask questions.

On the job, ITS installers must communicate freely and clearly with everyone affected by their work and those whose work may affect them. These people include:

- Coworkers.
- Supervisors and the building management.
- Building occupants (if any).
- Other workers (e.g., construction, electric utility) on-site.

When the work is being performed in two locations (e.g., electrical circuit is being switched off from one location to allow an ITS installer to work safely in another location), workers in each location should repeat each message and secure the confirmation that it was heard correctly before acting on the message. Never assume that related tasks have been performed; always obtain the confirmation.

NOTE: Portable radios use a limited number of frequencies; therefore, it is likely that different crews will be using the same frequencies. When using radios to communicate between two locations, workers should always confirm that they are talking to the correct person.

Be alert, and read any warning signs or markings. Bring them to the attention of coworkers who may have missed them. Encourage communication by politely accepting repeated information. It is better to be notified about the same hazard several times than not to be notified at all.

If ITS installers discover any defective or damaged equipment or facilities, installers must report them promptly to their supervisor or directly to persons qualified to handle the problem (e.g., report damaged electrical power lines to electrical workers on-site or to a building or construction supervisor who will contact electrical workers).

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Communication, continued

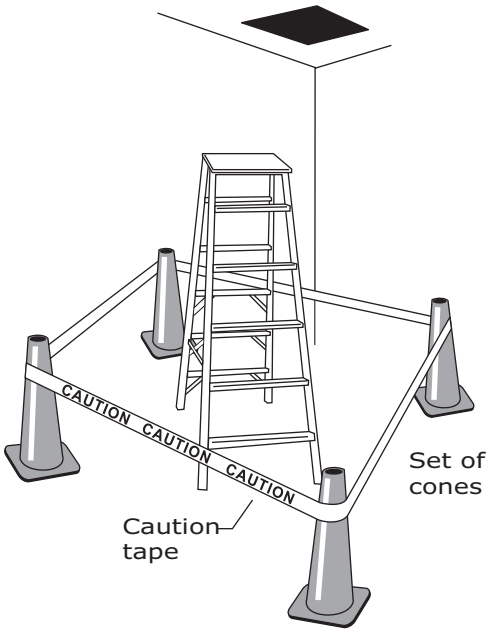
If the defect or damage poses an immediate hazard, the ITS installer should do everything safely possible to ensure that others are not harmed by the hazard before qualified personnel arrive to troubleshoot the problem. This may involve notifying other workers in the area, putting up signs and barriers, or standing guard until qualified personnel arrive.

IMPORTANT: ITS installers must promptly report all accidents or injuries to their employers.

Designating Work Areas

Always use proper visible safety barriers or delineators to designate work areas and to restrict access (see Figure 2.1). Yellow caution tape and folding A-frame signs may be used. Leave enough room inside the safety perimeter to do the required work.

Figure 2.1
Designated work area



Consider the needs of the building occupants whenever possible. Try not to block a doorway or hallway for which there is no alternate route any longer than necessary. When working near doors or hallway corners, try to ensure that oncoming pedestrians can tell there is a work area ahead. If working behind a closed door, mark the door with a sign that informs personnel that you are on the other side. Do not leave open floor systems (e.g., trench ducts), access floor panels, open ceiling systems with dangling access panels, or unattended equipment.

Tools and Equipment

ITS installers must use only the tools for which they are trained or certified to operate. Manufacturers require users to be certified to use certain devices (e.g., powder-actuated tools). Never be afraid to ask questions about the proper use of any tools. ITS installers should not use a specific tool if they are uncomfortable or untrained in the safe use of that tool.

Use the tools only for the purpose for which they are intended (e.g., use a tool designed for cable stripping to strip cable insulation; do not use a pocketknife for this purpose). In addition, utilizing a screwdriver as a scrapper, chisel, pry bar, framed wall saw, hole punch, or a drill for wood can easily cause injury to the ITS installer or others or damage to the materials or hardware being installed.

Examine both hand tools and power tools regularly to ensure that they are in safe working condition. Broken tools must be immediately tagged "broken" and removed from the work site. A detailed description of the problem should accompany the tag. This may help to prevent an injury to someone using the tool prior to the tool's repair or replacement.

Wooden or plastic handles of hand tools must be kept free of splinters, sharp-edge cuts, or other surface damage that could injure workers' hands. Do not use a hand tool if its handle is loose. Loose-handled tools can give way suddenly, causing injuries to people and damaging equipment.

When using powder-actuated tools, always verify that the area behind and around the work area is clear.

Do not attempt to drive nails or other fasteners into:

- Brittle or hard materials (e.g., glazed tile, glass block, face brick). The shattering of the material (fastener) can scatter dangerous shards across a wide area.
- Soft or easily penetrated materials. The nails or fastener can pass through the material and create a hazard for people on the other side.

NOTE: These precautions apply to both manual and powder-actuated tools.

Inspect power tools regularly to ensure that the automatic cutoff, guards, and other safety devices work properly. Follow the manufacturer's recommended maintenance schedule to ensure reliable operation.

Before each use, examine power tools to ensure that all guards are in place and securely attached.

Safety codes often require a ground fault circuit interrupter (GFCI) when temporary electrical wiring is used. Temporary electrical wiring may be defined by the local AHJ as an extension cord or even a building's entire internal electrical wiring prior to final inspection and acceptance.

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Tools and Equipment, continued

Power tools that require a three-conductor power cable must be grounded. Never use a power tool if the ground prong of the plug has been cut off. Never use a power tool with an extension cord or adapter that eliminates the ground prong before the cord reaches the outlet. Never use a tool's power cord to lift or lower the tool.

Carefully follow all manufacturer's instructions when mounting, securing, and using potentially dangerous mechanical equipment (e.g., cable winches, tension arms, cable wheels, cable brakes, powder-actuated guns). Do not set up or operate this equipment without first receiving adequate training and having access to the manufacturer's instructions. Ensure that no personnel are working within the danger zone of a cable winch.

NOTE: Keep original instructions for tools on file at the office. Keep photocopies of the instructions with each tool. This ensures that a set of instructions is always available at the office and used to make additional copies for the work sites.

Ensure adequate lighting is available to safely and efficiently perform work. Proper lighting will help prevent accidents and rework. Use portable lighting, and keep it away from combustible materials. Ensure that any halogen lighting remains in a level position. Halogen bulbs get very hot, and some lamps, if tilted, can melt or cause a fire hazard. Read and follow manufacturer's instructions when using halogen lights.

Ladder Safety

ITS installers must know how to choose, securely place, climb, and safely work on a ladder. The location of ITS cabling and equipment requires that ladders be used often for both installation and repair work.

NOTE: The local AHJ often requires that manufacturers print ladder use guidelines on the ladders. Read and follow these guidelines.

The local AHJ does not always require workers to wear fall-arresting safety equipment while working on portable ladders. However, the local AHJ regulation enforcement at the site level may have unique requirements that add to the requirements set at the national level. Even though it may not be required, it is a good safety practice to tie off to a secure anchorage when working aloft with heavy equipment or over a prolonged period. Always place a ladder so that the ladder is between the user and any potential fall hazard, especially at the edge of a floor.

Use the correct type of ladder. Never use a conductive ladder if the ITS installer or the ladder could come in contact with energized electrical cables or equipment. Use ladders made of a nonconductive material (e.g., fiberglass or wood, if dry) in these situations. Many construction sites will not allow metal or wood ladders on site for safety and insurance reasons. When working over three steps high, a fixed or mobile scaffold is recommended in place of a ladder.

Ladder Safety, continued

Inspect ladders before each use. Check to ensure that:

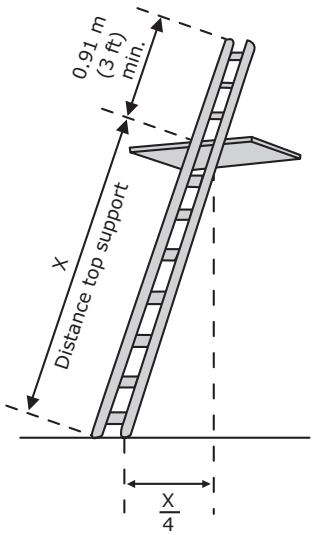
- Joints between the steps and side rails are tight.
- Anti-skid feet are secure and operating properly.
- Moving parts operate freely.
- Rungs are free of dirt, liquids, or other substances that could cause slipping.
- Side rails are not cracked, excessively bent, or dented.
- The ladder is designed and rated for the height and weight load it will be required to support.

Choose a secure location to set up the ladder that is solid and level and offers adequate traction for the ladder's feet. If adequate traction is not available, the ladder must be lashed in place or held in position by other workers. Never set a ladder on top of a box, furniture, or any other unstable surface to gain height.

For a stepladder, verify that the supports that link the ladder rails to the back rails are fully extended and locked in place.

For an extension ladder, ensure that both side rails are supported at the top. Verify that the extension ladder is set at the proper pitch (angle). The horizontal distance from the base of the ladder to the supporting wall should be one-quarter (25 percent) the working length of the ladder (length of ladder from bottom to top support) (e.g., a ladder extended 6.1 meters [m (20 feet [ft])] up a wall would have its base 1.52 m [5 ft] from the wall). See Figure 2.2.

Figure 2.2
Extension ladder



ft = Foot
m = Meter
min. = Minimum

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Ladder Safety, continued

Extension ladders should always overlap between sections by at least three rungs. The top of the ladder should extend up to the work area and 1 m (3.28 ft) above catwalks or lofts. This allows the ITS installer to safely find the steps when getting back onto the ladder from the catwalk or loft. Lash ladders to anchors if the ladder will be used for an extended period of time.

Never paint a ladder. Doing so will hide any stress cracks or damage.

Try to place the ladder where it will be out of traffic's way. Use safety barriers or delineators to designate a restricted area around the base of the ladder. Never set a ladder in front of a door that opens toward the ladder unless the door is locked or can be blocked or guarded from the other side. When climbing up or down a ladder, always face it.

When using a ladder, never:

- Exceed the ladder's weight rating. Most ladders are designed for one person only. Consider the weight of any materials or tools being used as well.
- Stand on the top two rungs of a ladder.
- Leave any object (e.g., tools, gloves) on top or on any rung of a ladder.
- Straddle a ladder or stand on the rear rungs. The rear rungs are narrower than the front steps, and they are not designed to support weight.
- Drop or throw down anything (e.g., tools, excess wire, scraps) when on a ladder. Use a hand line and a grunt sack to raise and lower items.
- Fasten two or more ladders together to create a longer section unless they are specifically designed for such use.
- Move, shift, or extend a ladder while it is in use.
- Over reach or extend the center of your waistline beyond the sides of the ladder. Keep your belt buckle between the side rails at all times.
- Walk, bounce, or move a ladder while climbing or standing on it.
- Use a stepladder as a straight ladder as it may slip out from under you.
- Use a ladder as a platform, plank, or brace.
- Separate sections of an extension ladder to use individually.

Do not stand on furniture, boxes, or any other makeshift ladder substitute. If a ladder is broken or stressed, tag it according to company policies with a large "do not use" sign to keep others from becoming injured. Defective equipment should be removed from the work site immediately and returned to the office for repair or disposal. Consider the following guidelines:

- Never use a ladder with missing or modified parts.
- Never repair a damaged ladder without permission from the manufacturer.
- Read all labels, and only use a ladder if you are in good physical condition.

Personnel Lifts (Elevating Work Platforms)

A personnel lift is required when a ladder or scaffold cannot be used safely or is impractical because of the required working height, weight of personnel, and equipment or customer requirements.

IMPORTANT: All operators must be trained and have received proper instructions before operating aerial platforms. For your safety, warnings are on the platform and in the manufacturer's manual. Failure to obey warnings can cause injury or death. BICSI® recommends that the user be properly trained and certified in the use of lifts.

Two common types of lifts are:

- Boom-supported elevating work platforms (boom lift)—This is a basket mounted on the end of an extendable arm in which the user stands. The articulating arm allows the user to approach the work area from several angles and to avoid obstacles and possible safety hazards. These units are typically large and can be used in limited areas. A full-body harness and lanyard are required for anyone in the basket of this type of lift.
- Self-propelled elevating work platforms (scissor lift)—This is a work platform mounted on a large scissor jack. The scissor lift is very stable, but it is not very flexible in its use. As the scissors are extended, the platform moves straight upward. If there are any obstacles above it, the platform is unable to maneuver around them. The Occupational Safety and Health Administration (OSHA) does not require a body harness and lanyard for this equipment, but your company, the AHJ, or customer might require them.

Factors that determine if a lift is suitable include:

- Maximum working height of the lift.
- Size of the work area.
- Obstacles that may obstruct the lift.

Your lift may be equipped with:

- Stabilizers, outriggers, or extending axles.
- Chain, gate, or bar closures.
- Turntable lock.
- Emergency controls.
- Ground controls.
- Audible and visual alarms (e.g., tilt alarm).

Know which devices are required on your machine. Never remove or modify any of them. Setting brakes and using stabilizing legs or outriggers, if equipped, must secure lifts. Personnel must follow the safety requirements for fall-arresting personal protection devices described later in this chapter.

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Personnel Lifts (Elevating Work Platforms), continued

Read, understand, and follow the danger, warning, caution, and other signs on your machine. Read and understand the manufacturer's operator's manual before using the machine. If there is no manual with the machine, obtain one. If there is something in the manual you do not understand, ask your supervisor to explain it to you.

Check the equipment before you begin to operate machinery, you must inspect your machine and report all deficiencies. Do not operate the machine until deficiencies are corrected and all systems are in good operational condition. The inspection should be conducted in this order:

- Walk-around inspection of the machine and work area before use
- Functional check of the ground controls and equipment in the base of the lift
- Functional check of the upper controls located in the platform or basket of lift

The walk-around inspection should include the following items:

- Missing, damaged, or unreadable equipment signage
- Broken, missing, damaged, or loose parts
- Tire cuts, bulges, and pressure as specified by the manufacturer
- Maintenance procedures outlined by the manufacturer of your machine
- Cracked welds or other evidence of structural damage
- Hydraulic system check for leaks and damage

General safety rules when using lifts include the following:

- Load limits for the platform or basket shall not be exceeded.
- Employees shall always stand firmly on the floor of the basket. Do not sit or climb on the edge of the basket. Do not use planks, ladder, or other devices for a work position.
- Scissor lifts must only be elevated on a firm and level surface.
- Close the gate, or fasten the entry chain after entering the basket.
- Do not tie off the machine or your body harness to an adjacent structure when using a lift.
- Stay at least 3 m (10 ft) away from exposed energized electrical conductors, such as wires or crane bus bars, operating at 300–50,000 volts (V). If necessary, lock out cranes and other equipment that may strike the lift when it is elevated.
- Check the path of travel for the lift. Do not drive the lift over hole covers unless you are sure they can support the weight of the lift.
- Ensure that adequate clearance is maintained around overhead obstacles and underneath the platform when lowering it.
- When driving the lift, lower the platform first, and keep a safe distance from drop-offs, holes, depressions, ramps, and other hazards.
- Keep people out from under the aerial work so that they are not exposed to a falling object hazard.
- The lift operator and others in basket should wear a hard hat, safety glasses, and boots.

Personnel Lifts (Elevating Work Platforms), continued

Consider having a ground person whenever doing aerial work. This person can do the following:

- Keep people away from the area around the bottom of the lift, and use barriers as necessary to establish a work area.
- Check the path of travel for the lift.
- Operate the ground controls of the lift in the event the upper controls fail.

NOTE: Clients may require specific types of powering for the lifts, depending upon working environments (e.g., electrical, fuel, mechanical).

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Personal Protective Equipment (PPE)

Overview

When used correctly, personal protective equipment (PPE) greatly decreases the risk of injury. When PPE is used incorrectly or not used at all, it can leave the ITS installer exposed to a wide variety of dangers.

The PPE that an ITS installer is required to wear when performing a task depends on the:

- Hazards of the task.
- Hazards at the work site.
- Local, state, and national safety requirements.

PPE must fit well and be comfortable. Equipment that fits properly and comfortably ensures that the ITS installer and the protective equipment can work at the same time.

Pay careful attention to the training for each item of PPE. Learn:

- When the equipment must be used.
- How to put on, adjust, and take off the equipment.
- What the equipment can and cannot protect against.
- How to care for and maintain the equipment.

It is important to inspect PPE each time it is used. Look for wear, cracks, tears, punctures, weak joints, or other signs that the equipment may not be capable of providing protection. Report any problems to the proper supervisor. Never use defective protective equipment.

Remember that no amount of protective equipment can provide complete protection. Often, the best personal protection comes from using caution, proper procedures, and common sense when working.

Headgear

ITS installers must wear protective headgear (hard hats) when working in any area where there is danger from:

- Falling or flying objects.
- Electrical shock.
- A blow to the head.

Generally, hard hats provided for ITS installers afford both physical and electrical protection. ITS installers should ensure that their hard hats provide electrical protection before working near power lines or equipment (e.g., ANSI Z89 Class B). The hard hat must fit securely enough to ensure that it will not slip and block the ITS installer's vision or fall on the equipment the ITS installer is working on. ITS installers may choose to use a chinstrap to secure the hard hat only if the chinstrap is thin enough to give way easily if the hard hat catches on something during a fall.

Headgear, continued

Before putting the headgear on, inspect it for cracks, weakness of the internal support structure, or other defects. The date of manufacture appears stamped on the underside of each hat's brim. The date allows easy identification if a certain run of hats has to be recalled because of a defect. Hard hats typically have up to a five-year life span if not subjected to abuse. ITS installers must wear properly rated hard hats.

Replace hard hats that show signs of scratches and cracking or if a shiny surface appears dull or chalky. Do not place stickers on hard hats because they may hide defects or their adhesive may react chemically and weaken the hat.

NOTE: Foil stickers could void the electrical protection of a hard hat.

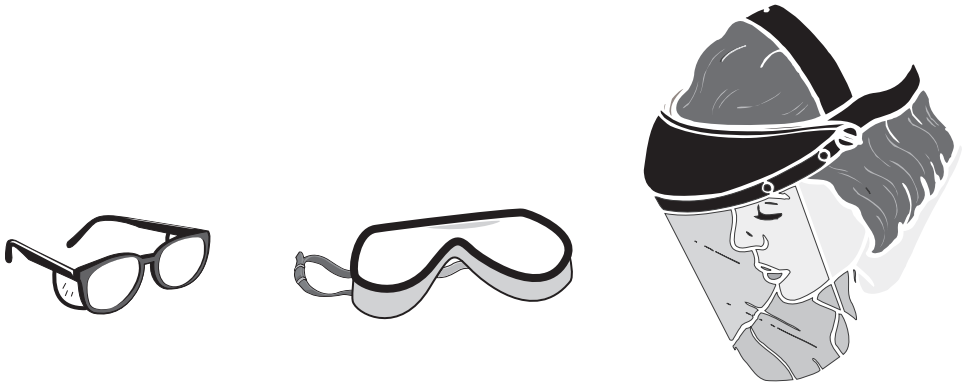
Eye Protection

ITS installers must wear eye protection (e.g., glasses, goggles, full-face shield). See Figure 2.3. If the ITS installer must wear vision-correcting prescription glasses, prescription safety glasses with side shields may be required, or goggles that fit over personal prescription glasses can be used. All eye and face protection must meet or exceed local AHJ requirements (e.g., ANSI Z87).

A wide variety of work situations require eye protection, including:

- Working with batteries (e.g., wearing a full-face shield if there is danger of splashing chemicals).
- Using powder-actuated tools.
- Working with optical fibers.
- Working above eye level and looking up at the work.

Figure 2.3
Eye protection



Glasses Goggles Full-face shield

Wear protective goggles or glasses that provide side protection as well as front protection when the hazards involve flying objects.

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Breathing Protection

ITS installers must wear a respirator whenever harmful dust, gas, smoke, chemical vapor, or other pollutants are present at the work site. If you have reason to believe the air in the working environment may be hazardous, contact your employer. An assessment should be done to determine if a hazard is present and what kind of respirator is appropriate.

Never work without the proper breathing protection. The effects of breathing some harmful substances may not show up until hours, weeks, or years after the exposure.

Filter masks are used in cases where the atmosphere is only moderately hazardous and there is no asphyxiation hazard. Very hazardous atmospheres require the use of protective masks or positive pressure self-contained breathing apparatus (SCBA).

To provide appropriate protection, each mask must seal itself to the user's face. This may require removal of facial hair.

NOTE: Several chemical manufacturing plants and other industrial sites will not allow personnel with excess facial hair (e.g., heavy beards) to work on site.

ITS installers should not try to work while wearing a breathing protection device unless the:

- ITS installers have been fully trained to use the device.
- Device has been carefully fitted.
- ITS installers have been found physically fit to work while wearing the device.
- Device is designed for the specific breathing hazard or chemical to which it may be exposed.

When exposure is limited to nuisance dusts below the OSHA-permissible exposure limit, installers may wear dust masks.

Although employers are required to inspect and maintain breathing protection devices, the ITS installer should inspect the device every time it is used. Report any problems to the supervisor in charge of breathing protection devices.

Lifting Belt

A lifting belt does not give the user any added strength; however, the belt does help to support the stomach muscles while encouraging good posture. It should be noted that these belts might give wearers a false sense of security. These belts do not enable wearers to lift heavy objects with a decreased chance of injury.

Use correct lifting techniques when lifting any object on the job. The following guidelines should be followed:

- Never bend to pick up a heavy object. This is the most frequent cause of back injury and strain.
- Lift with the legs, not with your back. Keeping your chin up helps to keep the back straight.
- Turn with your feet and not at the waist. Avoid twisting the torso.
- If possible, wear a lifting belt when lifting or moving heavy objects or equipment.

Lifting Belt, continued

When carrying or moving items, always know the path to the destination point, and ensure that the items do not block your vision.

A safe rule for supervisors to follow is to restrict lifting of loads to about 25 kilograms (kg [55 pounds (lb)]) per person. If heavier materials need to be moved, two ITS installers should provide assistance, or use appropriate lifting machinery.

Most government contracts in the United States require that workers wear lifting belts.

Protective Footwear

Wear protective footwear on work sites where feet could be injured by falling objects, rolling carts or cable reels, or stepping on sharp objects. A suitable pair of shoes will protect feet from injury and fatigue.

Safety toe footwear, which usually contains steel toe shielding, meets applicable standards (e.g., ANSI Z41) and will help protect toes while metallic or nonmetallic shanks will offer protection from stepping on sharp objects. Metallic or nonmetallic shanks help distribute weight across the base of the shoe. This reduces foot fatigue while standing on the thin rungs of an extension ladder. Leather-soled shoes are not advisable because leather conducts electricity when wet and can be slippery.

Check with the AHJ for the approved standard of protection regarding footwear.

Gloves

Wear protective gloves when performing any work that has the potential for hand or forearm injuries:

- Cut-resistant gloves are rated to provide protection against cuts and abrasions while providing some dexterity.
- Leather gloves provide protection against punctures, extreme temperatures, and limited protection against abrasion. They are not rated for cut protection.
- Rubber, plastic, or latex gloves provide protection from harmful chemicals.

NOTE: Rubber and leather gloves are not for high-voltage use. All high-voltage situations should be referred to qualified persons.

Detection Badges/Exposure Monitors

Some work sites may require that ITS installers wear detection badges or use monitors to ensure that the exposure to a hazardous substance does not exceed safe levels. Understand how the badge or monitor works before entering the hazardous area.

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Detection Badges/Exposure Monitors, continued

Some monitors or badges will provide real-time feedback; they show actual exposure levels as they happen. They may change colors or have a dark stripe that gets longer with the amount of exposure.

Other types will only absorb the toxins at the same level the ITS installer is being exposed to them. These need to be inserted into a scanner to determine the amount of exposure. It is extremely important to check these types of monitors frequently to limit the ITS installer's exposure levels.

Always observe time limits specified for working in a hazardous environment.

High-Visibility Vest or Jacket

On most construction sites, a high-visibility vest or jacket with reflective tape is required.

Hearing Protection

Hearing loss is one of the most frequent injuries encountered in the construction trades. The injured person does not feel pain, but after years of exposure to high levels of construction noise, varying frequencies of his or her hearing may be lost.

Wear hearing protection while working near loud noises. Even the sound of a hammer striking a metal clamp onto red iron requires hearing protection. If the ITS installer experiences a ringing in the ears, adequate hearing protection has not been used.

There are three major types of hearing protection (see Figure 2.4):

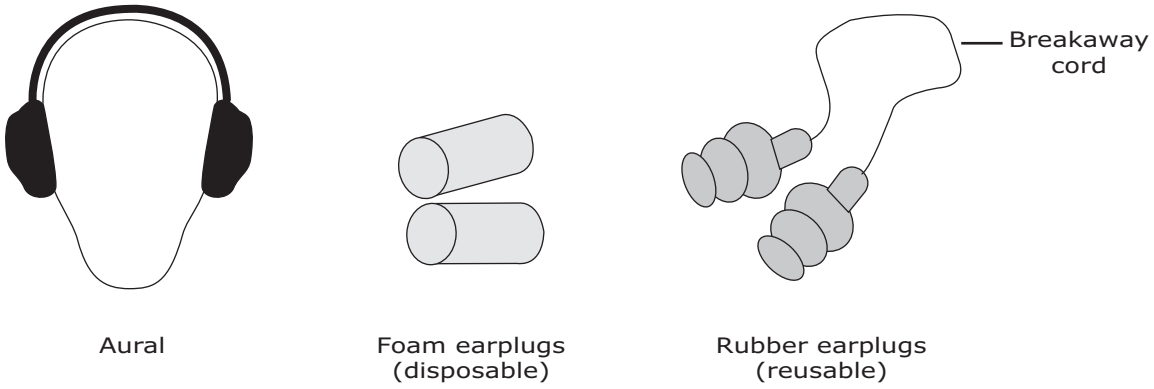
- Aural—These plugs resemble earmuffs, and they are available in passive or active models. When wearing the active models, normal conversation can be heard; however, when a loud noise occurs, the protection automatically dampens the louder sound.
- Foam earplugs (disposable)—These plugs can be rolled between the fingers and slipped into the ear canal.
- Rubber earplugs (reusable)—These may be on a breakaway cord or individually housed in a pocket-sized plastic container. These are convenient because they can be attached to a hard hat or around the ITS installer's neck and tucked inside the ITS installer's shirt. It is vital that they be on a breakaway cord to prevent strangling.

Certain sites require specific types of hearing protection. Check with the local AHJ for further information.

When working in a noisy work site (with or without earplugs), do not rely on hearing to detect the location of machinery, coworkers, or other hazards.

Hearing Protection, continued

Figure 2.4
Hearing protection



Fall Protection

Fall protection is required whenever a person is exposed to a fall hazard to another level of more than 1.83 m (6 ft). It can take the form of a hole cover, a safety net, guard rails, or a personal fall arrest system (PFAS). A PFAS includes a full-body harness, a shock-absorbing lanyard, and a secure anchorage point capable of supporting 2268 kg (5,000 lb). If ITS installers are required to work near fall hazards, their employer must ensure that they receive training on the proper use of PFAS.

ITS installers use elevating devices such as a boom or scissor lifts to reach their work location when ladders are impractical because of height or weight requirements.

To prevent falls, ITS installers must wear a full-body harness and one lanyard any time they use a boom lift. OSHA does not require body harnesses for operators of scissor lifts under normal circumstances.

NOTE: The sides of a boom lift do not typically meet the requirements of a safety barrier because the bucket can tilt and may not provide a stable platform. Boom lifts usually require a full-body harness with one lanyard attached to the lift.

The use of a full-body harness and two lanyards is required whenever the ITS installer leaves the safety of the elevating device or is using catwalks (see Table 2.1). Using two lanyards allows the wearer to always have one lanyard attached to a safety support. If the users have to move along a catwalk but run into an obstacle, they can simply attach their second lanyard beyond the obstacles prior to disconnecting the first one, allowing them to be safely attached to the structure at all times.

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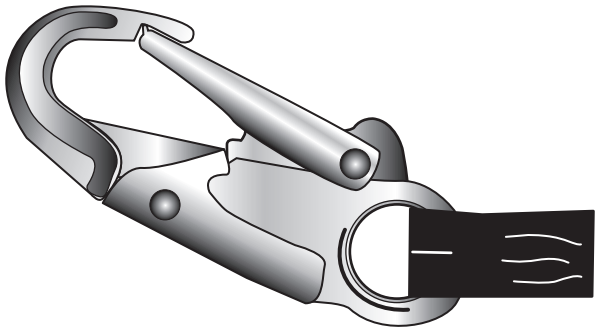
Fall Protection, continued

Table 2.1
Harness specifications

Lift Usage Description	Full-Body Harness Required	Number of Required Lanyards
Fully enclosed safety barrier	No	None
Open or no surrounding barrier	Yes	One
Leaving lift	Yes	Two (for 100% contact)

Safety lanyards are available as simple nylon ropes with self-closing and locking keepers (snap hooks) on each end, or they can incorporate a shock absorber into the line (see Figure 2.5). If a fall were to happen, the shock absorber would reduce the force of the sudden stop to the injured person.

Figure 2.5
Snap hook used on lanyards



All snap hooks must be self-closing and double-action.

BICSI does not recommend the use of safety belts and lanyards equipped with the nonlocking type of self-closing keepers (snap hooks) within buildings and other types of structures.

Many work sites do not allow the use of safety belts. They do not provide the same level of protection as the full-body harness and may cause back injuries.

Before ascending or descending:

- Inspect the harness and its hardware carefully for signs of wear or damage.
- Ensure that the harness is properly secured to the elevating device's anchoring point and never to the supporting guardrail or platform.

Fall Protection, continued

Whenever securing the lanyard, always check the connection. The ITS installer must ensure that the snap hook has captured the lanyard's rope or the equipment's safety ring and that it is securely fastened.

Anchorage for fall protection must be able to support 2268 kg (5,000 lb) per person. Do not connect anchorage to construction materials (e.g., pipes, conduit).

Clothing

Work clothing should be reasonably snug but must allow the ITS installer to move freely. Do not wear dangling or floppy clothing that may get caught on tools or surroundings. Keep shirttails tucked in and cuffs, if any, buttoned or neatly rolled up. This is especially important when the ITS installer is working in a confined space, on an elevating device, or near operating machinery.

Clothing made of cotton is typically more comfortable and safer than synthetic materials that could melt to the worker's skin in the event of a fire.

Do not wear metal jewelry or metal watchbands when working on ITS circuits or equipment. Field-damaged clothing shall be repaired immediately, or the individual must leave the job site. Duct tape may be used to temporarily mend torn clothing.

Grooming

Long hair can be extremely dangerous when working around operating machinery and working aloft. Hair can easily be pulled into machinery or become caught on ceiling grids. Pulling the hair back in a ponytail usually provides better protection while allowing the worker to wear safety equipment, but the safest way to ensure that hair does not get caught on or in something is to tuck it completely under a hat.

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Hazardous Environments—Indoor

Overview

Although there are hazards involved in any ITS cabling installation work, some indoor situations are especially hazardous. These situations require extra safety precautions and, often, extra PPE.

A complete study of hazardous indoor environments is beyond the scope of this manual. The following sections provide a brief overview of several hazardous environments and some of the extra precautions they require.

Always carefully follow all safety procedures when working in an indoor hazardous environment.

Electrical Hazards

The presence of electrical power cabling and electrical equipment is probably the most common environmental hazard faced by ITS installers. Like ITS cables, electrical power cables run in walls, under floors, and over ceilings. Power is required for ITS equipment in telecommunications rooms (TRs) and equipment rooms (ERs).

OSHA requires that live parts of electrical equipment operating at 50 V or more be guarded against contact. Also, unqualified workers must stay at least 3 m (10 ft) from exposed energized conductors operating at 300 to 50,000 V.

All electrical systems are potential killers; therefore, all personnel should be aware of the dangers and have electrical safety training. Use power tools and equipment only for the purposes for which they are made. Use tools only according to the manufacturer's instructions.

Wear rubber-soled shoes, and remove all metallic jewelry. Most jewelry is made of gold or silver, and both are extremely good conductors of electricity.

Never intentionally expose yourself to an electrical shock (e.g., do not run your finger down a termination block to check for ringing current).

The physical effects of current are as follows:

- 2 to 3 milliamperes (mA) produce a tingling of the skin.
- 10 mA produce a painful shock, and the muscles cannot release the contact.
- 50 to 100 mA cause breathing to become difficult.
- 100 mA trigger ventricular fibrillation, which causes the heart to repeatedly relax and violently clamp shut. This occurrence severely damages the heart and usually results in death.
- 200 mA and above cause the heart to clamp shut, and severe burns occur on skin and hair. At this level, the damage to the heart may actually be less than at 100 mA, allowing the injured person a better chance of survival if medical treatment is given in time.

Electrical Hazards, continued

Treat all electrical circuits as if they were live (energized). Even after the circuits have been turned off and tested to ensure that they are off, treat electrical circuits as if they were likely to become live again at any moment. Always lock out and tag all electrical circuits that have been turned off. Continue to maintain appropriate clearances, wear the proper PPE, and take the recommended precautions.

ITS installers must be especially careful in situations where electrical circuits or equipment may be contacted blindly (e.g., drilling into walls and fishing conduits).

WARNING: Never use a metal fish tape in a conduit if the exit point is unknown.

Avoid working in standing water. If ITS installers must work in standing water (e.g., in a basement tunnel), take extra care to ensure that no electrical power circuits are near the water or the work area.

Never cut the ground prong off a power tool plug. Removing the ground prong creates a serious possibility of severe electrical shock for the worker using the tool. Check power cords regularly with a visual and electrical inspection. Also check grounded outlets with an outlet tester before plugging equipment into them to ensure that they are properly grounded. Use a GFCI outlet when at construction sites, outside, or in damp environments when using electrical equipment.

ITS installers should use voltage detectors to check conduit, raceway, ceiling grid, or other items when they believe these may be energized.

Avoid working on energized equipment. If the ITS installer must work on an energized circuit (e.g., performing an alignment in a microwave radio, troubleshooting a telephone system), have a qualified safety person standing by.

All technicians must know:

- Where and how to secure electrical circuits.
- How to administer first aid and CPR.
- Where and how to get help.

Many ERs are outfitted with an emergency electrical safety board. This board is mounted to the wall and may have a:

- First aid kit.
- Static grounding wrist strap—This is used to take the built-up static charge from the ITS installer to the ground and avoid damaging sensitive circuits.
- Safety grounding wand—This is an insulated handle with a metal tip. It is connected to an insulated cable with a large metal clip on the opposite end. The clip is connected first to a ground source. The metal tip is used to short any transient voltages left on a de-energized circuit.

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Electrical Hazards, continued

- Pair of high-voltage rubber gloves and protective leather outer shells—The rubber gloves should be inspected regularly for holes and cracks, and the leather outer shell must show no signs of wear. Only ITS installers trained in high-voltage rescues should use these gloves.
- Wooden cane—The cane should be lacquer free in order to be a nonconductive rescue device. It may be used to pull live wires off an injured person or pull the injured person to safety.

In the case of an electrical fire, it is most important to protect people. Protection involves four steps easily remembered by an acronym, RACE, which stands for:

- Rescue—Get people out of danger.
- Alarm—Sound the alarm; call for help.
- Confine—De-energize all electrical circuits involved with the fire. Close windows and doors, and deactivate the heating, ventilating, and air conditioning (HVAC) system.
- Extinguish—Control the fire with the correct type of firefighting equipment. All TRs and ERs should have access to a fire extinguisher designed to fight an electrical fire.

When working in TRs, make it a habit to check for an approved fire extinguisher. Extinguishers may be designed for:

- Combustibles (e.g., paper, wood, anything that leaves ashes).
- Liquids (e.g., gas, oil, alcohol).
- Electrical fires.
- Metal fires (e.g., magnesium fires).

The extinguishers used shall be compliant with the classifications or categorizations dictated by the AHJ.

These designations are important since using the wrong rating could electrocute the user or possibly spread the fire (e.g., spraying water into a grease fire).

Lightning Hazards

Although lightning is generally thought of as an outside plant (OSP) hazard, it can endanger indoor workers. This is especially true during construction or renovation when protective systems may be incomplete or disconnected. Exercise caution during an electrical storm when working on premises cables that are electrically connected to OSP cables.

Access Floors

Raised computer room flooring is becoming very popular in ERs. There are potential dangers associated with access flooring:

- Whenever floor tiles are removed, the area must be marked off with barricades or caution tape to warn others of the hazard.
- Floors are usually part of the HVAC distribution system. When a floor tile is removed, pressure is released, and dirt, dust, and debris may fly at the ITS installer. Safety glasses are necessary, and a dust mask is suggested.
- Floor systems are usually constructed with metal pedestals interconnected with stabilizing stringers joining them. The floor tiles are then placed on top, so each pedestal will support the intersection of four separate tile corners. These systems are very stable even with several tiles removed. It may be necessary to remove several stringers to install longer sections of cable tray under the raised floor. Use caution when doing so, and limit the number of sections installed before moving on to other areas.

Another construction method is without the stringers. The floor maintains its stability when all the tiles are in place. Never remove all the tiles in a single row if stringers are not used for stability. If stability shifts toward the open row where the tiles have been removed, the entire floor may collapse.

- When tiles are replaced, it is often like a jigsaw puzzle. If the tiles are not placed exactly in the same spot, the floor will often have loose tiles that wobble when walked on.
- When working in a live communications space where an access floor is installed, permissions will be needed to remove tiles as they may affect the fire and smoke detection system.

NOTE: Prior to removing tiles, put a piece of tape in the corner of every tile to be removed. Place the tape in the same corner of each tile (e.g., northeast corner), and put a unique number on the tape. This ensures that the tiles will go back exactly as they came out.

Catwalk Hazards

In large buildings or industrial facilities, a catwalk may be provided to help workers reach utilities. When working from a catwalk, stay on the catwalk. Do not climb or walk onto beams or other support structures. If the catwalk is not equipped with proper handrails and toeboards, personal fall arrest equipment may be necessary to access the area safely.

Never intentionally drop or throw anything (e.g., tools, excess wire, scraps) from a catwalk or other elevated work location. Use a hand line and a grunt sack to raise and lower items.

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Crawl Space Hazards

ITS cabling often runs above suspended ceilings, below raised floors, in attics, and in other spaces where ITS installers cannot stand upright. These areas are called crawl spaces.

It is a good idea to wear protective headgear (e.g., hard hat) when working in crawl spaces, especially when electrical wiring is present. The hard hat will protect the ITS installer's head from the hard surfaces and sharp edges that may be found on the supporting hardware for the floor or ceiling system. Leather gloves and knee pads may also be needed to prevent injury when crawling in these places.

Ensure that lighting is adequate to see the work clearly. If not, use a flashlight or other work light for extra light.

Before beginning work in any crawl space, take the time to locate and identify other facilities that are routed through the crawl space (e.g., electrical power wiring, pipes, HVAC ducts). Identifying surrounding hazards can keep ITS installers from accidentally damaging another system or endangering themselves.

A dust mask or other breathing protection may be required if dust, fibrous insulation, or other breathing hazards are present in the crawl space. Check with employers and the building management to determine the nature of the hazard and the protection required.

When moving through a crawl space, walk or crawl only on surfaces designated to support walking or crawling. The ITS installer should never put weight on the ceiling support hardware that is not designed to support crawling or walking. Before putting full weight on a walk or crawl surface, the ITS installer should ensure that the surface is strong enough to bear weight. Never put weight on cable support devices (e.g., cable trays).

Never intentionally drop or throw anything (e.g., tools, excess wire, scraps) from a crawl space above a suspended ceiling. Do not drop, place, or throw anything on top of the ceiling tiles.

Crawl spaces may be considered confined spaces that require additional precautions (e.g., venting).

Confined Spaces

Working in confined spaces poses additional safety risks. Comply with applicable codes, standards, and regulations associated with confined spaces.

There are two types of confined spaces. A confined space that requires a permit for entry is classified as a permit-required confined space (PRCS), and one that can be entered without a permit is called a nonpermit confined space (NPCS).

A confined space:

- Is large enough and so configured that an employee can enter bodily and perform assigned work.
- Has limited or restrictive means for entry or exit (e.g., tanks, vessels, silos, storage bins, hoppers, vaults, pits).
- Is not designed for continuous employee occupancy.

A PRCS fits the definition of a confined space and has one or more of the following characteristics:

- Contains or has a potential to contain a hazardous atmosphere
- Contains a material that has a potential for engulfing the entrant
- Contains inwardly converging walls or a floor that slopes downward and tapers to a smaller cross section where an entrant could be trapped or asphyxiated
- Contains any other recognized serious safety or health hazard (e.g., unsafe temperature, electrical shock, corrosive chemicals)

Maintenance holes (MHs), cable vaults, crawl spaces, and attics can fall under the definition of a confined space.

Confined spaces may require testing for a hazardous atmosphere because they may contain:

- Unsafe oxygen levels below 19.5 or above 23.5 percent.
- Flammable gas, vapor, or mist.
- Combustible dust.
- Toxic substances in a concentration greater than deemed safe by safety standards. Nonlethal or incapacitating toxins are not covered by this provision.
- Any other atmospheric condition that is immediately dangerous to life or health.

When toxins, gases, or combustibles are detected, the ITS installer shall:

- Provide continuous forced air ventilation to purge the contaminants from the space.
- Periodically monitor the air quality within the space.
- Evacuate the space immediately if contaminants return.
- Determine why the contaminants returned, and take corrective action prior to reentering the space.

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Confined Spaces, continued

Certain confined spaces may require:

- Breathing apparatus.
- Protective clothing.
- A trained safety person stationed outside the space.
- A lifeline attached to the worker inside the space.

Hazards from toxic or flammable gas are rare when working inside a building. TRs and ERs should be completely free of gas hazards. However, there may be some situations where a sealed vault-type structure (e.g., entry facility, splice pit) may accumulate gases.

Always use caution when entering any room or work area that is marked with warning signs that prohibit open flames or indicate other potential gas hazards.

When opening a vault-type structure, treat the vault like an MH. Before entering the vault, use a gas detector to determine if any dangerous gases are present. If dangerous gases are present, the gases must be cleared from the vault before any worker enters. Testing vaults and MHs for gases are usually OSP procedures and are outside the scope of this manual.

Optical Fiber Hazards

Optical fiber systems involve some hazards that balanced twisted-pair cabling systems do not. Most of the optical fiber cabling hazards involve the:

- Optical fiber glass shards.
- Chemicals used for termination procedures.
- Transmission light source.

When performing splicing or termination processes, because of the nature of the optical fiber, there will be optical fiber glass shards or short pieces of optical fiber that need to be handled and disposed of properly.

The ITS installer should have a designated container fitted with a removable secure lid to store these pieces of optical fiber glass. The container should be labeled properly. When it is full, the closed container should be disposed of in an approved manner. A soft drink can or plastic cup is not acceptable for this purpose. Electrical tape or masking tape formed into a loop with the sticky side out is also not an acceptable method of disposing of optical fiber ends.

Using a short piece of tape to pick up a small piece of optical fiber from a work surface is acceptable as long as the ITS installer is careful not to apply pressure so that the shards of glass penetrate the tape and cause injury. Eating and drinking is also not permitted in the work area as optical fiber glass may be ingested by the ITS installer.

Never throw bare fiber scraps into community trash containers. Always seal fiber scraps in a container. Tape the container closed, and mark it as optical fiber glass scraps. Take the container directly to the dumpster to avoid accidents to the unsuspecting customer.

Optical Fiber Hazards, continued

Consult standards that provide rules for safe practices in the handling, installation, testing, use, and disposal of optical fiber cabling and associated materials and equipment (e.g., AS/NZS 2967). Some standards provide safety rules for optical fiber telecommunications systems and associated materials and equipment, which cover the following:

- Handling, use, and disposal of optical fiber materials and associated chemicals
- Testing and use of laser light sources
- Use, installation, and operation of an optical fiber cabling system (OFCS)

WARNING: Never look into the end of an optical fiber cable. Most optical fiber transmission light is invisible (infrared) and can burn the retina of the eye before the ITS installer realizes that the light is present. Light sources for test equipment may be just as hazardous as the regular system light source.

Always wear eye protection when handling exposed fibers. Small fragments of optical fiber can easily fly into the eyes during cleaving. Exposed fiber ends can injure the eyes when cables twist, flip, or fall.

Optical fiber termination kits may contain chemicals (e.g., epoxy, alcohol) that are subject to chemical hazards. MSDSs must be readily available on the work site.

NOTE: See Chemical Hazards in this section for more information.

Battery Hazards

Working with or around vented lead–acid (wet) cell or nickel cadmium (NiCd) batteries requires:

- An eyewash station.
- Training in handling electrolytes.
- Full-face shield protection.
- Acid-resistant gloves and apron.
- Training in emergency procedures for spills.

Always use care when working around batteries. Batteries are always live. Lead–acid batteries release hydrogen and oxygen gases as they are charged. Hydrogen is extremely combustible and must be vented outdoors. Most batteries are vented into the room, and an exhaust fan pulls the hydrogen and oxygen outdoors. If the fan fails to operate, the gases will build up and create a potential hazard.

Neutralize small acid spills with sodium bicarbonate (baking soda), and clean up with damp rags.

Flush electrolyte burns to the skin with large quantities of fresh water. Do not attempt to neutralize acid burns to the skin with sodium bicarbonate as this will cause further injury. Seek immediate medical attention.

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Asbestos Hazards

Asbestos is a microscopic fibrous mineral substance that was used in many buildings as an insulation or fire-resistant material between the mid-1940s and 1978. Asbestos was widely used in acoustical ceilings, wall and ceiling insulation, wall panels, floor tiles, fireproofing for structural steel, and pipe and boiler wrappings.

Asbestos often looks like plaster and cloth tape wrapped around pipes or an expanding insulation that is sprayed on boilers and structural steel. The difficult part of identifying asbestos is that it resembles other forms of insulation and must be checked in a laboratory.

Schools and other public institutions in many, but not all, countries were required to locate asbestos-containing materials in their buildings and determine the threat they posed. The asbestos-containing materials were then either:

- Removed.
- Cleaned and sealed to prevent fiber releases.
- Labeled as asbestos and left intact.

The mere presence of an asbestos-containing substance is not hazardous as long as it is not releasing fibers into the air. However, disturbing a substance that contains asbestos by sawing, drilling, breaking, or rubbing may cause it to release fibers and create a serious breathing hazard.

Once airborne, asbestos can easily be inhaled. The microscopic fibers resemble a fish hook and attach to the lining of your respiratory system. The fibers do not dissolve over time and can ultimately lead to serious respiratory problems and even cancer.

Laboratory tests are required to determine whether a substance contains asbestos. Building managers and owners are required to maintain records of any known or suspected asbestos-containing substances in their buildings.

If ITS installers encounter a labeled asbestos-containing substance and cannot perform the job without disturbing it, they should stop work immediately and consult their employer about alternative plans.

Chemical Hazards

Many products used in the ITS industry contain chemicals that can be hazardous to people and the environment. To help the ITS installer work safely with commercial products, chemical manufacturers are required to provide MSDSs, and employers are required to provide access to them.

MSDSs are provided for all products used in a commercial environment that can be absorbed through the skin, inhaled, ingested, or require special handling for disposal.

Chemical Hazards, continued

MSDSs must be readily available at the work site where the products are being used. They may be indexed and retained in a three-ring binder at the work site, or they may be made available electronically as long as there is a backup method of accessing the material in the event of an equipment failure. The company must identify the person responsible for obtaining and updating the MSDSs on a regular basis.

Each MSDS must contain, and all employees should be aware of, the following information regarding the product:

- Health hazards, including warning signs and physical symptoms
- Physical characteristics of the hazard (e.g., vapors, flash point, skin contact)
- Permissible exposure limit
- General procedures and precautions for safe handling and use of the product
- Applicable control measures
- First aid and emergency procedures
- Identification of the responsible manufacturer

Chemicals and chemical vapors can be very dangerous. Without proper handling and ventilation:

- Toxic vapors can overwhelm the user, causing immediate and long-term effects. Fumes may cause nausea, headache, vomiting, or death. Prolonged exposure can cause disease to internal organs.
- Vapors may be flammable and create a fire when exposed to a spark.
- Vapors may be explosive when concentrated in a confined space.

When working with products that produce toxic or flammable vapors, it is always best to use them outdoors. When this is not practical:

- Notify other workers, and have a safety person check the area periodically.
- Open windows.
- Restrict air flow to other areas where people are working.
- Blow toxic air directly outdoors, paying attention not to send the vapors into an unsuspecting office next door.
- Blow fresh air into the work area.
- Take frequent breaks to keep the exposure levels of toxins low.

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Other Hazardous Locations

Some work sites are considered hazardous regardless of the work actually undertaken. Working around electrical equipment is considered hazardous, and ITS installers must be current on their knowledge of safety in that environment.

Other sites considered hazardous by some jurisdictions include:

- Aircraft hangers and other structures where any part of an aircraft might undergo service or repairs.
- Bulk storage plants (e.g., flammable liquids).
- Grain shipping facilities (e.g., combustible dusts).
- Milling plants (e.g., fibers, other airborne material).
- Portions of hospitals (e.g., gases, bacteria).
- Chemical plants and refineries.

Each of these facilities, as well as several others, has very specific safety rules of which the ITS installer must be aware. It is not enough to be simply careful; the ITS installer must obtain specific direction and training when working in such areas.

Hazardous Environments—Outdoor

Outside Plant (OSP)

Hazardous outdoor working environments (e.g., MHs, tunnels, ditches, aerial facilities) are outside the scope of this manual. Special OSP training is required for working in these environments. Refer to BICSI's current *Outside Plant Design Reference Manual* (*OSPDRM*) for further information.

Safety Planning

Overview

Most large companies have established safety plans and training following federal and state guidelines. However, many small firms have not. Some rely on materials provided by general contractors or specific industry organizations.

Although it is not the intent of this manual to provide any formal safety plan, this section of the manual provides an overview of what such a plan should contain, identifies sources for this information, and includes a sample checklist for safety practices.

The following are the major elements of an effective program.

Management Commitment and Employee Involvement

The employees generally will not fully implement a program not actively supported by management. Conversely, without the support of every employee, even a good plan is doomed to fail.

At a minimum, the following actions are needed:

- Clearly state the company policy on health and safety.
- Establish a clear goal for the program.
- Provide visible top management support.
- Encourage employee participation.
- Provide adequate authority and resources.
- Hold everyone accountable.
- Review and update the program.

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Work Site Analysis

Each work site must be examined to identify existing and potential hazards and to anticipate and prevent problems.

The following measures are recommended:

- Conduct baseline work site surveys.
- Analyze planned and new facilities.
- Perform hazard analysis.
- Conduct risk assessments on workers' tasks.
- Conduct regular inspections of the site.
- Provide a reliable system of problem notification.
- Investigate accidents and incidents promptly.
- Analyze trends over time to detect patterns.

Hazard Prevention and Control

The goal is to minimize hazards in the workplace.

To accomplish this, the following procedures must be in place:

- Utilize specific safety-defined engineering job techniques.
- Follow safe work practices through training and enforcement.
- Use PPE.
- Maintain the site in a manner that reduces risk.
- Plan and prepare for problems.
- Know the location of first aid facilities.

Health and Safety Training

Training is a major portion of any effective program and must include the following components:

- Employee training
- Supervisory training
- Management support

An example of a work site inspection checklist is included at the end of this section.

Example of a Work Site Inspection Checklist

ITS Work Site General Inspection

Company Name: _____

Work Site Address: _____

Superintendent: _____

Date and Time: _____

Inspector(s): _____

Date	Yes	No	N/A	Correct	Area/Issue Inspected
					1. Project site safety analysis complete?
					2. Hazardous materials identified and planned for or removed from site?
					3. Safety activities and protective equipment identified?
					4. Site emergency response and evacuation plan prepared?
					5. Monitoring plan prepared?
					6. Subcontractor conformance accepted?
					7. Employee and manager training completed?
					8. Posters, barricades, and safety signs in place?
					9. Safety meetings scheduled?
					10. First aid kit stocked and available?
					11. Emergency contact telephone numbers displayed?
					12. Emergency communications in place?
					13. Site safety supervisor assigned?
					14. Site recordkeeping system in place?
					15. Adequate toilets and washing facilities provided?
					16. Adequate work area illumination provided?
					17. Electrical service and grounding adequate?
					18. Support equipment (e.g., ladders, lifts, lights, hand tools) checked and serviceable?
					19. Work site cleaned daily?

NOTE: This general safety inspection checklist is not designed to supersede existing safety inspection checklists. It should be used only as a general guideline.

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Chapter 3
Cabling, Pathways, and Spaces

Chapter 3 prepares information technology systems (ITS) installers for working with structured cabling systems (SCSs) and installing cable support structures. This chapter provides information on the administration of SCSs, various topologies, and telecommunications spaces.

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Structured Cabling Systems (SCSs)

Overview

A structured cabling system (SCS) is defined as the complete and collective configuration of cabling and associated hardware that has been installed at a given site to provide a comprehensive information technology systems (ITS) infrastructure. This ITS infrastructure is intended to serve a wide range of uses, including access to:

- Traditional plain old telephone services (POTS).
- Innovative telephone services such as voice over Internet protocol (VoIP).
- Unified messaging solutions.
- Videoconferencing.
- Computer networking.

In this chapter, an SCS is further defined in terms of ownership. The SCS begins at the point where the service provider (SP) terminates. This point is known as the point of demarcation or network interface device (NID). An SP is the operator of any service that furnishes telecommunications content (transmissions) delivered over access provider (AP) facilities. An AP is a company (e.g., telephone company) that provides a circuit path between a SP and the client user. An AP also can be the SP.

For example, in a telephone system installation, the SP furnishes one or more telephone service lines (per customer requirements). The SP connects the telephone service lines at the demarcation point.

Every SCS is unique. This is due to variations in the:

- Architectural structure of the building that houses the ITS cabling installation.
- Cable and connecting hardware.
- Function of the ITS cabling installation.
- Types and characteristics of active equipment that the ITS cabling installation will support, both present and future.
- Configuration of an existing cabling installation (e.g., upgrades, retrofits).
- Customer requirements.
- Warranties offered by manufacturers.

Standardization of ITS Cabling Installation

Although the specifics of an ITS cabling installation are unique, the overall components of an SCS and the methods used to complete and maintain the ITS cabling installation are relatively standard. The standardization of ITS cabling installations, valid all over the world, is necessary to ensure acceptable system performance from increasingly complex systems.

NOTE: Application of standards is described in Appendix A: Codes, Standards, Regulations, and Organizations.

Standards provide the following benefits:

- Consistency of ITS design and cabling installation
- Conformance to physical and transmission requirements
- A basis for examining a proposed system expansion
- Uniform documentation

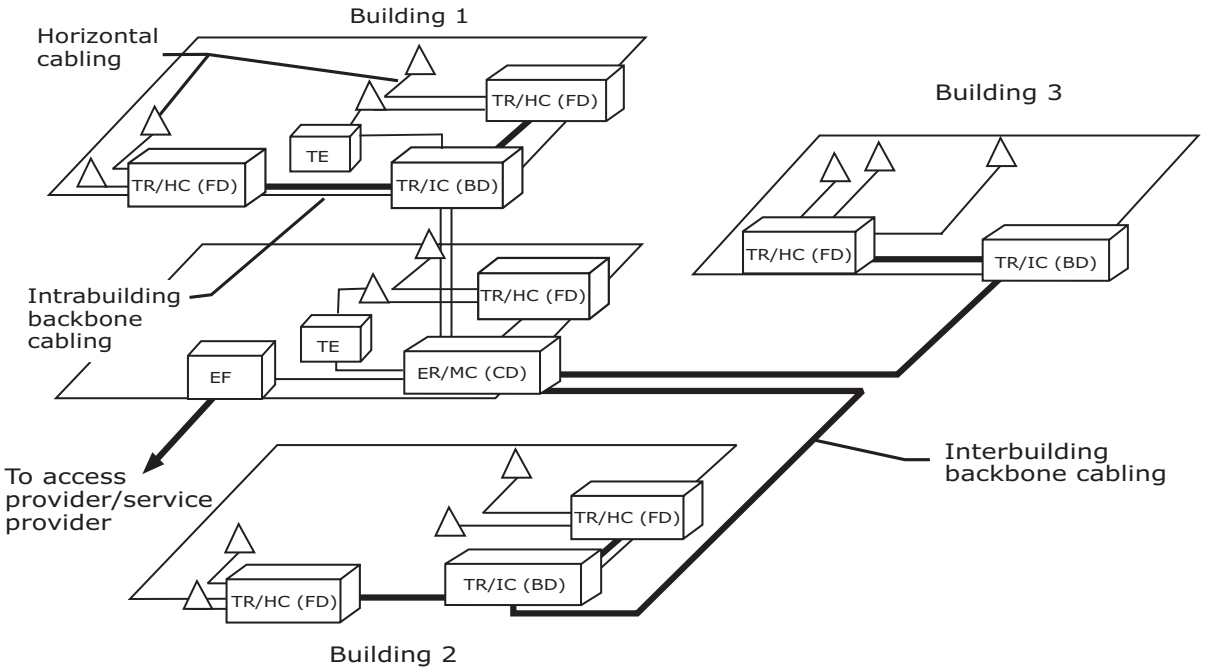
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Generic Structured Cabling System (SCS)

Overview

Figure 3.1 shows a generic SCS. The scope of a generic SCS covers the physical connectivity for many ITS.

Figure 3.1
Example of a structured cabling system



Δ = Work area
EF = Entrance facility
ER = Equipment room
HC (FD) = Horizontal cross-connect (floor distributor)
IC (BD) = Intermediate cross-connect (building distributor)
MC (CD) = Main cross-connect (campus distributor)
TE = Telecommunications enclosure
TR = Telecommunications room

The only type of ITS cabling installation presented in this chapter is an installation within a single building.

NOTE: Outside plant (OSP) systems are addressed in the BICSI® *Outside Plant Design Reference Manual* (*OSPDRM*).

Overview, continued

An SCS includes most or all of the following components:

- Backbone cabling and associated pathways
- Cross-connection facilities
- Interconnection facilities
- Cabling methodologies
- Horizontal cabling and associated pathways
- Work areas
- Telecommunications outlets/connectors
- Consolidation points (CPs)
- Multiuser telecommunications outlet assemblies (MUTOAs)
- Transition points (TPs)
- Centralized cabling
- Distributed cabling
- Administration (e.g., labeling, documentation)

Backbone Cabling

The term backbone is used to describe cabling that handles the bulk of network traffic. The function of the backbone cabling is to provide interconnections between TRs, ERs, main terminal space, and entrance facilities (EFs) in the ITS cabling structure.

Backbone cabling consists of the backbone cables, intermediate and main cross-connects, mechanical terminations, and patch cords or jumpers used for backbone-to-backbone cross-connection. Backbone cabling includes cabling between buildings.

NOTE: The term mechanical terminations refers to all optical fiber and balanced twisted-pair terminations of cable to connectivity, including optical fiber splicing and balanced twisted-pair splicing.

There are two types of backbone cabling:

- Interbuilding backbone cabling distributes telecommunications services between buildings.
- Intrabuilding backbone cabling distributes telecommunications services between telecommunications spaces (e.g., ER, TR) within a single building.

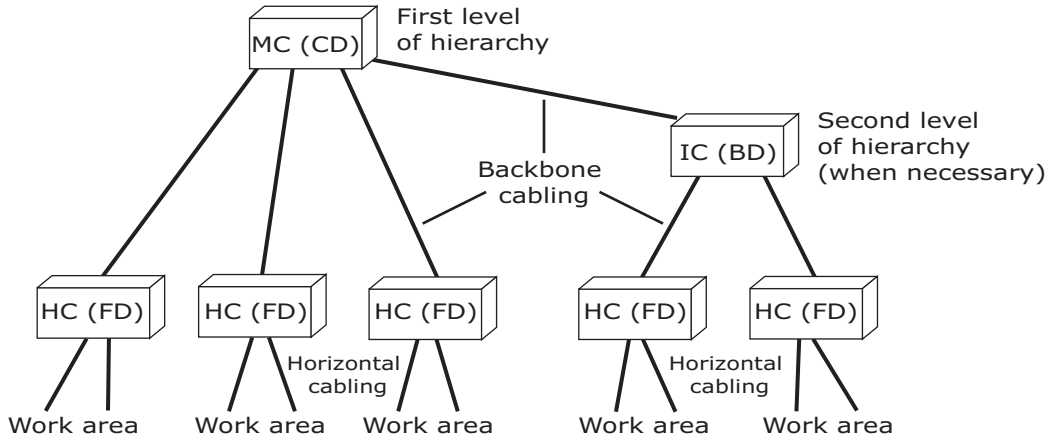
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Backbone Cabling, continued

Cabling standards identify two administrative levels of backbone cabling (see Figure 3.2):

- A first-level backbone consists of cabling that is installed between a main cross-connect (MC [campus distributor (CD)]) and an intermediate cross-connect (IC [building distributor (BD)]) or a horizontal cross-connect (HC [floor distributor (FD)]).
- A second-level backbone is a cable that is installed between an IC (BD) and an HC (FD).

Figure 3.2
Example of structured backbone cabling installation



HC (FD) = Horizontal cross-connect (floor distributor)
IC (BD) = Intermediate cross-connect (building distributor)
MC (CD) = Main cross-connect (campus distributor)

Backbone Cabling, continued

The main components of backbone cabling are:

- Cabling pathways—Shafts, conduits, raceways, and floor penetrations (e.g., sleeves, slots) that provide routing space for the cabling.
- The cables—Optical fiber, balanced twisted-pair, coaxial, or some combination of these cables.
- Connecting hardware—Connecting blocks, patch panels, interconnections, cross-connections, patch cords, equipment cords, or some combination of these components.
- Miscellaneous support facilities—Cable support hardware, firestopping, and bonding and grounding (earthing) hardware.

Certain considerations should be addressed when installing a backbone cabling system:

- The useful life of the backbone cabling system is expected to consist of several planned growth periods (each period spanning three to ten years). This is shorter than the overall life of the premises cabling system.
- Prior to the start of a planning period, the maximum amount of backbone cabling for the planning period should be projected. Growth and changes during this period should be accommodated in order to eliminate installing additional cabling during the planned growth period.
- Planning the routing and support structure for balanced twisted-pair cabling should avoid areas where potential sources of electromagnetic interference (EMI) may exist.

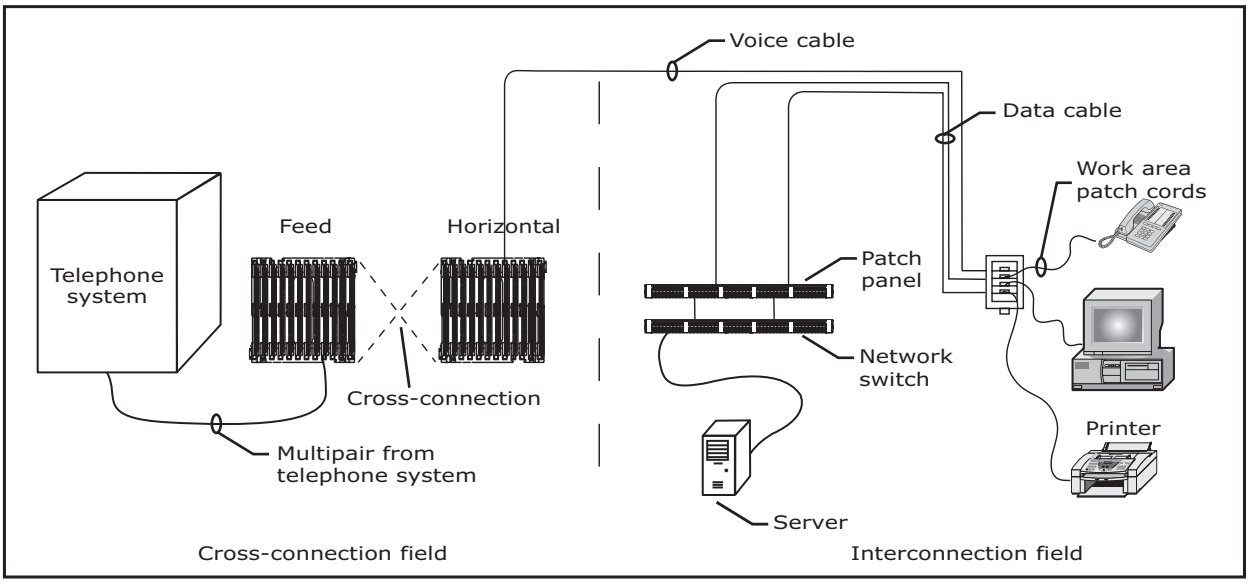
NOTE: The physical orientation of the cabling (e.g., up, down, sideways) has no bearing on classifying the cable as horizontal or backbone. See the discussion of Horizontal Cabling later in this section.

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Cross-Connections

One of the primary functions of the TR is to house the floor-serving cross-connections and interconnections. Figure 3.3 shows a comparison of the two.

Figure 3.3
Cross-connection and interconnection



NOTE: This figure shows two methods of attaching common equipment to the cabling system. Other cabling methods may be used (e.g., modular patch panels, insulation displacement connection [IDC] termination blocks).

Cross-connections are required between horizontal and backbone cabling and when multiport equipment connections (e.g., 25-pair connectors) attach to horizontal or backbone cabling. Interconnections may be made when single-port equipment connections (e.g., 4-pair and optical fiber connectors) attach to horizontal or backbone cabling.

There are three types of cross-connections:

- MC (CD)—Building- or campus-serving cross-connect in the ER for connecting entrance cabling, backbone cabling, and equipment cabling
- IC (BD)—Building-serving cross-connect points located between the MC (CD) and HC (FD) in interbuilding backbone cabling
- HC (FD)—Floor-serving location for the cross-connection of horizontal cabling to other cabling and equipment

Cross-Connections, continued

Cross-connections are available in two types:

- Patch cords (e.g., optical fiber, balanced twisted-pair)
- Jumper wires (e.g., balanced twisted-pair cabling in multiples of 1-pr, 2-pr, 3-pr, 4-pr)

The following recommendations apply to all cross-connections:

- Horizontal and backbone cabling are to be permanently terminated on connecting hardware.
- All connections between backbone and horizontal cabling are to be cross-connections.
- Equipment cables that consolidate several ports on a single connector are to be terminated on dedicated connecting hardware.
- Equipment cables may be either cross-connected or interconnected to horizontal or backbone terminations (refer to Figure 3.3).
- Direct interconnections reduce the number of connections required to configure a link; however, this may reduce flexibility.
- When used as cross-connections or interconnections, patch cords and equipment cords should be made of stranded cable.

More often, customers use equipment racks or cabinets within telecommunications spaces to improve their ability to terminate and manage an SCS. The designer often specifies these systems, but the ITS cabling installer must be aware of the intended use for each rack or cabinet. Simply attaching patch panels to a rack or cabinet is not sufficient for most cabling installations. Cable support and cross-connect raceways need to be installed to promote the correct use of the cabling systems. The rack or cabinet needs to be mounted with work and safety clearances and in such a manner that it can be connected to other equipment or cabling terminations.

Horizontal Cabling

The term horizontal cabling is used because this part of the cabling system typically runs horizontally along the floor and ceiling of a building.

The horizontal cabling is the portion of the telecommunications cabling system that extends from the work area telecommunications outlet/connector to the HC in the TR.

See Figures 3.4 and 3.5 for examples of horizontal cables.

The horizontal cabling includes horizontal cables, telecommunications outlet/connectors in the work area, mechanical terminations, and equipment cords, patch cords, or jumpers located in the TR and may include MUTOAs, CPs, or a combination of both.

NOTE: The term mechanical terminations refers to all optical fiber and balanced twisted-pair terminations of cable to connectivity, including optical fiber splicing and balanced twisted-pair splicing.

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Horizontal Cabling, continued

Horizontal cabling systems consist of two basic elements:

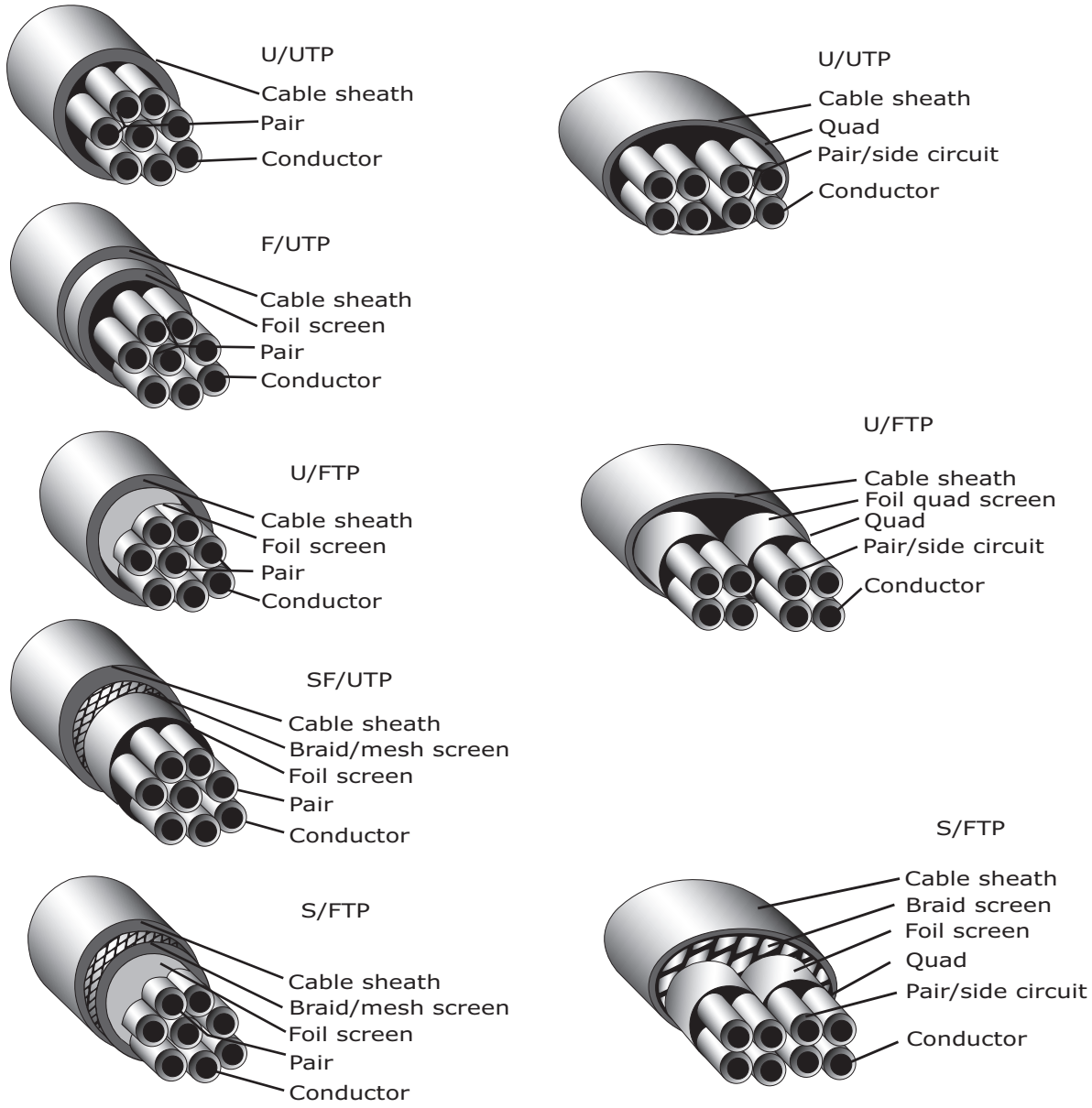
- Horizontal cable and its associated connecting hardware provide the means of transporting signals between the telecommunications outlet/connector and the HC (FD) located in the TR. This type of cabling and its associated connecting hardware are referred to as a permanent link.
- Horizontal pathways and spaces are used to distribute and support horizontal cable and connecting hardware between the telecommunications outlet/connector and the HC (FD) located in the TR.

BICSI recommends addressing the following considerations when selecting horizontal cabling:

- The maximum allowable horizontal cable length is 90 meters (m [295 feet (ft)]).
- A minimum of two telecommunications outlet/connectors is recommended per work area. The first cable at the work area shall be a minimum of a 4-pair 100-ohm balanced twisted-pair cable, category 5e/class D minimum required (category 6/class E minimum is recommended). The second cable shall be either one of the following:
  - 4-Pair 100-ohm balanced twisted-pair cables
  - Two or more strands of optical fiber multimode cable, OM2 50/125 micrometers (µm), or OM1 62.5/125 µm minimum (OM3 50/125 µm minimum recommended).
- Horizontal cabling is usually not readily accessible. The time, effort, and skills required to make future changes can be costly.
- Horizontal cabling should accommodate a variety of user applications (e.g., voice, data, video, other low-voltage services) to minimize required changes as needs evolve.
- Routing and supporting structures for balanced twisted-pair horizontal cabling shall take into account areas where potential sources of EMI exist.

Horizontal Cabling, continued

Figure 3.4
Examples of foil-screened and braid-screened cables

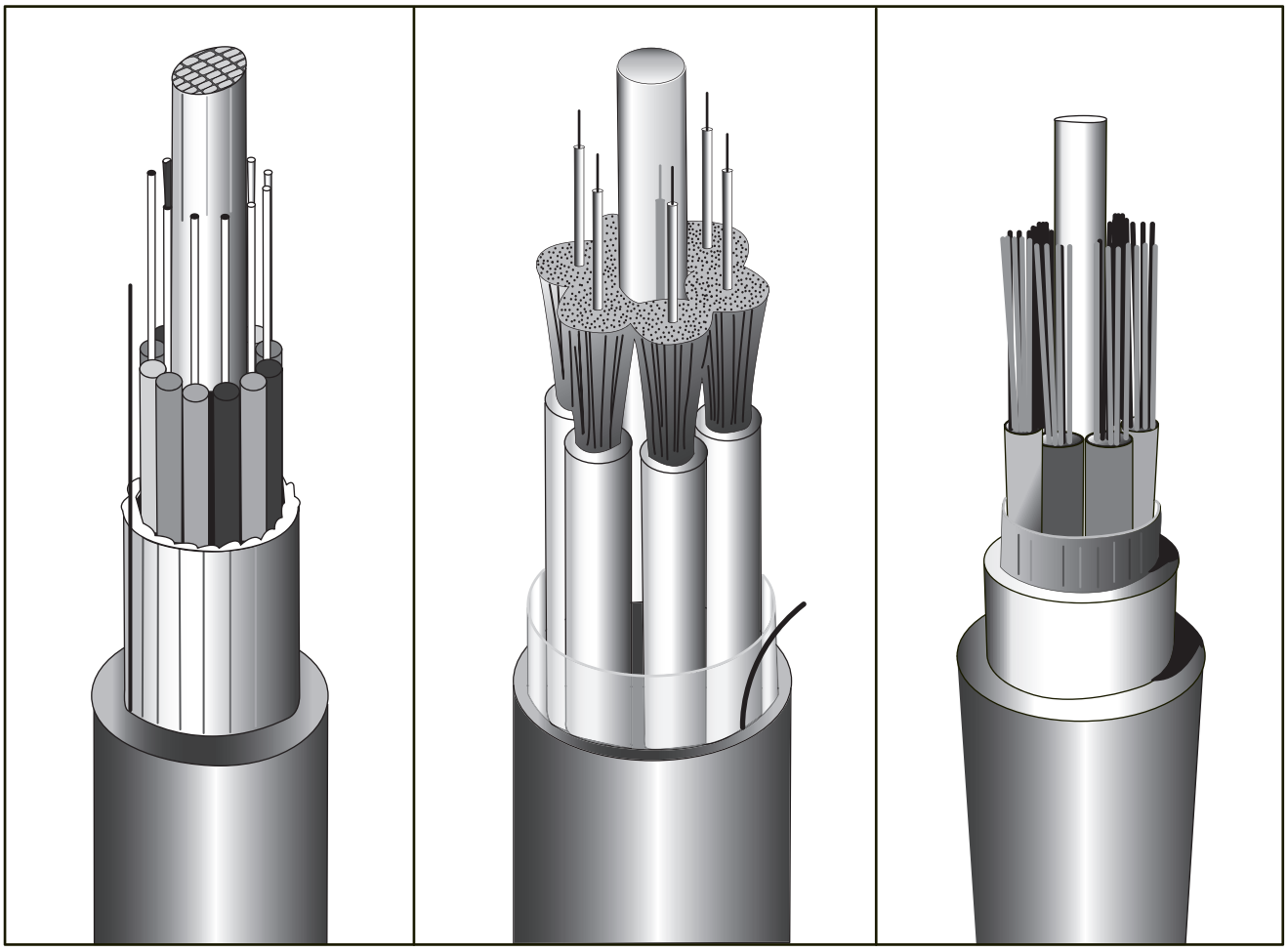


F/UTP = Overall foil screened with unshielded twisted-pair
S/FTP = Overall braid screen with foil screened twisted-pair
SF/UTP = Overall braid and foil screened with unshielded twisted-pair
U/FTP = Overall unshielded twisted-pair with foil screened twisted-pair
U/UTP = Overall unshielded twisted-pair with unshielded twisted-pair

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Horizontal Cabling, continued

Figure 3.5
Optical fiber cables



Tight buffered
900 µm
Buffered fibers

Breakout
3.0 mm (1/8 in)
Jacketed fibers

Loose tube
250 µm
Coated fibers

in = Inch
mm = Millimeter
µm = Micrometer

Work Area

A typical work area is approximately 10 m^2 (108 ft^2). Work areas include the components that extend from the telecommunications outlet/connector to the station equipment. These components can include station equipment (e.g., telephones, office equipment, video equipment, computer equipment). Included within the work area is the cabling that routes from this station equipment to the telecommunications outlet/connector. The equipment cord that connects the telecommunications outlet/connector to the station equipment is part of the SCS.

When planning for work area cabling, keep the following items in mind:

- Equipment cords are designed to provide easy routing changes.
- The maximum horizontal cable length is 90 m (295 ft).
- Except in particular cases, the maximum equipment cord length in the work area is 5 m (16.4 ft).
- An equipment cord with identical connectors on both ends is most commonly used. Equipment cords should be factory assembled and tested, and they should match the category rating of the horizontal cabling system to which it connects.
- Balanced twisted-pair equipment cords may be constructed from stranded cable. Stranded cable allows flexibility; however, stranded cables may attenuate up to 20 percent more for 24 American wire gauge (AWG [0.51 millimeters (mm [0.020 in])]) and 50 percent more for 26 AWG [0.41 mm (0.016 in)] than solid cables, depending on wire gauge and cable construction.
- Each 4-pair cable shall be terminated in an eight-position modular outlet at the work area in a telecommunications outlet/connector or a MUTOA.
- When application-specific adapters (e.g., baluns, modular Y-adapters) are needed at the work area, they shall be installed external to the telecommunications outlet/connector.

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Consolidation Point (CP)

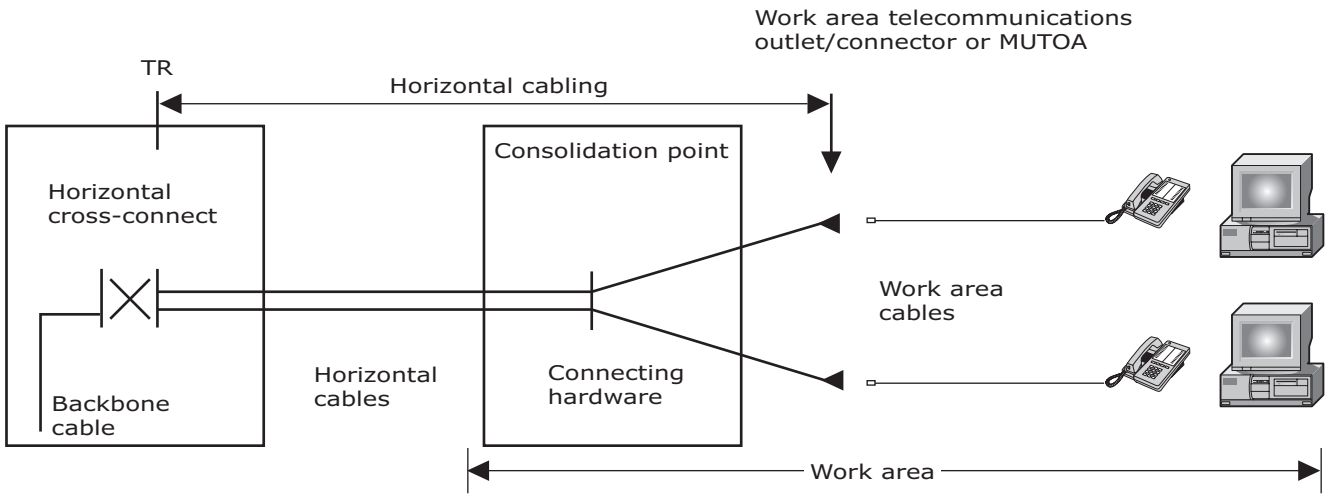
A CP is an interconnection device that is permanently installed in the horizontal cabling in close proximity to the telecommunications outlet/connectors or MUTOAs in or near the work areas. Unlike the MUTOA, the CP is not a user interface. The CP provides a convenient method for rearrangement of horizontal cabling that may be employed in furniture system layouts.

A CP allows horizontal cabling to be extended into work area pathways and terminated on telecommunications outlet/connectors that are dedicated to each individual user (see Figure 3.6). In this type of implementation, the total length of horizontal cabling is restricted to 90 m (295 ft) from the cable termination at the HC (FD) to the cable termination at the telecommunications outlet/connector or MUTOA, regardless of media type. The use of a CP does not extend the length of the horizontal cable. A CP is similar to a TP in that its purpose is for the interconnection of horizontal cabling extending from building pathways and cabling extending into furniture pathways rather than serving as a user interface. However, the CP is not a transition to an undercarpet cable like the TP.

NOTE: A CP may only be used for making a direct connection to the telecommunications outlet/connectors. Never use a CP as a cross-connect location, for cross-connect patching, or direct connections to active equipment.

When used, each open office furniture cluster should be served by at least one CP. The CP should be limited to serving a maximum of 12 work areas.

Figure 3.6
Application of consolidation point



MUTOA = Multiuser telecommunications outlet assembly
TR = Telecommunications room

Consolidation Point (CP), continued

Consolidation and Transition Points

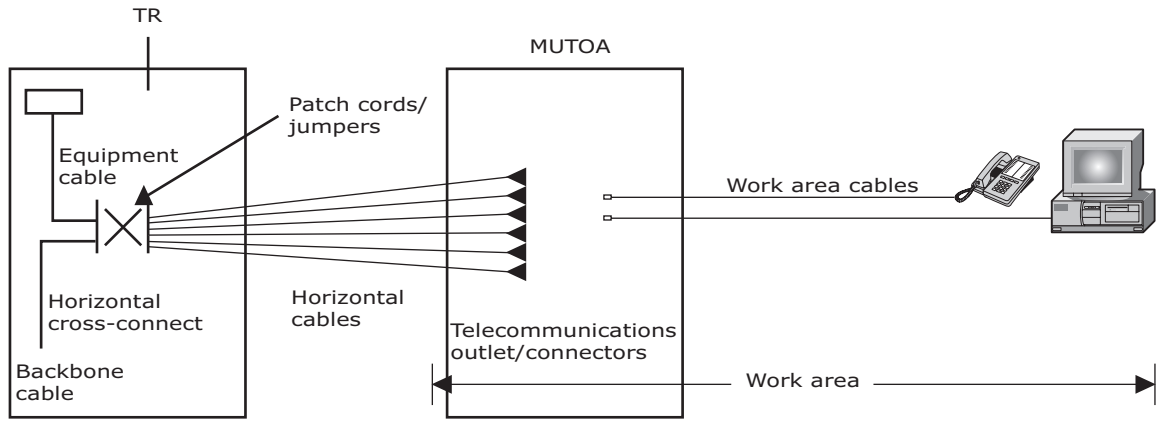
Horizontal cabling systems may not contain more than one CP or one TP in a horizontal cabling run. CP and TP connectors must meet the performance and reliability requirements specified in applicable standards.

Multiuser Telecommunications Outlet Assembly (MUTOA)

A MUTOA is a specialized telecommunications outlet assembly located in work area clusters. MUTOAs are suitable for use in open office spaces that are frequently reconfigured. A MUTOA allows horizontal cabling to remain intact when the open office plan is changed. Multiple work areas are served by one or more MUTOAs.

Work area equipment is directly connected to the MUTOA by work area equipment cables. Work area equipment cables are typically routed from the MUTOA through the work area pathways (e.g., furniture pathways). Horizontal cables extend from the MUTOA to the HC (FD) in the TR using horizontal cabling pathways (see Figure 3.7).

Figure 3.7
Application of multiuser telecommunications outlet assembly



MUTOA = Multiuser telecommunications outlet assembly
TR = Telecommunications room

NOTE: The MUTOA shall be marked with the maximum allowable work area cable length. Cabling adapters in the work area may have detrimental effects on the transmission performance of the cabling system. Therefore, it is important that adapter compatibility with premises cabling and equipment is considered before they are connected to the telecommunications network.

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Multiuser Telecommunications Outlet Assembly (MUTOA), continued

When used, each open office furniture cluster should be served by at least one MUTOA. The MUTOA should be limited to serving a maximum of 12 work areas. The actual number of outlets within the MUTOA depends on the number of cables that support each work area.

The use of a MUTOA cabling design option allows work area cables to extend beyond 5 m (16.4 ft), depending on the length of the horizontal cable. The total channel length is reduced as the horizontal cable is shortened because stranded conductor cables contribute more insertion loss (attenuation) than solid conductor cables.

NOTE: A MUTOA must be labeled to include the maximum length of work area cables (see Table 3.1).

Work area equipment cables extending from the MUTOA to the work area equipment must be uniquely identified and labeled and should include to and from information. A MUTOA may only be used for making a direct connection to work area equipment. Never use a MUTOA as a cross-connect point.

The length determination is simplified when using Table 3.1 as shown below. When using this table, be aware that the jumpers and patch cords located within the TR must not exceed 5 m (16.4 ft) for 24 AWG [0.51 mm (0.020 in)] balanced twisted-pair cords and must not exceed 3.96 m (13 ft) for 26 AWG [0.041 mm (0.016 in)] balanced twisted-pair cords.

Table 3.1
Maximum length of stranded work area equipment cords based on length of horizontal cables

24 AWG [0.51 mm (0.020 in)] Balanced Twisted-Pair Cords			26 AWG [0.041 mm (0.016 in)] Balanced Twisted-Pair Cords	
Length of horizontal cable	**Maximum length of work area cable**	**Maximum combined length of work area cables, patch cords, and equipment cable**	**Maximum length of work area cable**	**Maximum combined length of work area cables, patch cords, and equipment cable**
H m (ft)	**W m (ft)**	**C m (ft)**	**W m (ft)**	**C m (ft)**
90 (295)	5 (16.4)	10 (33)	3.96 (13)	8 (26)
85 (279)	9 (30)	14 (46)	7 (23)	11 (36)
80 (262)	13 (42.65)	18 (59)	11 (36)	15 (49)
75 (246)	17 (56)	22 (72)	14 (46)	18 (59)
70 (230)	22 (72)	27 (89)	17 (56)	21 (69)

AWG = American wire gauge
ft = Foot
in = Inch
m = Meter
mm = Millimeter

Centralized Optical Fiber Cabling

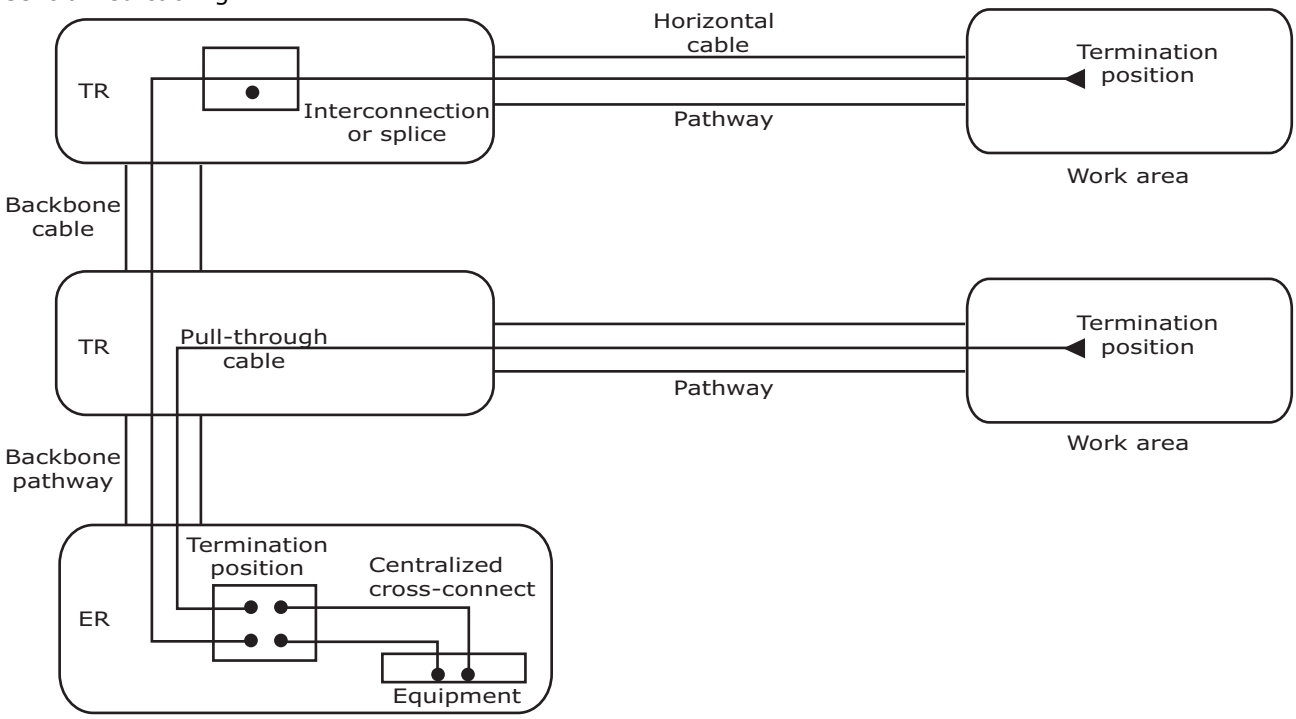
Single-tenant users of optical fiber cabling may implement computer networks with centralized electronics versus distributed electronics in the building. Centralized optical fiber cabling is designed as an alternative to the optical cross-connection located in the TR (when deploying multimode or singlemode optical fiber cable in the horizontal in support of the centralized electronics). Centralized cabling provides three centralized implementations:

1. Pull-through cabling (continuous sheath cables)
2. Interconnection in the floor-serving TR
3. Splice in the floor-serving TR (see Figure 3.8)

Implementation of centralized cabling shall be within the same building as the areas served. Centralized cabling design and installation shall allow for migration (in part or in total) of the pull-through, interconnection, or splice implementation to a cross-connection implementation.

The design and installation should allow sufficient length (service loop) to facilitate this migration. Service loops may be stored as cable or unjacketed fiber (buffered or coated). Service loop storage shall provide bend radius control so that cable and fiber bend radius limitations are not violated. Administration of moves and changes shall be performed at the centralized cross-connect.

Figure 3.8
Centralized cabling



ER = Equipment room
TR = Telecommunications room

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Administration of Structured Cabling Systems (SCSs)

Overview

This section offers four different classes of administration based on the size and complexity of the infrastructure being administered. Classes are scalable and allow expansion without requiring changes to existing identifiers or labels.

Determination of Class

Class 1 administration addresses the needs of premises served by a single ER. This ER is the only telecommunications space administered, but there are no TRs, backbone cabling, or OSP cabling systems to administer.

Class 2 administration addresses infrastructure with one or more telecommunications spaces in a single building.

Class 3 administration addresses infrastructure with multiple buildings at a single site (e.g., campus environment).

Class 4 administration addresses infrastructure with multiple sites or campuses.

Color Coding

The color codes for cross-connect fields (e.g., backboards, covers, labels) are shown in Table 3.2 and Figure 3.9.

Table 3.2
Color codes

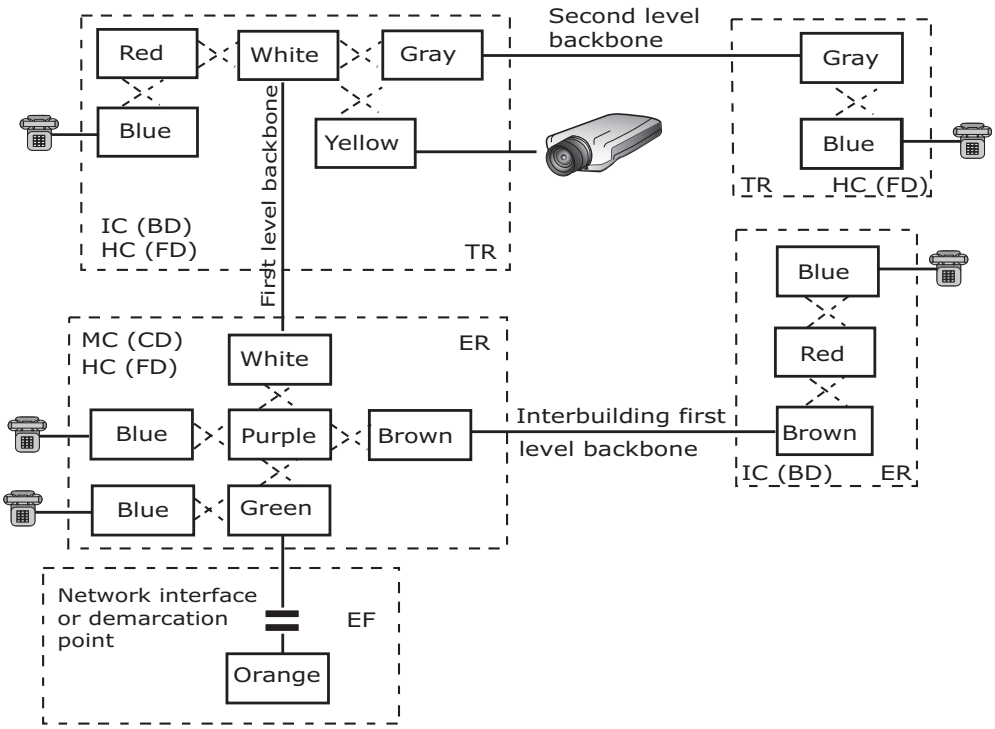
The Color…	Identifies…
Orange	Demarcation point (e.g., AP/SP central office connections).
Green	Network connections (e.g., network, auxiliary equipment).
Purple	Common equipment (e.g., connections to PBX, mainframe computer, LAN, multiplexer).
White	First-level backbone (e.g., termination of building backbone cable connecting MC (CD) to ICs (BDs).
Gray	Second-level backbone (e.g., termination of building backbone cable connecting ICs [BDs] to HCs [FDs]).
Blue	Horizontal cable (e.g., horizontal connections to telecommunications outlet/connectors, formerly referred to as "station cable").
Brown	Interbuilding backbone (campus cable terminations). NOTE: Brown takes precedence over white or gray for interbuilding runs.
Yellow	Miscellaneous (e.g., auxiliary, alarms, security).
Red	Reserved for future use (also key telephone systems).

AP = Access provider
HC (FD) = Horizontal cross-connect (floor distributor)
IC (BD) = Intermediate cross-connect (building distributor)
MC (CD) = Main cross-connect (campus distributor)
PBX = Private branch exchange
SP = Service provider

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Color Coding, continued

Figure 3.9
Backboard color coding



— = Telecommunications media
= Telecommunications outlet
= Cross-connect
EF = Entrance facility
ER = Equipment room
HC (FD) = Horizontal cross-connect (floor distributor)
IC (BD) = Intermediate cross-connect (building distributor)
MC (CD) = Main cross-connect (campus distributor)
TR = Telecommunications room

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Topologies

Overview

An item's topology refers to its features, shape, or physical appearance (e.g., a topological map represents the physical appearance of the area shown). Topologies can have physical and/or logical configurations. In many ways, a standard cabling plan's topology is the same—it is representative of the plan's features and physical appearance.

LAN topology is related to the topology of the physical media that supports it. LAN topology is primarily determined by how transmission channels are used to connect network devices. Typically, it refers to how the LAN is physically set up, its electrical and logical configuration, and the cabling strategy used.

Within the context of LANs, the word topology takes on a dual meaning. Both aspects are important to how the LAN will function:

- First, topology refers to the physical appearance of the LAN. This is known as the physical topology.
- Second, topology refers to how the LAN functions. This logical topology is determined by how the messages are transmitted from device to device.

It is necessary to make the distinction between the physical topology and the logical topology of a LAN. There are many instances where a LAN has a certain physical appearance but logically transmits its messages in a different topology. This section illustrates the physical appearance of a LAN.

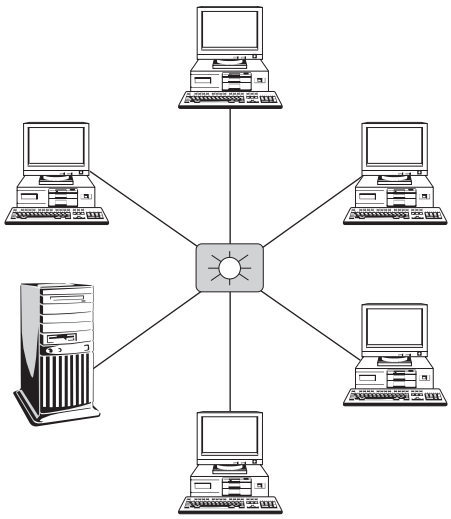
There are three fundamental physical topologies—star, bus, and ring. From these three, a number of hybrid topologies have developed, including tree, star-wired ring, clustered star, and hierarchical star.

In an SCS, the required physical topology is the star topology. Because it can be configured to accommodate each of the logical topologies (star, bus, ring, and hybrids), the star topology offers the greatest flexibility.

Star Topology

In a star topology, the network switch is placed in the physical, as well as logical, center of the network. The remaining network devices are connected to this switch like the points on a star (see Figure 3.10).

Figure 3.10
Star topology



Each device has its own direct, dedicated connection to the switch. Any network device instructed to send a message to another network device does so through the switch. A switch is a network access device that provides a centralized point for LAN communications, media connections, and management activities where each switch port represents a separate collision domain.

Star topology advantages are that:

- Cabling is easier to install and maintain.
- If one device is disabled or isolated from the switch, it is the only device affected.
- Faults are easier to locate and isolate.
- It provides a central location for network management.

Star topology disadvantages are that it:

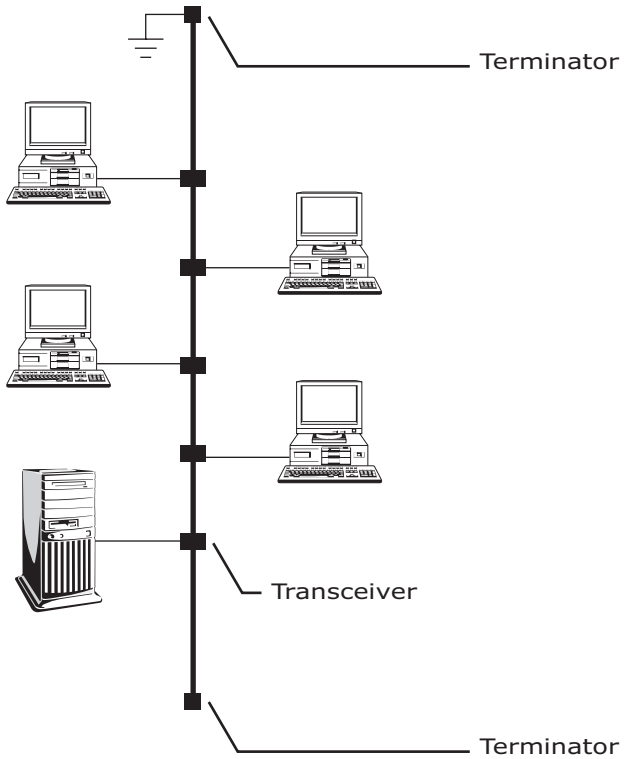
- May be vulnerable to breakdown as the network is essentially controlled by one device at a central location.
- Is more expensive.

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Bus Topology

A bus topology is a linear configuration, which places all of the network devices on one length of cable, similar to stops on a city bus route. The hubs, server, stations, and peripheral devices all use the same continuous length of cabling (see Figure 3.11).

Figure 3.11
Bus topology (10BASE5)



In this arrangement, the end of the cable is not connected to network devices. Ordinarily, problems would occur when the transmitted signal is sent along the cable and reaches either of the ends. For this reason, each end of the cable is connected to a terminator.

When a message is sent using this topology, the transmission signal leaves the sending device and travels along the cable in both directions. The device for which the message is intended will recognize the transmission and read the message.

Bus topology advantages are that it is:

- Adaptable to many environments and can be configured to suit most situations.
- Expandable by adding devices at various points along the cable.

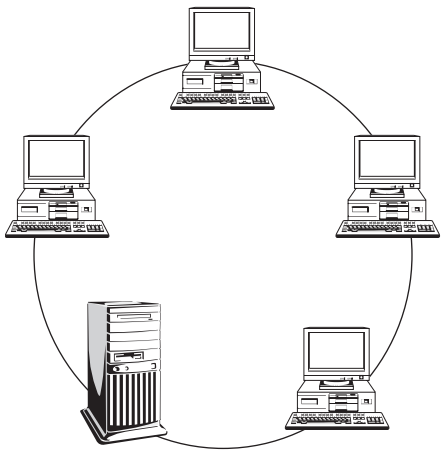
Bus topology disadvantages are that:

- It lacks central control—finding a fault is difficult.
- If the cable is damaged or either end of the cable loses its termination, the entire network will fail.

Ring Topology

A ring topology places all of the network devices in a circle (see Figure 3.12). It uses one cable to connect between devices. Each device is connected to the next one. The last device is connected to the first, closing the circle.

Figure 3.12
Ring topology



When a message is sent, it travels from device to device around the circle. The sending device sends its message toward the destination device. Each device between the sender and the receiver listens to the message as it passes by. If the message is not intended for a particular device, it resends the message, and the next one in the ring repeats the procedure. This continues until the intended destination receives the message.

The advantage of ring topology is that there is no reliance on a central device; all messages pass through all devices.

Ring topology disadvantages are that:

- Additional network devices can only be connected while the network is inoperative because breaking the ring would cause network failure.
- If any device fails, the entire network is affected.

Although the ring topology is considered one of the three fundamental network topologies, it has never been popular in its basic form. The more popular dual-ring topology provides two paths between stations—a primary path and a backup path. While raising the costs, in the event of a failure in the primary path, the signal can be diverted to the backup path by stations on either side of the point of failure, preventing total network failure.

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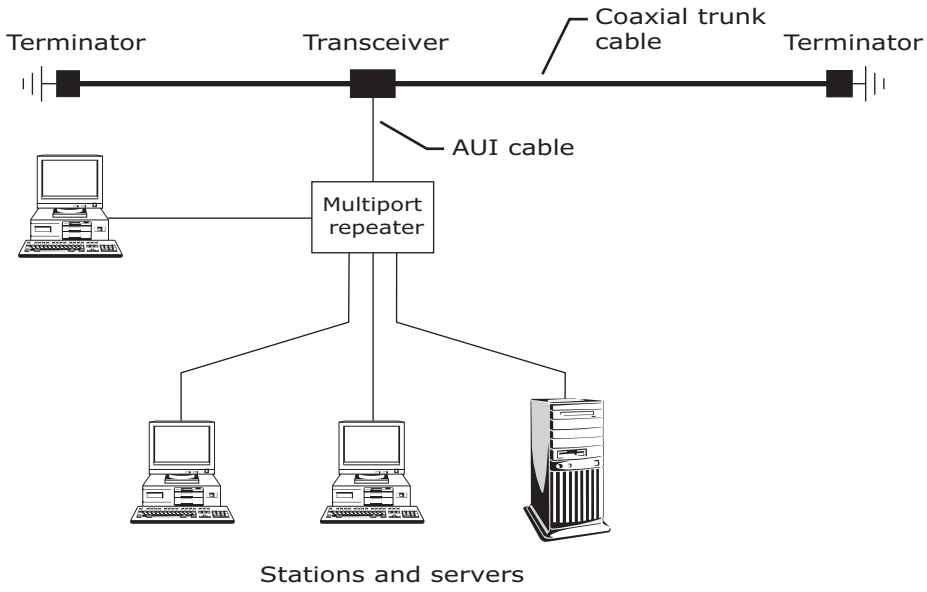
Hybrid Topologies

Hybrid topologies resulted from a need to meet specific requirements or technological advancements. While there are many variations of the three topologies discussed above, certain hybrids are more popular than others.

Tree Topology

The tree topology is an extension of the bus topology (see Figure 3.13). By adding cable extensions to the basic bus topology, a larger network can be achieved using less cable. Each additional cable extends from the underlying bus structure and supports multiple network devices along its length.

Figure 3.13
Tree topology



AUI = Attachment unit interface

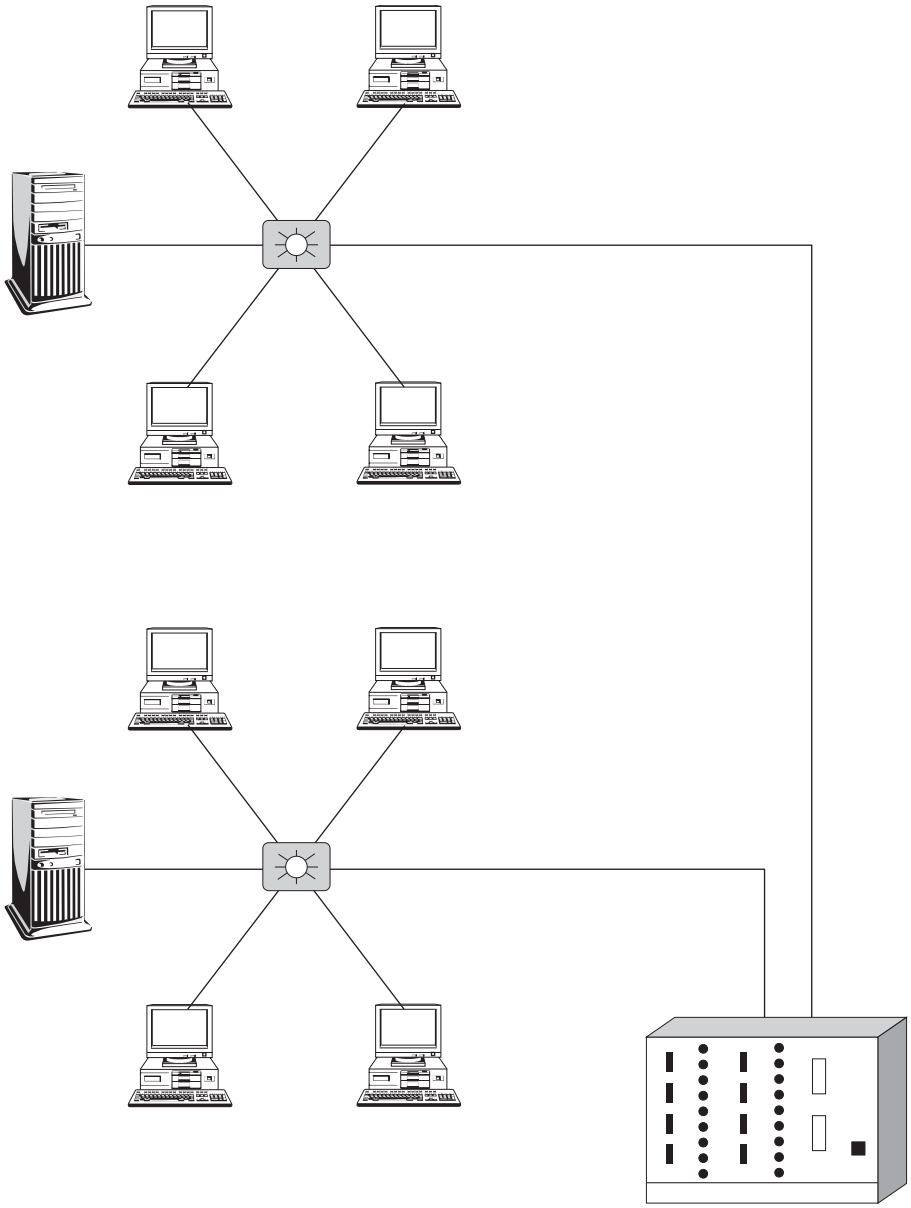
Hybrid Topologies, continued

Hierarchical Star Topology

A hierarchical star topology is an extension of the star topology (see Figure 3.14). In this configuration, departmental network devices are connected to a switch as in a star topology. These switches are then connected to each other via a central hub, following a star configuration. This is the recommended topology for structured cabling backbone distribution systems in buildings and in campus environments.

NOTE: Hierarchical stars are sometimes referred to as clustered stars.

Figure 3.14
Hierarchical star topology



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Telecommunications Spaces

Overview

Telecommunications spaces are the rooms and areas where telecommunications cabling systems are terminated and telecommunications equipment is installed.

This section defines guidelines for the following telecommunications spaces:

- Entrance facilities (EFs)
- Equipment rooms (ERs)
- Telecommunications rooms (TRs)
- Telecommunications enclosure (TE)

Entrance Facilities (EFs)

The EF consists of the telecommunications service entrance to the building, including the entrance through the building wall, and continuing to the entrance room or space. The EF may contain the building pathways that link to the ER or common equipment room (CER) and to other buildings in campus situations. Wireless device entrances may also constitute part of the EF. The EF includes the cabling components needed to provide a means to connect the outside service facilities to the premises cabling. This can include:

- Service entrance pathways.
- Cables.
- Connecting hardware.
- Primary surge protection devices.
- Transition hardware (transition from OSP to inside plant [ISP] cabling).
- SP electronics.

The SP is generally responsible for the installation of the items listed above to a specified demarcation point, which is the interface between the SP's facility and the customer.

For purposes of this manual, the ITS cabling installer is responsible for extending services from the demarcation point to the SCS.

An EF may provide:

- A demarcation point between the SPs and customer premises cabling (if required).
- Space to house the transition between cabling used in the OSP to cabling approved for intrabuilding use. This usually involves transition to fire-rated cable. ITS distribution designers and ITS installers should refer to the appropriate codes, standards, and regulations.

An EF must enter and terminate within the building at the most suitable location needed to serve the occupants of the building. The EF includes the:

- Route these facilities follow on private property.
- Entrance point (EP) to the building.
- TP within the building.

Entrance Facilities (EFs), continued

The EF depends on the:

- Type of entry being used.
- Route for the facility.
- Building architecture.
- Aesthetic considerations.
- Electronics being considered.

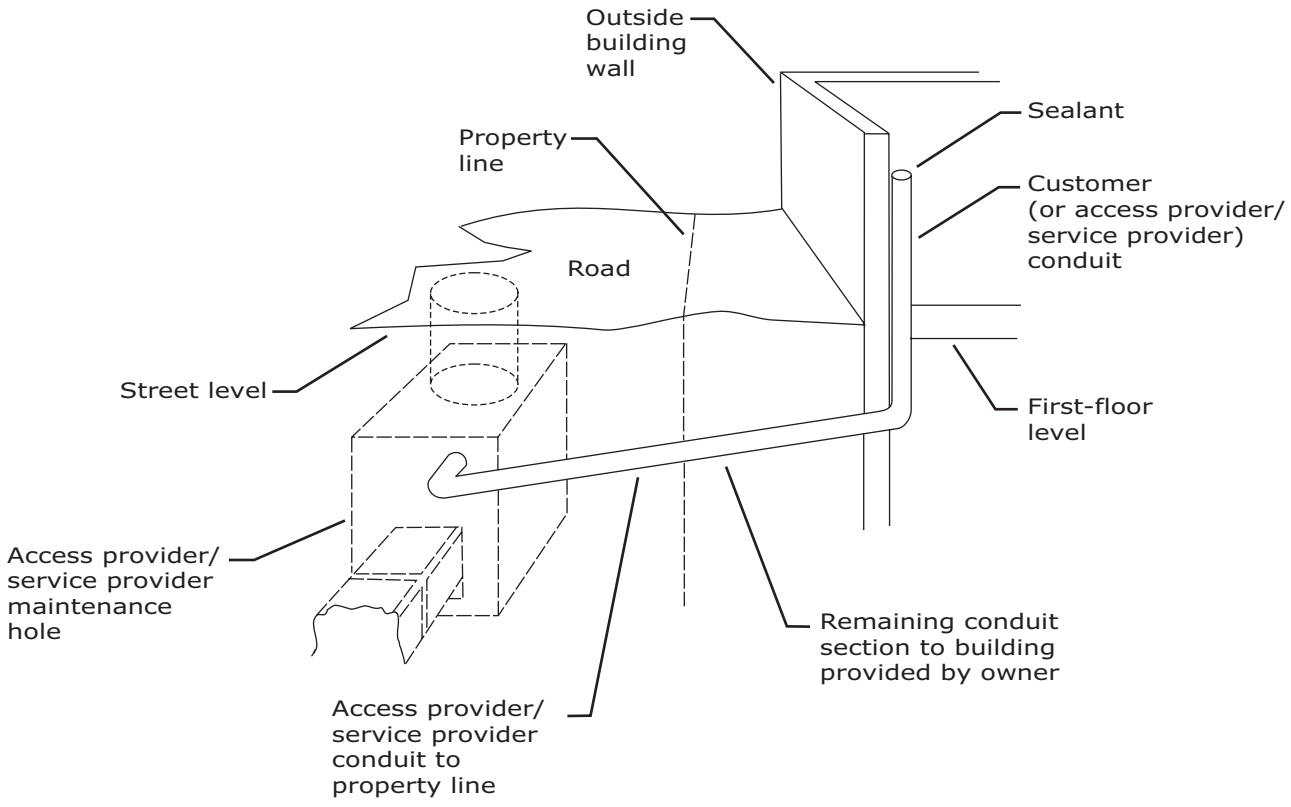
There are several principal types of entrance pathways to EFs:

- Underground
- Tunnel
- Buried
- Aerial
- Wireless

Underground Entrance

An underground entrance uses conduit or other types of mechanical pathways to provide out-of-sight service to a building (see Figure 3.15).

Figure 3.15
Example of underground entrance



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Entrance Facilities (EFs), continued

The pathway for an underground service:

- Is usually provided by the building owner from the building to the property line (or to another customer-owned building on the same property).
- Runs from the building entrance location to a pole, pedestal, or maintenance hole (MH) provided and maintained by the AP/SP.

The advantages of underground entrances are that they:

- Preserve the aesthetic appearance of the building.
- Are economical over the life cycle.
- Provide the security of additional physical cable protection.
- Minimize the need for possible subsequent repairs to the property when growth is required for existing facilities.

The disadvantages of underground conduit entrances are that they:

- Have a high initial cabling installation cost.
- Require careful route planning.
- Provide a possible path for water or gas to enter buildings if improperly sealed.
- Usually take more time to install.

Tunnels

In some situations, utility tunnels (either new or existing) are the only means available to provide service into or throughout a building. For large, new projects, tunnels require extensive advanced planning and cooperation among all involved utilities, the customer, municipal planning boards, and environmental groups.

The following considerations are particularly critical:

- Routing
- Safety
- Sizing
- Facility protection
- Rights-of-way
- Cost

Smaller tunnels may also be found in buildings where no full basement or crawl space exists.

Entrance Facilities (EFs), continued

The main advantages of constructing tunnels are that they:

- Decrease the chances of accidental dig-ups.
- Reduce ground corrosion factors.
- Allow a continuous inspection path for all utilities.
- Offer permanent space allocation.
- Reduce surface interference to both vehicular and pedestrian traffic except during the open-cut phase.

The main disadvantages of tunnel construction are the:

- Heavy expense.
- Significant planning and approvals required.
- Increased liability and work priority factors.
- Sabotage possibilities that are facilitated.

Buried Entrance

A buried entrance (trenched or plowed) is a means of providing out-of-sight service to a building without conduit (see Figure 3.16). The trench:

- Is usually provided by the building owner from the building to the property line or to another customer-owned building on the same property.
- Runs from the building entrance location to a pole, a pedestal, or an MH. From here, the SP takes it to a pole or MH in the provider's system.
- Requires a sleeve or entrance conduit through the perimeter wall.

The advantages of the buried entrances are that they:

- Preserve the aesthetic appearance of the building.
- Usually have a lower initial cabling installation cost than an underground installation.
- Can easily bypass obstructions compared with underground installations.

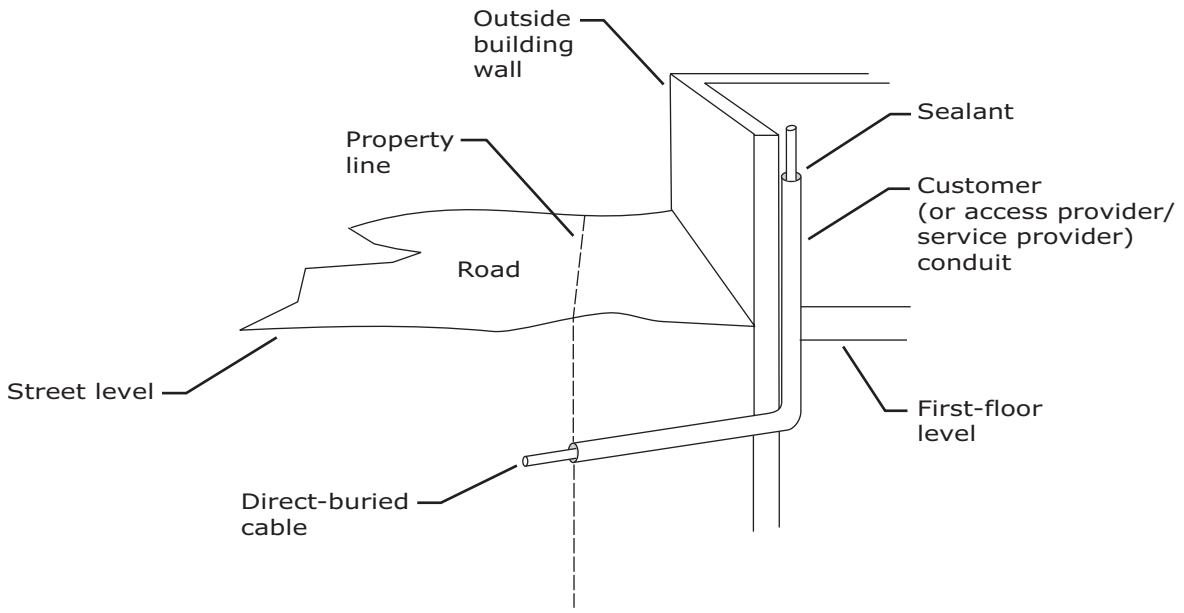
The disadvantages of buried entrances are that they:

- Are inflexible for future service reinforcements or changes.
- Do not provide the same physical protection for the cable sheath as underground systems.
- May be difficult to locate unless metallic warning tape or other means are collocated, especially in the case of optical fiber with no metallic member.
- Discourage accurate route planning and recordkeeping.

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Entrance Facilities (EFs), continued

Figure 3.16
Example of buried entrance



Aerial Entrance

Aerial entrance is another means of providing service to a building (see Figure 3.17). Aerial refers to cables placed overhead.

The advantages of aerial entrances are that they:

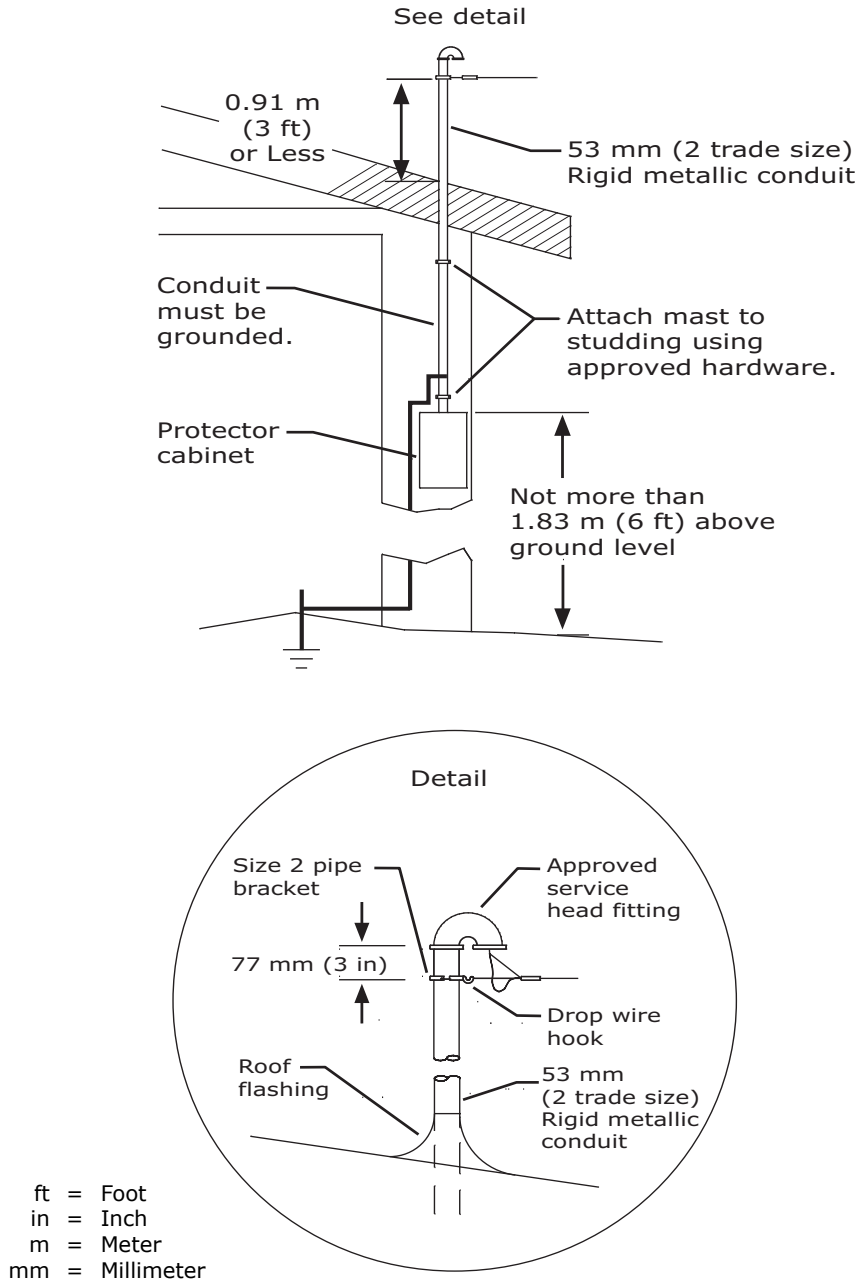
- Usually provide the lowest cabling installation cost.
- Are readily accessible for maintenance.

The disadvantages of aerial entrances are that they:

- Affect the aesthetic appearance of the building.
- Are subject to traffic and pedestrian clearances.
- Can damage a building's exterior.
- Are susceptible to environmental conditions (e.g., falling tree limbs, wind, lightning, ice loading).
- Are usually joint-use cabling installations with the power company, community antenna television (CATV) company, and telephone or data APs/SPs.

Entrance Facilities (EFs), continued

Figure 3.17
Example of aerial entrance



NOTES: Rigid metallic conduit (RMC) must be permanently bonded and grounded.

Service mast must be sufficiently high to provide proper drop wire clearance over sidewalks, streets, or roadways in compliance with codes and regulations.

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Entrance Facilities (EFs), continued

Wireless Entrance

There are two options for wireless entrance within a facility. The first option is the use of the existing ER. Normally, this is used by cellular services providers. The second option is a separate wireless entrance, routinely called a radio room. This option is typically used when public safety land mobile radio (LMR) is provided to the facility. This is routinely found in hospitals and government offices.

When using an existing ER, the wireless service provider (WSP) is normally providing the donor wireless signals vial fiber optic cabling. The WSP will provide the fiber and media converters needed to feed the building distributed antenna system (DAS).

The following items will need to be considered by the installer:

- Service entrance pathway
- Fiber optic cable management
- Media converters
- DAS equipment
- Connecting hardware

The DAS headend is normally housed in this room and will be discussed in detail in Chapter 12: Specific Applications of this manual. The roof-top antennas need to be fed to this room; bi-directional amplifiers (BIDA) to support copper cabling may need to be used. Media converters may also be used to convert the copper cabling from the antenna to fiber and into the DAS.

The radio room is typically located on the top floor of a building or within the building rooftop mechanical space. The radio room is the TP for connecting donor antennas that the DAS systems will support.

The following rooftop items will need to be considered by the installer:

- Antennas
- Jumpers
- Transmission line
- Rooftop penetrations (e.g., hoods, roof and wall penetrations)
- Roof mats
- Wall mounts
- Nonpenetrating mounts
- Lightning rods
- Grounding (earthing)

Entrance Facilities (EFs), continued

The radio room will house the public safety radios and repeaters needed to feed the DAS. The DAS headend may also be located in this room.

The following additional items will need to be considered by the installer:

- Two walls of fire rated plywood for cable management
- Surge protection devices
- Installation of batteries to support the equipment
- Grounding (earthing)

Local building and electrical codes and manufacturer's specification must be followed.

Equipment Rooms (ERs)

An ER is a special-purpose room that provides space and maintains a suitable operating environment for large telecommunications equipment.

ERs are generally considered to serve an entire building or a campus, whereas a TR typically serves one floor of a building or a portion of a floor (see Figure 3.18).

An ER should:

- Provide for termination and cross-connection of backbone and horizontal cables.
- Provide work space for service personnel.
- Be designed according to specific requirements associated with the cost, size, growth, and complexity of the equipment.
- House large pieces of common control equipment (e.g., voice, data, video, fire alarm, energy management, intrusion detection equipment).
- Be capable of providing space for APs/SPs.

Although an ER usually serves an entire building, buildings occasionally use more than a single ER to provide one or more of the following:

- Separate facilities for different types of equipment and services
- Redundant facilities and disaster avoidance
- A separate facility for each tenant in a multi-dwelling building

Certain considerations should be kept in mind for an ER. An ER must:

- Be versatile. An ER must be designed to accommodate both current and future applications. It must have provisions for growth and the ability to go through numerous equipment replacements and upgrades during its life with minimal service disruption and cost.
- Meet lighting, air conditioning, floor loading, electrical, and minimum space requirements.

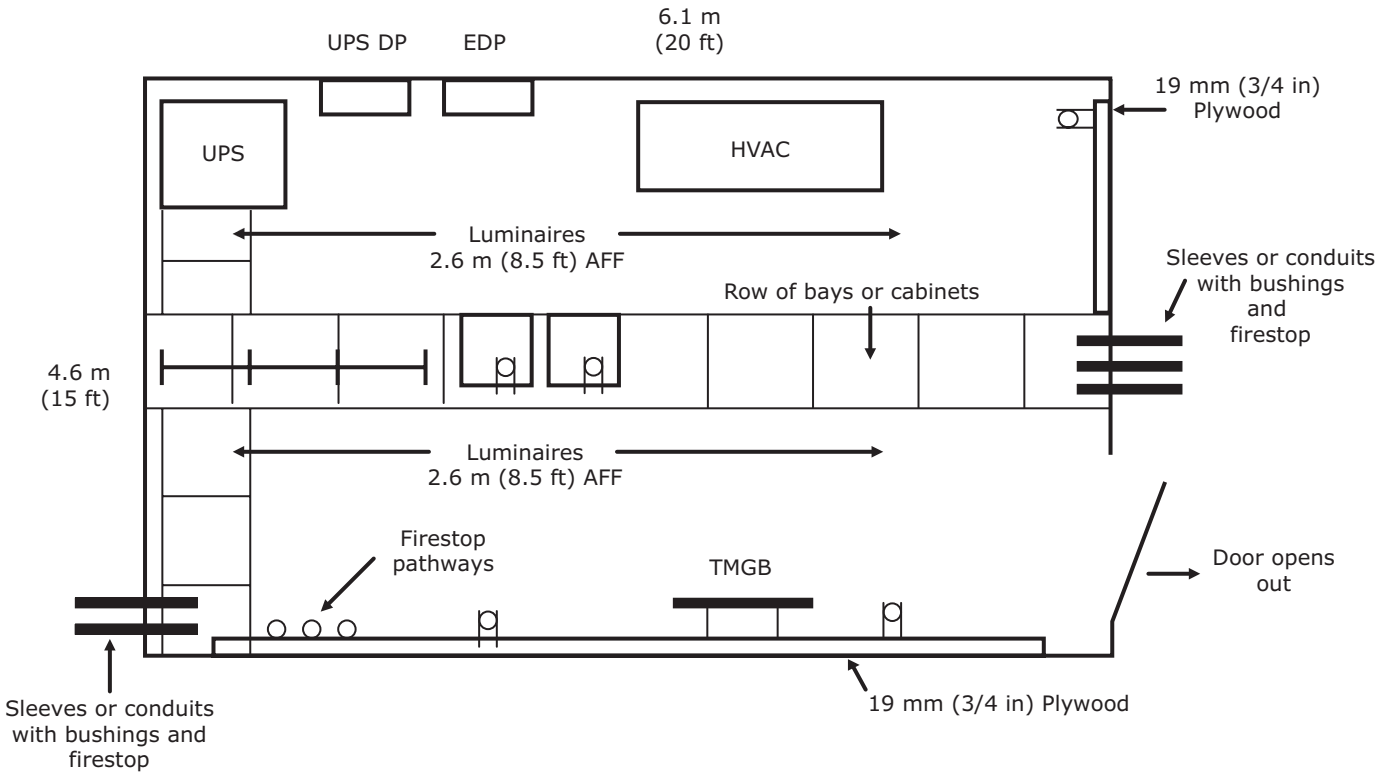
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Equipment Rooms (ERs), continued

Luminaire

A luminaire is a complete electrical unit used to create artificial light. It typically contains the light source (e.g., lamps), ballast, or power supply, lamp holder, reflector, and an aperture or lens for distributing the light. Luminaire is the term specified by the American National Standards Institute (ANSI), Underwriters Laboratories® (UL®), and International Electrotechnical Commission (IEC). Light fixture is a common term in the United States for luminaire.

Figure 3.18
Example of a typical equipment room



AFF = Above finished floor
EDP = Electrical distribution panel
ft = Foot
HVAC = Heating, ventilating, and air conditioning
in = Inch
m = Meter
mm = Millimeter
TMGB = Telecommunications main grounding busbar
UPS = Uninterruptible power supply
UPS DP = Uninterruptible power distribution panel

Telecommunications Rooms (TRs)

TRs differ from ERs and EFs in that they are generally considered to be floor-serving as opposed to building-serving facilities.

NOTE: Dedicated, floor-serving TRs shall be provided on each floor to service flexible, high-density horizontal distribution systems in floors and ceilings to facility work areas.

TRs:

- Serve as a point of termination for horizontal and backbone cables on compatible connecting hardware.
- House the HC (FD)—A collective reference for the connecting hardware, jumpers, and patch cords used for completing cross-connection or interconnection of horizontal and backbone cable terminations.
- May contain IC (BD) points for different parts of the backbone cabling system.
- Provide a controlled environment for the telecommunications equipment, connecting hardware, and splice closures.

In planning TRs, consider the:

- Size of the building, usable floor space served, occupant's needs, and telecommunications service to be used.
- Need to optimize the ability of the TR to accommodate change.
- Lighting, air conditioning, floor loading, electrical, and spacing requirements.

NOTE: The TR shall be located as close as practicable to the center of the area served and preferably in the core area.

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Telecommunications Enclosures (TEs)

Overview

While a TR is an enclosed architectural space for housing telecommunications equipment, cable terminations, and cross-connect cabling, a TE is a case or housing for telecommunications equipment, cable terminations, and cross-connect cabling. A TE facilitates the interconnection or cross-connection of horizontal cabling to work areas. A TE is generally applied as a subset to the traditional TR. This case or housing is much smaller than a TR and is typically used to service a specific area of a building floor.

General Requirements for All Telecommunications Enclosures (TEs)

A TE is simply a case or housing for telecommunications equipment, cable terminations, and cross-connect cabling.

The TE is dedicated to the telecommunications function and related support facilities. The TE may contain access points for wireless services. Although TEs serve much in the same capacity as that of a TR, a TE is not allowed to replace a TR.

Access

The TEs must be accessible. Access to TEs should be controlled against unauthorized access (e.g., with a lock and key held by the facility or property manager).

Bonding and Grounding (Earthing)

If the enclosure consists of metallic components, the enclosure must be bonded to the telecommunications bonding and grounding (earthing) infrastructure.

Door

The TE door(s) may be hinged or removable. If the door is hinged, mount the enclosure so that the door swings open a minimum of 90 degrees or otherwise provides unobstructed access to the inside of the enclosure.

The door should remain open until manually closed. Provide and maintain sufficient working space for a technician to gain ready and safe access to the TE.

Electrical Power

A minimum of one dedicated, nonswitched duplex receptacle should be available for equipment power in each TE.

An accessible means of disconnecting power to the TE must be provided. If standby power is available, automatic switchover of power should be provided.

General Requirements for All Telecommunications Enclosures (TEs), continued

Fire Protection

Fire protection of the TEs, if required, must be provided per applicable code. If sprinklers are required within the area of the TE, the heads should be provided with a protective cover to prevent accidental operation.

A TE should not be installed where subject to leakage from fire suppression sprinklers. Drainage troughs must be placed under the sprinkler pipes to prevent leakage onto the enclosure.

Heating, Ventilating, and Air Conditioning (HVAC)

When active devices (e.g., heat-producing equipment) are present, a sufficient number of air changes should be provided to dissipate the heat from all sources. Active device manufacturers should be consulted for guidelines. Audible noise created by the equipment within the TE should not adversely affect the productivity or satisfaction of nearby workers.

Interior Provisioning

To facilitate the mounting of hardware, mounting holes should be installed where appropriate within the enclosure. Optionally, the TE may be equipped with a plywood backboard that is secured to the back or side of the interior portion of the enclosure.

Lighting

Light, as measured within the TE, should be a minimum of 500 lux (50 foot-candles).

Location

The TE should not be installed in furniture systems unless that unit of furniture is permanently secured to the building structure.

Pathways

Pathways must not pass through TEs. Cables that enter and exit the TE are to be protected from sheath abrasion and conductor deformation by means of grommets, bushings, and suitable management hardware.

Size and Spacing

A TE should serve an area not greater than 335 m^2 (3606 ft^2). Size the TE to accommodate immediate requirements and foreseeable growth. Sufficient space within the TE should be provided to ensure compliance with cable bend radii limitations.

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Installing Cable Support Structures

Overview

This section describes supporting structures and associated hardware that may be required in an ITS cabling installation project. It provides an overview of the methods necessary to properly plan, design, and install cable support structures in telecommunications pathways and spaces.

Telecommunications pathways and spaces must have the proper cable support structures to make the installation function properly.

Proper cable support:

- Assures that certain local building and electrical code requirements will be met.
- Accommodates future retrofits and new technologies.
- May provide EMI protection.

Particular attention must be paid to the requirements of relevant codes, standards, and regulations when planning and installing these support structures. Proper design of the components described in the standards leads to a successful initial installation and makes future additions and rearrangements possible. Failure to adhere to these requirements may cost hours or even days of delay or additional work to complete the job, which will have an adverse financial impact.

The components identified in this section are readily available from a variety of manufacturers and vary in size, color, configuration, and cost. The ITS cabling installer must become familiar with the various manufacturers' products and how they adapt to individual installation requirements.

While this section is not intended to identify the entire range of products available to meet a specific need, the items outlined are representative of those available in the marketplace. In addition to those identified, there are many specialty components available that allow the ITS cabling installer to meet particularly difficult or unique requirements.

Electromagnetic Interference (EMI) Considerations for Support Structure Installation

Overview

Special considerations should be given to the effects of EMI on ITS cabling for any support structures installed. When installing a telecommunications cabling system and associated pathways, select cabling systems designed to keep interference at a level below the regulatory limits. The active equipment manufacturer should provide a recommendation of cable types for approved regulatory operations. When designing a cabling system for critical environments in terms of EMI, the ITS installer shall follow cable separation guidelines presented in this chapter.

Minimizing Electromagnetic Interference (EMI)

Equipment Room (ER)

Do not place telecommunications cabling systems and associated pathways next to active equipment that can generate EMI such as can be found in an ER. Keep electrical feeders and branch circuits of interfering equipment separate from the telecommunications systems cabling systems and associated pathways.

Likely sources of EMI are heavy-duty electromechanical equipment (e.g., copiers, door openers, elevator systems, factory equipment, uninterruptable power supplies [UPSs], computer room air conditioner [CRAC] units). Telecommunications cabling separation guidelines for minimizing EMI are provided for the ITS installer in Table 3.3 and Table 3.4 below.

Installation of Horizontal Cabling and Associated Pathways

Treat potential sources of EMI as a primary consideration when selecting and installing various types of telecommunications cabling and associated pathways.

Typical sources of EMI include:

- Electric motors, transformers, and fluorescent lighting that share distribution space with telecommunications cabling.
- Copiers that share work area space with equipment cords and terminals.
- Electrical power cable that supports such equipment.

Screened/shielded cabling has been the traditional choice for buildings with high levels of ambient EMI (e.g., industrial facilities with large inductive loads). High-performance unshielded cabling (e.g., category 6_A/class E_A) offers a higher degree of unwanted signal rejection when compared with lower performance categories/classes of cabling (e.g., category 5e/class D) and may be suitable for use in typical commercial building environments. Consult with cable suppliers, and review installation guidelines to determine the level of unwanted signal rejection offered by various grades and types of balanced twisted-pair cabling.

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Minimizing Electromagnetic Interference (EMI), continued

EMI is an important consideration in the installation of telecommunications pathways. Providing safe separation distances from EMI sources for these elements is mandatory to assure applications performance.

Locate telecommunications cabling and associated pathways away from sources of EMI (e.g., electrical power cabling and transformers, RF sources and transmitters, large motors and generators, induction heaters, arc welders, x-ray equipment, copiers).

The following precautions should be considered to reduce interference from sources of EMI:

- Use grounded metallic pathways to limit inductive unwanted signal coupling between the telecommunications cabling and potential sources of EMI.
- Use sheathed power cables or other power branch circuit cable constructions (e.g., taped, twisted, bundled) that prevent separation of the line, neutral, and bonding/grounding (earthing) conductors to minimize EMI emission from the electrical power conductors.
- Use surge protectors (e.g., overvoltage, overcurrent) in power branch circuits and telecommunications cabling to limit the propagation of electrical surges and associated interference.
- Higher balanced twisted-pair cabling categories result in better noise rejection response.
- Multipair cables (e.g., multiples of 25 pairs) should have an overall shield to further improve electromagnetic compatibility (EMC).
- Terminate all cabling conductor pairs at both ends of a cabling link.
- Telecommunications cabling should not be installed parallel to electrical power lines.
- Use localized magnetic barriers when signal lines are found close to switchgear. Consult with an EMC expert for guidance in such cases.
- Avoid burying cable below and parallel to high-voltage transmission lines or in areas subject to high-ground currents.
- Where cables of different signal conditions must cross, crossing should be at 90 degree angles.
- Tray and conduit separation spacing should be considered in potential problem areas when designing and maintaining telecommunications cabling systems.
- Source suppression should be considered. Dealing with unwanted signal at the source helps eliminate major corrective action on cabling systems.
- Use metal conduit for electrical power circuits:
  - Premises cabling feeder and branch circuit conductors serving telecommunications systems should be fully enclosed by metal conduit.
  - Each branch circuit should be in a separate conduit or be implemented with shielded cables.

Minimizing Electromagnetic Interference (EMI), continued

- Use metal conduit for metallic telecommunications circuits in critical areas (use of shielded telecommunications cables in these areas is preferred). Metal conduit is recommended, especially in the vicinity of electrical power conductors.
- Signal conductors shall not be installed into conduit containing electrical power conductors.
- Maintain an adequate physical separation between potential EMI sources and susceptible telecommunications equipment.
- Use surge protection devices to reduce transients that emanate from inductive devices that are being switched off. Locate external surge protection devices as close as possible to the source of the transient.
- Reduce EMI from fluorescent lamps and ballasts located inside an enclosure. Consider the following precautions:
  - Place a shielding grid between the lamp and the telecommunications cabling.
  - Install shielded cable between the lamp and the electrical power switch.
  - Install a metal-enclosed electrical power switch.
  - Place a filter between the electrical power switch and the electrical power line.
  - Shield the electrical power line cable.
- Use grounded conduits and enclosures. Continuously grounded metal conduit helps to reduce emission and reception of EMI.
- Minimize proximity to radiating antennas and towers. Electric field strength can overwhelm sensitive receivers.
- Provide effective bonding between the grounding (earthing) terminals of multiple surge protection devices placed on both the electrical power and signal circuits of the telecommunications unit.
- Use optical fiber cables or high-performance, unshielded balanced twisted-pair cabling or screened shielded balanced twisted-pair cabling in critical signal circuits.
- Always assume that electrical unwanted signal exists in the proximity of telecommunications cabling and equipment.

Telecommunications Cabling Separation Guidelines

For safety purposes, keep power cabling physically separated from telecommunications cabling. Maintain specified distances from possible sources of EMI exceeding 5 kilovolt-amperes (kVA) as shown in Table 3.3 and Table 3.4. For branch circuits of 5 kVA or less, no additional separation should be necessary.

If national or local codes, standards, or regulations establish different separation rules or require maintaining distances that differ from those provided in Table 3.3, the more stringent requirements must be met.

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Telecommunications Cabling Separation Guidelines, continued

Table 3.3 provides specified distances from possible sources of EMI for both safety and performance issues.

Table 3.3
Recommended minimum separation distances from possible sources of electromagnetic interference exceeding 5 kilovolt-amperes

Condition Distance	Minimum Separation
Unshielded power lines or electrical equipment in proximity to open or nonmetal pathways	610 mm (24 in)
Unshielded power lines or electrical equipment in proximity to a grounded metal pathway	305 mm (12 in)
Power lines enclosed in a grounded metal (or equivalent shielding) in proximity to a grounded metal conduit pathway	152 mm (6 in)
Electric motors and transformers	1220 mm (48 in)

in = Inch
mm = Millimeter

Table 3.4
Separation requirements between metallic cabling and specific electromagnetic interference sources

Source of Disturbance Distance	Minimum Separation
Fluorescent lamps	130 mm (5.12 in)[a]
Neon lamps	130 mm (5.12 in)[a]
Mercury vapor lamps	130 mm (5.12 in)[a]
High-intensity discharge lamps	130 mm (5.12 in)[a]
Arc welders	800 mm (31.5 in)[a]
Frequency induction heating	1000 mm (39.37 in)[a]
Hospital equipment	[b]
Radio transmitter	[b]
Television transmitter	[b]
Radar	[b]

[a]The minimum separations may be reduced provided that appropriate cable management systems are used or product suppliers' guarantees are provided.
[b]Where product suppliers' guarantees do not exist, analysis shall be performed regarding possible disturbances (e.g., frequency range, harmonics, transients, bursts, transmitted power).
in = Inch
mm = Millimeter

Support Structures in Telecommunications Spaces

Overview

Telecommunications spaces provide a location for the placement and ongoing support of ITS cabling and equipment. These spaces must be specifically designed to serve this function and be equipped with adequate floor space, lighting, power, access (e.g., ingress, egress), and environmental support.

Four common terms are used to describe these telecommunications spaces:

- Equipment room (ER)
- Telecommunications room (TR)
- Entrance facility (EF)
- Telecommunications enclosure (TE)

Equipment Room (ER)

An ER generally houses equipment that serves an entire building, campus, or customer. It provides the space and environmental support necessary to:

- Terminate and cross-connect backbone and horizontal cabling.
- Provide workspace for service personnel.
- Serve as an EF into a building.
- House large pieces of common active equipment (e.g., PBX node, UPS, data network equipment, video distribution system, fire-life-safety [FLS] or energy management control equipment, security systems).

Telecommunications Room (TR)

A TR generally serves a single floor or portion of a floor and is designed for the installation of a limited amount of equipment necessary to serve a dedicated floor area. It provides the space and environmental support necessary to:

- Terminate and cross-connect horizontal and backbone distribution systems.
- House splices, connecting hardware (e.g., cables to connectors or splicing), and equipment racks and cabinets.
- House equipment (e.g., servers, switches, telephone system equipment).

Telecommunications outlet/connectors must be cabled to the connecting hardware in TRs. Horizontal cabling should be terminated in a TR on the same floor as the area being served. Cabling between TRs is considered to be backbone cabling.

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Entrance Facility (EF)

An EF is an entrance to a building for both public and private network service cabling (including wireless), including the EP at the building wall and continuing to the entrance room or space. It is also a facility that provides all necessary mechanical and electrical services for the entry of telecommunications cabling into a building and complies with all relevant regulations.

Telecommunications Enclosure (TE)

A TE generally serves a limited space (a maximum of 335 m^2 [3600 ft^2]) on a floor and:

- Is intended to support a dedicated local group of users.
- Shall not be used in place of a TR.

Room Layout

It is recommended that TRs have 19 mm (3/4 in) thick, fire-retardant plywood backboards installed on at least two walls of the TR. The plywood provides a structure on which to mount connecting hardware and secure cables and equipment. A 305 mm (12 in) wide cable tray should be mounted on the same wall(s) as the backboard. If possible, mount the plywood and cable tray or ladder rack on all walls of a telecommunications space to facilitate growth.

The ITS installers documentation should indicate the size, location, quantity, and nomenclature of the equipment to be installed in the room along with a routing diagram of the cables to be installed or that pass through the room. The drawings will show the location of the pathways entering or leaving the space.

If equipment racks and cabinets are to be installed, a plan view of the space will indicate the footprints and how they relate to other equipment being installed. In most instances, the ITS installer's documents will indicate where voice, data, and video cables are to be terminated.

Always ensure that appropriate clearances are maintained around all pieces of equipment. In the absence of a specified distance, plan for a minimum of 1 m (3.28 ft) work and aisle space between and around equipment. If a TR layout is not provided, prepare one for approval before beginning work. Details for laying out a TR may be found in the most current edition of the BICSI *Telecommunications Distribution Methods Manual* (TDMM) and can be referenced before beginning the work.

Some of the major points to remember when implementing a TR's design include:

- Space for all planned and future equipment.
- Adequate routing pathways for each type of cable.
- Proper support for each type of cable, including growth.
- Adequate working room, including any necessary clearances from equipment.
- Sufficient lighting, electrical, bonding and grounding (earthing), and other environmental support.
- Physical security.
- Distribution pathway access for both horizontal and backbone cabling.
- Product manufacturer's recommended installation practices.

Room Layout, continued

It is important that the ITS installer prepare at least a dimensioned sketch of the space and equipment to be installed to identify potential areas of conflict. The simple concept of "build left to right" may not apply when faced with cable terminals, equipment racks and cabinets, overhead lights, network equipment, and patch panels. Design field adjustments may be necessary.

A typical TR might include some or all of the following:

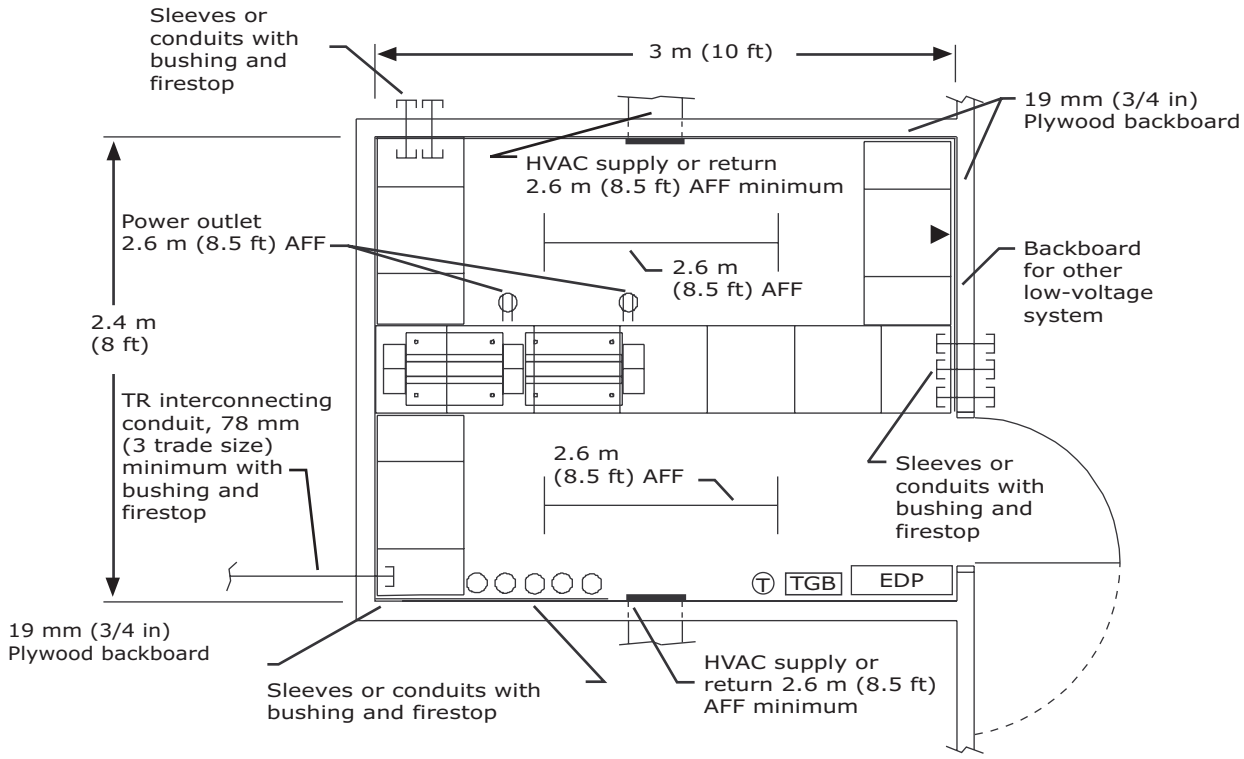
- IDC cross-connect field for horizontal and backbone cabling
- Patch panels for balanced twisted-pair or optical fiber horizontal cabling
- Patch panels for balanced twisted-pair or optical fiber backbone cabling
- Equipment racks and cabinets
- Cable trays or ladder racks
- Telecommunications bonding and grounding (earthing) components
- Active and passive network equipment (e.g., voice, data, video)
- Other low-voltage systems equipment
- Environmental support systems, including lighting, electrical services, bonding and grounding (earthing), supplementary power conditioning equipment, and air handling services
- Fire suppression system
- Room for expansion
- Sleeves or slots (floor and wall)
- Firestopping

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Room Layout, continued

See Figure 3.19 and Figure 3.20 for typical designs of a TR and backboard layout.

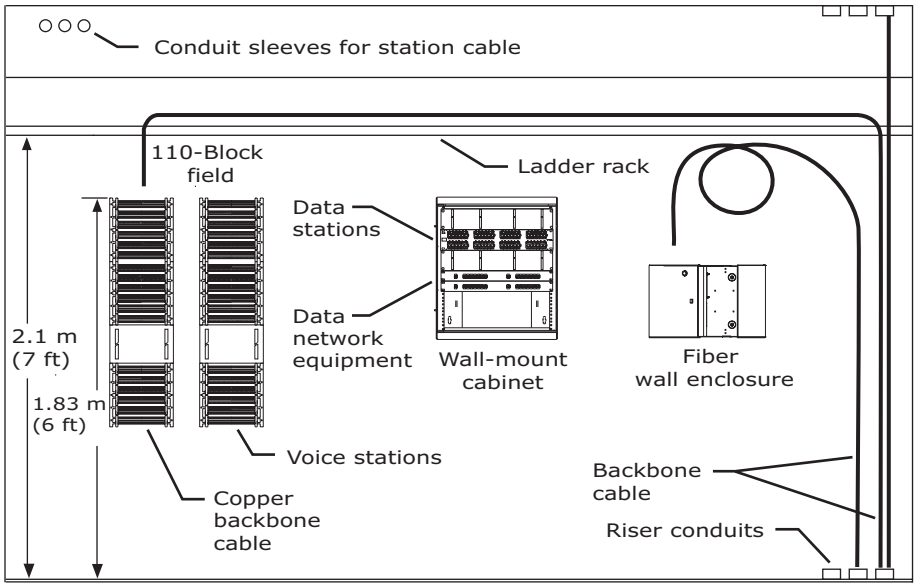
Figure 3.19
Typical telecommunications room layout



▼ = Telecommunications outlet/connector
Ⓣ = Thermostat
AFF = Above finished floor
EDP = Electrical distribution panel
ft = Foot
HVAC = Heating, ventilating, and air conditioning
in = Inch
m = Meter
mm = Millimeter
TGB = Telecommunications grounding busbar
TR = Telecommunications room

Room Layout, continued

Figure 3.20
Typical telecommunications backboard layout



ft = Foot
m = Meter

Plywood Backboards

Materials

Plywood backboards are mounted on walls in the ERs and TRs. Plywood is available in two types (interior and exterior) and in four grades (A, B, C, and D).

Sheets of plywood are normally sized 1.2 m (4 ft) wide by 2.4 m (8 ft) high. Appropriate thicknesses are readily available in a range of 19 mm (3/4 in) through 32 mm (1-1/4 in). The recommended thickness is 19 mm (3/4 in). Plywood that is too thin does not offer enough strength to ensure that mounted hardware is securely anchored. Plywood sheets thicker than 25 mm (0.98 in) are not usually required. Thickness is contingent on properly attaching the sheet of plywood to the building structure and the need to recess the heads of the mounting hardware.

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Plywood Backboards, continued

The finishing grade of plywood (A, B, C, or D) describes the quality of the surface (e.g., degree of knotholes or blemishes):

- Grade A is the highest grade and is without any surface blemishes.
- Grade B has the knotholes cut out and replaced with a patch of clean wood.
- Grade C contains some blemishes and an occasional small knothole.
- Grade D contains knotholes without any repair or corrective action by the manufacturer.

Grading of a sheet of plywood may result in a different grade for each of the two sides. For instance, a sheet of plywood could be graded A/B; one side is A, and the reverse side is B.

Plywood should be void free. This means that the space in each layer inside the plywood where the knotholes are removed is completely filled with replacement wood patches. Voids inside a sheet of plywood may create a weak spot where the attachment hardware (e.g., screws, toggle bolts) cannot hold fast. The plywood should contain 15 percent or less moisture to prevent warping.

For ITS use, grade A/C plywood should be used. The A side is exposed to the interior of the TR, and the C side is placed against the building structure or cabinet wall. Generally, start mounting the plywood 203 mm (8 in) above finished floor (AFF).

NOTE: BICSI strongly recommends that plywood be painted with two coats of fire-retardant paint. Some local codes may require use of fire-retardant plywood. If this applies, it is not recommended to paint the plywood. The effects of the treatment may cause the paint to crack, deteriorate, and peel off the plywood backboard. When local code requires use of treated plywood painted with a fire-retardant paint, verify with the authority having jurisdiction (AHJ) if the plywood's fire-retardant stamp should be painted over or left exposed to show the type of plywood that was installed.

Plywood Backboards, continued

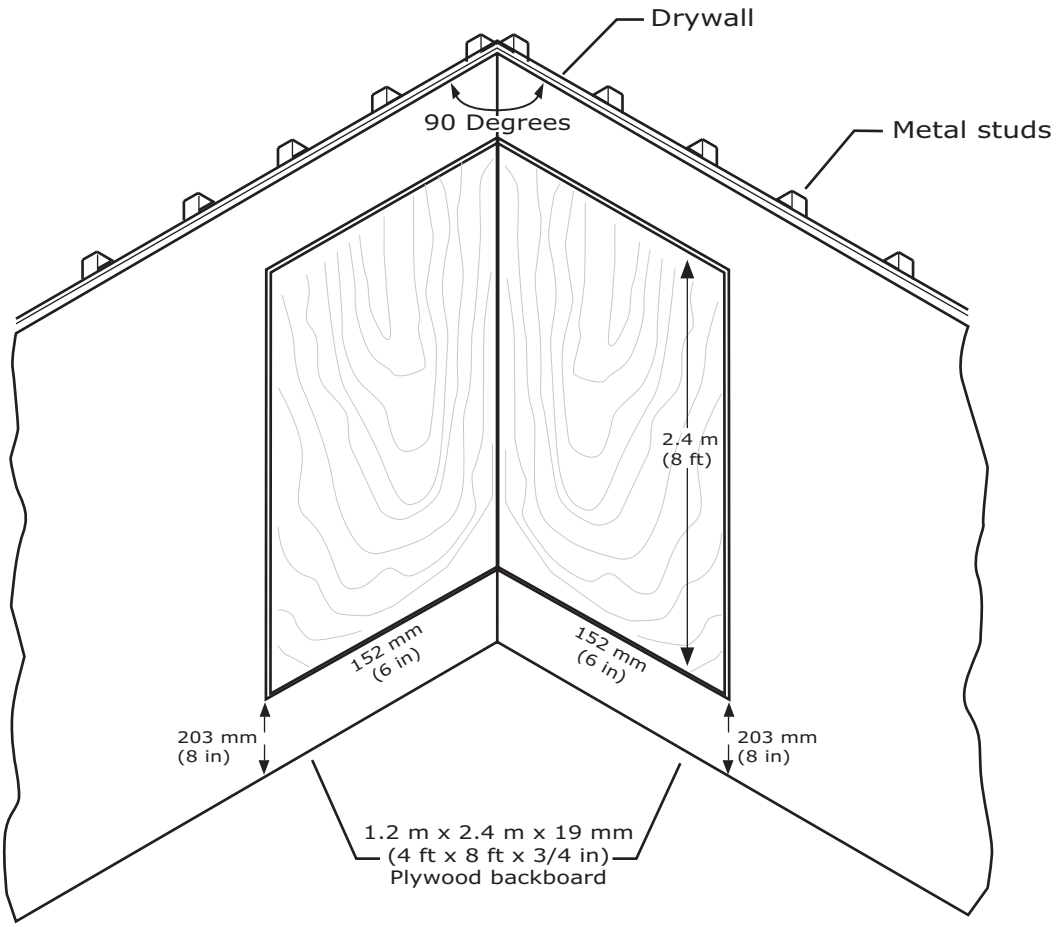
Placement

Plywood sheets used for backboards should be installed with the longest dimension reaching from 203 mm (8 in) AFF to an installed height of 2.6 m (8.5 ft). In the case of a TR with a 2.745 m (9 ft) or 3 m (10 ft) clear working height, do not raise the bottom of the plywood to split the difference. This will raise the working height level in such a way that a ladder may be required to work on the equipment mounted at the top of the plywood.

In the case of a TR with a clear working height of less than 2.6 m (8.5 ft), mount the plywood sheets starting 100 mm (3.94 in) to 152 mm (6 in) AFF up to the maximum clear working height in the TR.

Plywood should be installed in such a manner that there is no separation between adjacent sheets. When installing plywood in a corner (see Figure 3.21), the plywood backboard can be installed plumb and adjacent to the edge of one side of the wall at the corner with the sheet on the intersecting wall butted up against the first sheet to form a smooth, 90-degree corner.

Figure 3.21
Corner installation of plywood backboards



ft = Foot
in = Inch
m = Meter
mm = Millimeter

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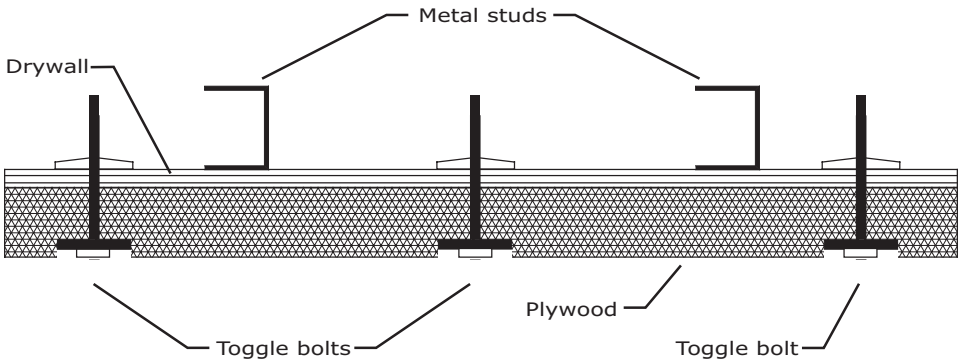
Plywood Backboards, continued

The plywood backboard must be rigidly affixed on top of the existing framed wall or to the studs in the perimeter walls of the room. When installing the plywood on bare metal studs (no framed wall), framed wall screws, or galvanized screws, a minimum of 12.7 mm (0.5 in) longer than the depth of the plywood backboard must be used. When using the metal studs for anchoring the plywood, predrill the framed wall, plywood, and metal stud with a bit sized smaller than the screw size.

When installing plywood on framed wall, it is good practice to use a construction adhesive between the plywood and framed wall. Position the plywood so that it aligns with the studs. As a result, the screws can easily provide a secure anchorage through the framed wall and into the studs.

When the plywood edges do not align with the studs, toggle bolts (butterfly bolts) may be required to attach the plywood to the framed wall (see Figure 3.22). Always verify the load rating of the wall prior to installing the plywood. These toggle bolts should be a minimum of 6.3 mm (0.25 in) in diameter and must be sufficient in length to allow the toggle (butterfly) to seat behind the framed wall after installation.

Figure 3.22
Installation using toggle bolts in framed wall construction

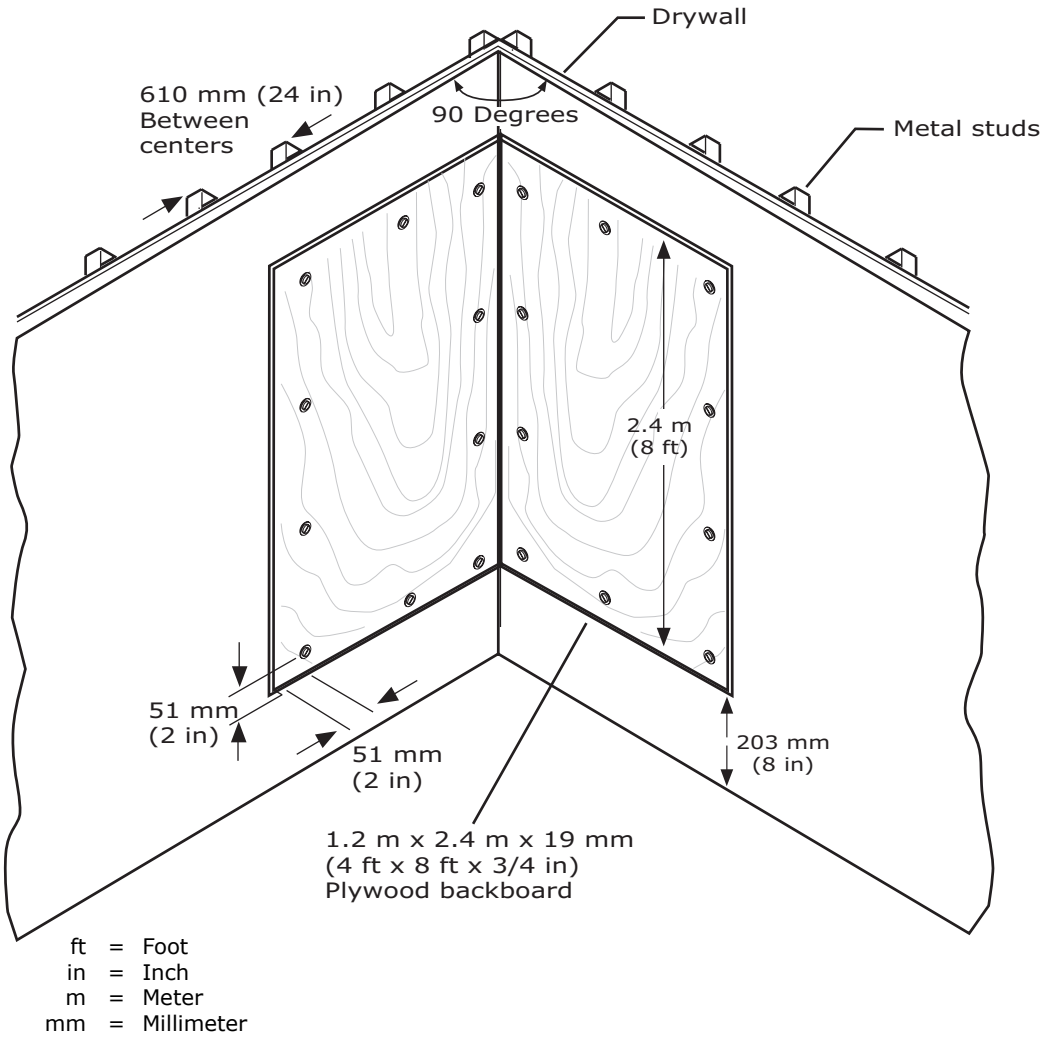


Plywood Backboards, continued

For this framed wall application, toggle bolts should be installed at approximately 610 mm (24 in) spacing around the entire perimeter of the plywood board (see Figure 3.23). If desired, recess the bolt heads to allow for use of the entire area on the plywood. Recessing the bolt head on plywood less than 25 mm (0.98 in) thick may affect the ability of the plywood to hold the desired load of equipment and termination hardware.

The toggle bolts should be installed 51 mm (2 in) from the edges of the sheet of plywood on approximately 610 mm (24 in) centers. Locate the toggle bolts, and use care to avoid the studs when drilling. The studs will prevent the toggle (butterfly) from opening behind the framed wall.

Figure 3.23
Plywood installed using toggle bolts



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Cable Support Systems

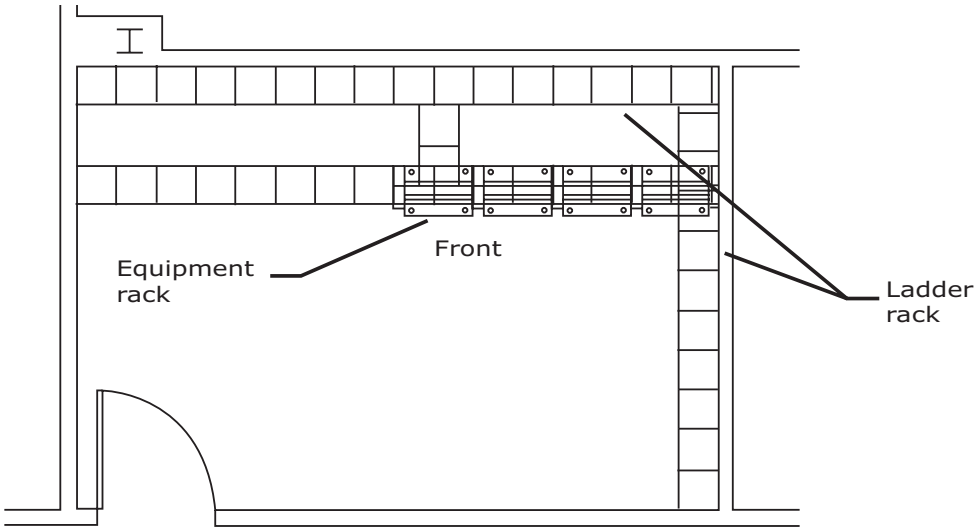
Layout

If possible, install plywood backboards around the entire perimeter of the TR. This will enhance the use of the wall space in the TR and allow cables to be installed around the walls where terminal equipment will be located. It will facilitate attaching cables that pass through vertically to TRs located on floors above or below.

Ladder Racks and Cable Trays

In the example that follows, a ladder rack or cable tray is installed from one wall to another in a TR (see Figure 3.24). Seismic bracing requirements should be considered during installation.

Figure 3.24
Plan view of a typical telecommunications room with ladder rack installed on two walls



As shown in Figure 3.24, the cable tray or ladder rack is installed from one wall to the opposite wall using wall angles to secure the cable tray or ladder rack at each end and by wall brackets to support the ladder rack in the middle. The cable tray or ladder rack should also be anchored to the top of each equipment rack as each is installed. By using these attachments, sufficient support for the equipment rack or cabinet and the installed cables is provided. The ITS installer may instead choose to support the ladder rack from the ceiling using channel stock and threaded rods.

It is suggested that a cable tray or ladder rack be installed on every wall in the TR. This will ensure that a proper pathway exists for cables that route from a point on the backboard of one wall to a location on a different wall. Distribution rings (D-rings) should not be used as a substitute for a ladder rack.

Ladder Racks and Cable Trays, continued

Where several large backbone cables are passing vertically through the room, a vertical cable tray or ladder rack should be appropriately positioned to support the cables from ceiling to floor level (see Figure 3.25). The cables should be secured to the cable tray or ladder rack in an orderly fashion to ensure that they are properly supported and that the entire weight of the cable is equally distributed over several cable supports. Each cable outer sheath should be labeled for identification.

Figure 3.25
Vertical ladder rack

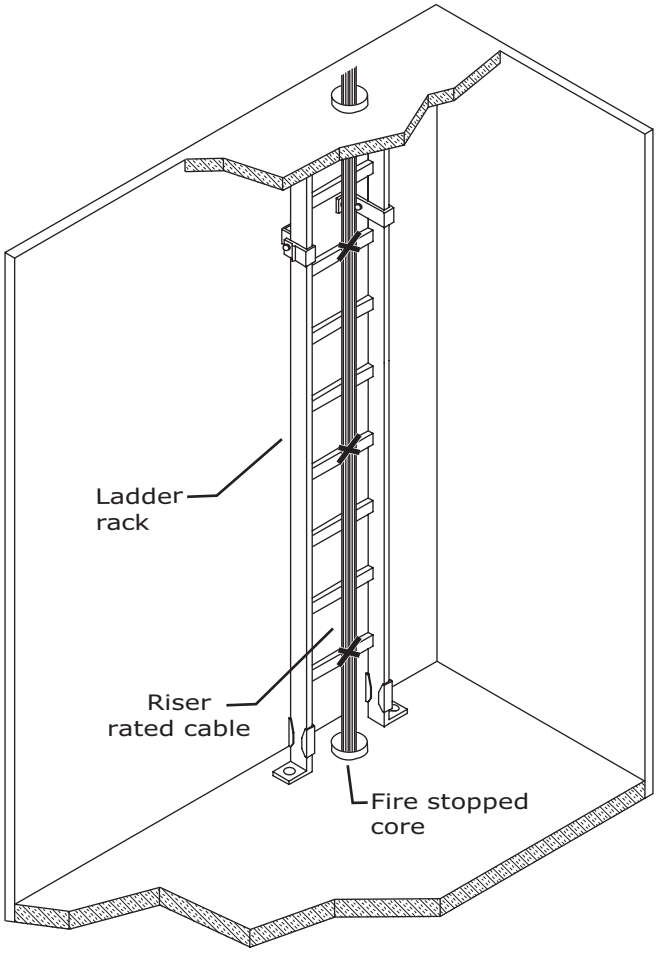


Figure 3.25 shows the hardware required to accomplish vertical support. Many manufacturers will provide a computer-aided design (CAD) drawing and a list of materials required.

The ITS designer's documents may already include the details referenced above; if so, the documents must be used for the installation.

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Distribution Rings (D-Rings)

D-rings are used to support small bundles of cables and cross-connections as they route from one termination point on the plywood backboard to another. However, the D-rings should not be substituted for a cable tray or ladder rack.

D-rings are available in many sizes, shapes, materials, and colors. D-rings are manufactured in metal (aluminum) and plastic and are formed in the shape of the letter D.

A half D-ring is available in both metal and plastic. The half D-ring is used to provide support and management primarily where cross-connect jumpers turn at a 90-degree angle. Figure 3.26 gives an example of a standard metal D-ring.

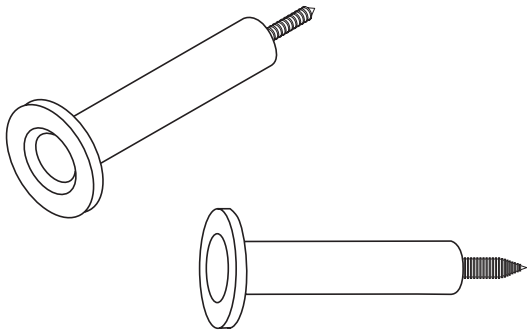
Figure 3.26
Typical D-ring



Distribution Rings (D-Rings), continued

An alternate to the half D-ring is the spool or "mushroom." Spools are constructed with plastic and contain a center-mounted screw for attachment to plywood backboards (see Figure 3.27). They are available with threaded bolts for installation on equipment racks.

Figure 3.27
Spools



Conduits

Conduits are raceways of circular cross sections that house backbone cables and horizontal cables.

Conduits that enter a TR should be terminated at specific locations on the wall to enable orderly routing of the cables to termination equipment in the TR or routed through the TR to another location. Ream metallic conduit ends, and install bushings. It is especially important to use sweep elbows when dealing with optical fiber cables or large backbone cables. These elbows preserve the cable bend radius. Severe bending can result in cable damage.

Conduit bend radius also needs to be addressed when installing conduit. The inside bend radius shall be 10 times the internal diameter of the conduit when used for optical fiber or trade size diameters greater than 51 mm (2 in). If the conduit has a trade size diameter of 51 mm (2 in) or less, the inside bend radius shall be at least 6 times the internal diameter. Metallic conduits must be grounded. Label each conduit for identification.

Conduit ends should be positioned adjacent to the left side of the backboard (in the case of a single piece of plywood) or in the left most corner of the room (where multiple sheets of plywood are installed around the perimeter walls of the room). If conduits cannot be located in these positions, regardless of the reason, ladder racks should be used to route the cables from one location in the room to another. This avoids encroaching on wall termination space.

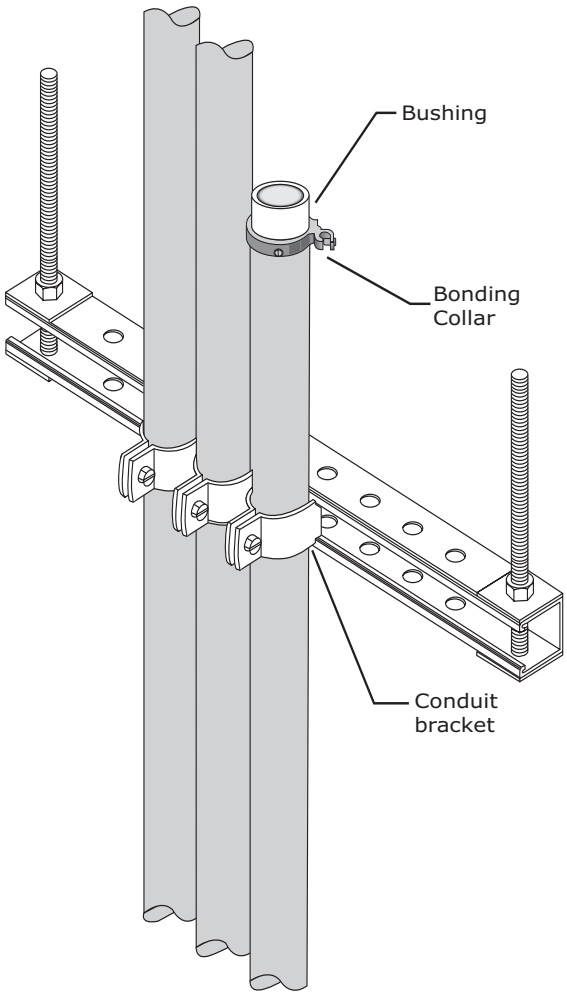
Conduits should be physically attached to the top of the plywood backboard using channel stock and conduit brackets when entering from overhead. When conduit enters from below grade, the floor cement slab or building structure is usually enough support to provide for a fixed installation without the use of channel stock. The ITS designer's drawings should indicate the location of each conduit and where it terminates in the TR.

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Conduits, continued

Metal conduit brackets provide electrical continuity between the conduit and the channel stock and can provide a bonding path between conduits and a bonding conductor (see Figure 3.28). This should then be bonded to either the telecommunications main grounding busbar (TMGB) or to a telecommunications grounding busbar (TGB). In places where a small number of conduits are installed, a grounding bushing should be installed at the end of each conduit for the attachment of a 6 AWG [4.1 mm (0.16 in)] copper wire, which connects to the TMGB or TGB. Conduits in close proximity to each other can be bonded together. One conduit in the string must be bonded to the TMGB or TGB.

Figure 3.28
Conduits on channel stock



Equipment racks, sometimes referred to as relay racks, equipment bays, rack frames, 2-post racks, 4-post racks, and network racks allow the installation of network components, cabling terminations, and support equipment in standard vertical supports. Equipment racks are metal frames, which usually provide a large number of vertically arranged, closely spaced mounting holes (see Figure 3.29). Normal height for these racks is 2.1 m (7 ft). Custom-sized racks are available in larger and smaller heights.

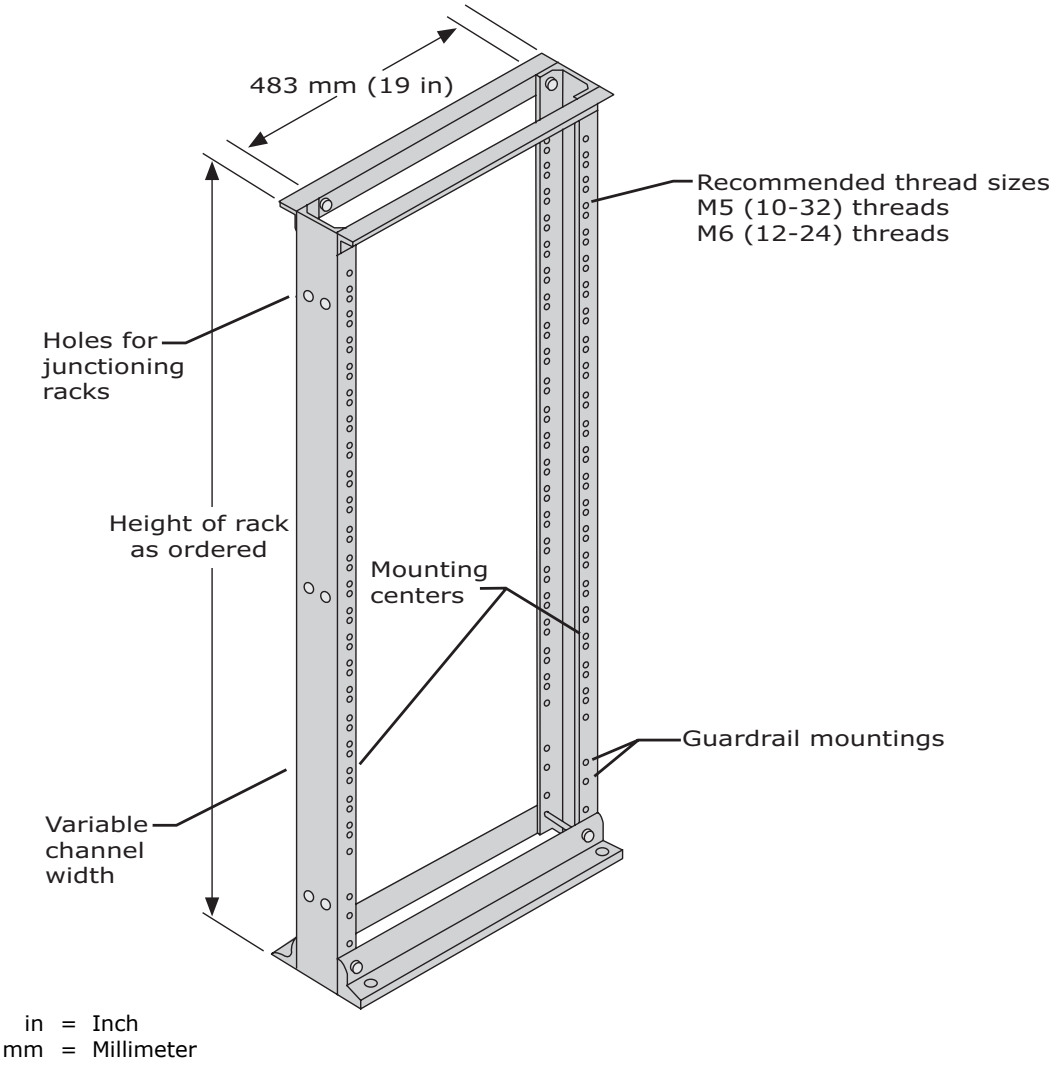
Equipment Racks

The common sizes are 483 mm (19 in) and 584 mm (23 in). For building ITS, most installations will require the 483 mm (19 in) by 2.1 m (7 ft) high racks. For AP/SPs (e.g., telephone company equipment), the installations may require the 584 mm (23 in) by 2.1 m (7 ft) high racks. It is recommended to always use double-sided racks with mounting holes on the front and rear. Racks should be accessible from the front and rear.

Equipment racks should be securely mounted to the floor and to cabling pathways (e.g., cable tray, conduit) or building structure above. In addition, the ITS installer should check with the AHJ for local seismic (bracing) installation requirements.

NOTE: Rack sizes do not denote actual width. Verify actual dimensions and footprint with the manufacturer.

Figure 3.29
Equipment rack



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Equipment Racks, continued

Equipment racks are available in two common depths:

- 100 mm (3.94 in)
- 152 mm (6 in)

Depending on the requirements for an installation, deeper racks may be needed to support a larger number of cables routed to the patch panels. These deeper racks may offer additional physical stability when several pieces of electronic equipment are attached to the racks.

Racks typically provide two holes for bonding the rack to the TMGB or TGB. A minimum 6 AWG (4.1 mm [0.16 in]), green insulated ground wire telecommunications equipment-bonding conductor (TEBC) is anchored to a two-holed, crimp-style lug at each end. A painted rack should be scraped to the bare metal. To resist oxidation, an antioxidant compound should be applied to the bare metal and the ground source metal before the lug is anchored. Label the cable with a permanent label, showing the location of each end.

Cables should be routed on the rear sides of the rack using cable management accessories attached to the rear of the rack's vertical channels or in cable management channels mounted vertically on the sides of the rack. Some manufacturers offer racks with built-in cable management that have deeper and wider vertical channels to allow cable management inside the vertical channels. These racks offer a neater installation with easy rear access to equipment.

NOTE: If not well planned, equipment can later obstruct access to cables inside the channels.

An equipment rack lineup (consisting of two or more racks) will require accessibility on both sides of the lineup for walk space. This will facilitate the installation of network equipment and cable management devices used to support the cables as they are routed to the rear of the patch panels for termination.

Where equipment racks are separated some distance from a wall, ladder racks should be installed overhead from the wall to the top of the racks and equipped with a radius drop (waterfall). This will provide a pathway for cables to be routed to and from the racks. Without a ladder rack, no means of support will be available, and the cables may incur damage. At a minimum, degradation of signal will result. Conduits do not offer sufficient cross-sectional area for large numbers of cables and are not easily attached to the tops of the racks. This is especially true when cabling from telephone PBX cabinets to equipment racks or from computer equipment to adjacent cabinets.

The ITS designer's drawings should indicate the method of supporting cables routed to the racks and the means for attaching such supports.

Equipment Racks, continued

Floor-Mounted Cabinets

Cabinet enclosures are available to house connecting hardware in lieu of equipment racks. They are basically enclosed equipment racks with additional specialized hardware installed. Cabinets are available with standard or specialized components. Most cabinets can be ordered with clear-paneled, solid, or vented doors at the front, sides, and rear. Top sections can be solid or vented and fan mounted. The vertical mounting hole spacing on the racks inside the cabinets is the same as for equipment racks. Sometimes the ITS designer will specify cabinets containing power strips, fans, or other electrical apparatus. When these are required, it is especially important that the electrical and bonding and grounding (earthing) requirements be carefully followed.

Cable access to the cabinet is normally provided by knockouts (prepunched holes) in the cabinet side, top, or bottom. Ladder racks and cable trays provide the means of routing cables to the cabinet. Verify the installation methods specified by the manufacturer prior to attempting to install cabinets. Ensure that the cabinets will fit the footprint allocated for them prior to installation. If there is a question regarding the space allocated, review the ITS designer's drawings or contact the ITS designer for further clarification.

Wall-Mounted Racks and Cabinets

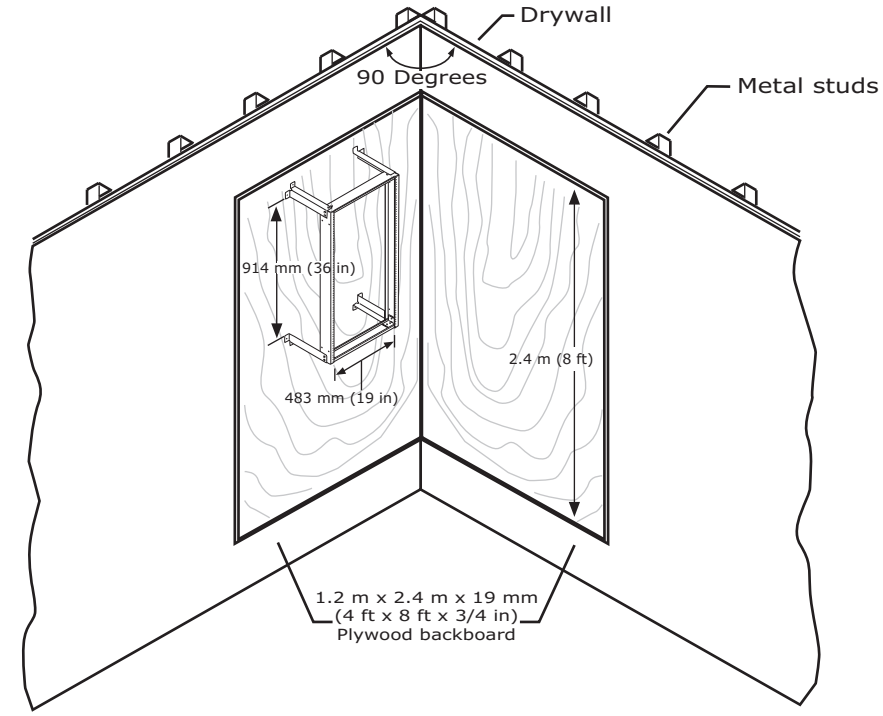
When floor space is at a premium or when other equipment is occupying most or all of the available floor space, racks and cabinets may not fit in the room. Wall-mounted racks and cabinets should be considered for the installation. Wall-mounted racks are available in several depths with or without easy rear access (hinged brackets). The wall-mounted rack or cabinet has to be solidly anchored to the plywood with lag bolts and washers. If electronic equipment is to be installed on the wall-mounted racks, allow for equipment depth when ordering and installing them (see Figure 3.30).

A LAN chassis, including cable management and chassis doors, may require a mounting depth of as much as 965 mm (38 in) when installed on a rack or in a cabinet. In this instance, a rack of at least 1220 mm (48 in) in depth would be specified. Follow the equipment manufacturer's specifications when mounting equipment within a wall-mounted apparatus.

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Equipment Racks, continued

Figure 3.30
Wall-mounted rack with hinge



ft = Foot
in = Inch
m = Meter
mm = Millimeter

Wall-mounted racks and wall-mounted cabinets are available in various heights up to 1.83 m (6 ft) and in widths of 533 mm (21 in) and 660 mm (26 in) with a depth of 152 mm (6 in), 305 mm (12 in), or 455 mm (18 in).

Wall-mounted cabinets may be either vented or unvented, and they can be equipped with clear plastic or metal doors. Some manufacturers offer cabinets featuring power strips and fans. Fans are required only when the equipment installed in the cabinets generates a significant amount of heat. Power strips should provide both overvoltage and overcurrent protection, and they should supply a minimum of six positions. It is important to understand the total load (amperage) of the equipment that will utilize the alternating current (ac) outlets on the power strip before selecting the power strip.

Many electronic equipment manufacturers use bulky external ac transformers to power their equipment. Use power strips designed with adequate spacing for these transformers, or every other outlet will be obstructed.

Always bond the cabinets using a minimum of 6 AWG [4.1 mm (0.16 in)], green-insulated copper wire (e.g., TEBC). Install the ground wire from the ground lug on the cabinet chassis to the ground busbar located in the TR. Use of a two-holed, crimp style lug is recommended. See Chapter 4 for additional guidance for bonding and grounding (earthing) installation.

Common Rack Installation Issues

Floor- or wall-mounted racks and cabinets all have common installation and setup issues, including:

- Attachment.
- Bracing.
- Design layout.
- Cable routing.

Attachment

Floor-mounted racks and cabinets must be securely mounted to the floor with expansion anchors and bolts with both flat and lock washers. This will require a concrete bit with hammer drill and a vacuum to clear the hole for the anchoring device. It will generally require the use of a socket set and screwdrivers to complete the assembly and setup of an equipment rack.

A fully loaded wall-mounted rack can put a significant strain on a building's structure and must be attached to material that can support the planned load (e.g., rack, cable, all other equipment). Simple metal or wooden studs may not be sufficient to support the weight, and the placement should be verified with the architect, engineer, general contractor, or owner.

Additionally, if the equipment rack needs to be electrically isolated from the floor or current-carrying materials, an isolation kit should be installed. This generally consists of isolation plates and/or knobs for placement under the rack and isolation grommets for the mounting points.

Bracing

The top of the floor-mounted rack, when required, must be supported to the:

- Wall.
- Support barrier.
- Cable tray.
- Ladder rack.

NOTE: In some geographical areas, seismic bracing may be required.

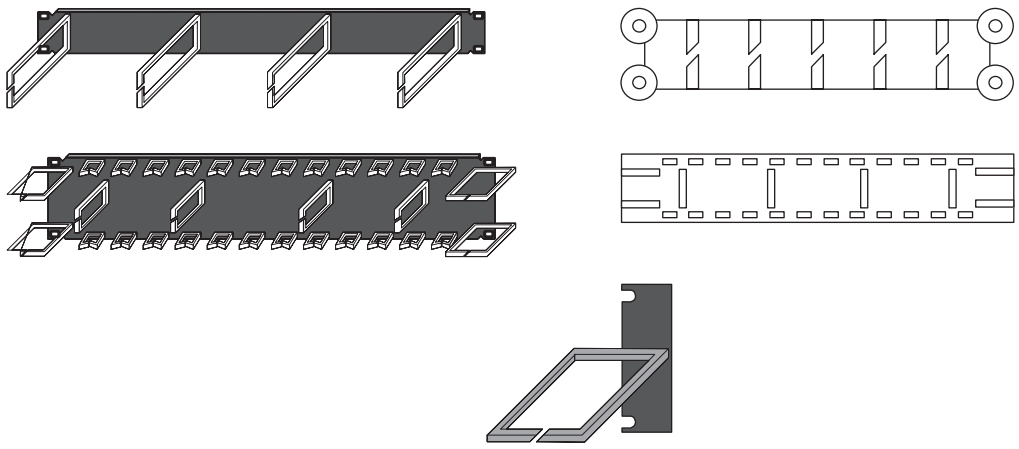
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Common Rack Installation Issues, continued

Design Layout

Design layout refers to the placement of components within the rack or cabinet (see Figure 3.31). Most equipment designed to be placed in racks is defined by the amount of space it requires in a rack. The minimum spacing is considered one rack-mounting unit (RMU) or one U. One U is equal to 45 mm (1.77 in).

Figure 3.31
Cable managers



The ITS installer must be aware of the number of RMUs required to support all of the equipment to be installed plus any open space recommended for airflow between electronic components or space for cable and cable terminations. If the ITS designer provides no installation details, the ITS installer should sketch the projected components, the required open spaces, and the total number of RMUs required. Work back from that point to define where on the rack the placement of components should start.

When securing equipment to a rack or cabinet, there are four popular thread sizes for the mounting screws—M5, M6, 12-24, and 10-32. Each should be used in conjunction with external star (lock) washers inserted between the rack and the panel for bonding purposes.

Common Rack Installation Issues, continued

Cable Routing Components

The primary use for equipment racks in TRs is the support of the electronics and their interconnection to the cabling system. This most often means the point at which the horizontal cabling is cross-connected to a patch panel in or near the active equipment.

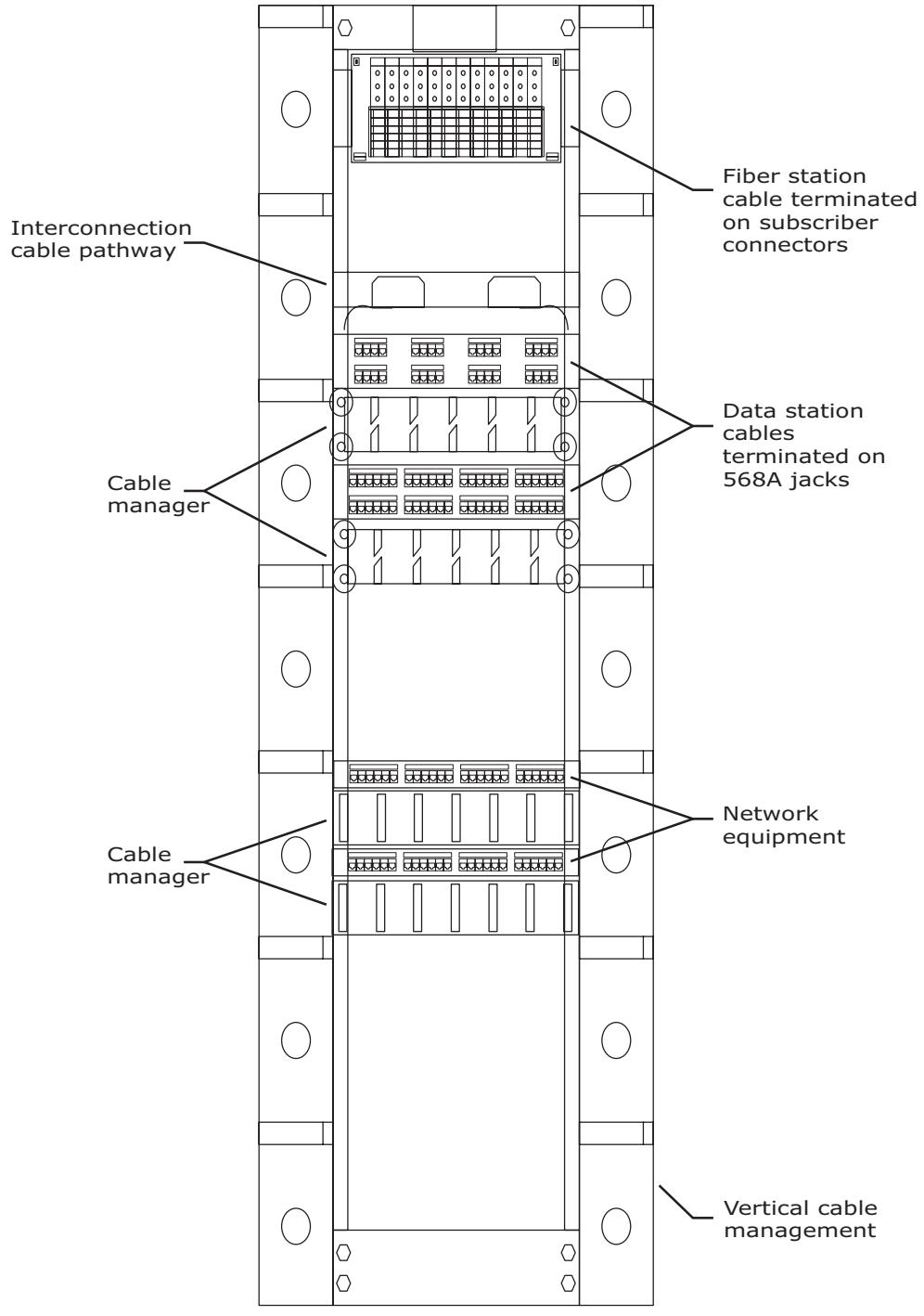
The layout and configuration of the rack or cabinet must support the actual termination of the horizontal cable and the equipment cords and patch cords necessary to complete the connection. It will be difficult, or even impossible, to install patch cords to exact lengths needed for interconnection. The rack layout must make allowances for extra patch cord slack somewhere in its design (see Figure 3.32).

When laying out and installing cable routing components on the rack, it is important to understand in which order the active and passive equipment will be interconnected. In some cases, network managers may designate specific connecting hardware jack positions (e.g., patch panel jacks) to individual electronic component ports, allowing them to be vertically collocated on a rack. More often, flexibility requires two groupings—network equipment and cable. The ITS installer must ensure that there is sufficient space to make cable attachments and run the patch cords to both components.

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Common Rack Installation Issues, continued

Figure 3.32
Equipment rack detail



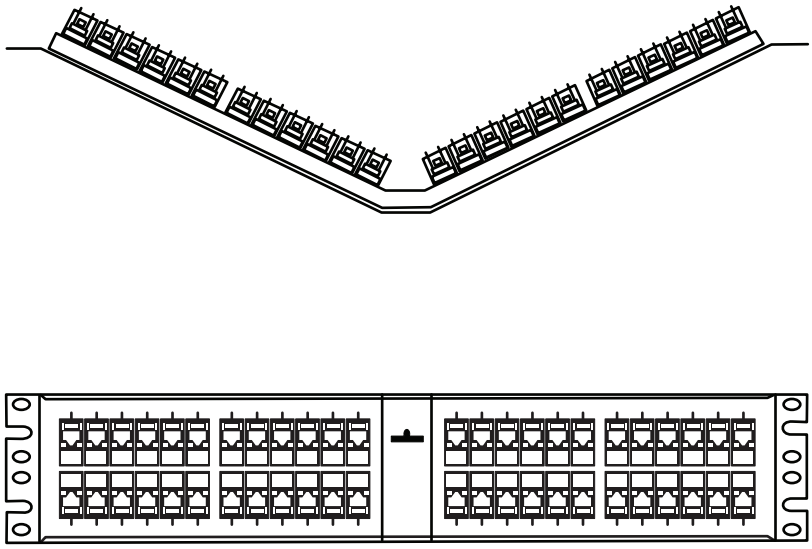
in = Inch
mm = Millimeter

Common Rack Installation Issues, continued

For ease of use and long-term cable management, balanced twisted-pair patch panels of 48 ports or less are preferred. Each patch panel or network component may have a horizontal equipment cord or patch cord support pathway installed directly above or below the patch panel. The size of this pathway will depend on the number and outside diameter (OD) of equipment cords or patch cords and the location from which they will originate (left, right, or both).

Where angled patch panels are used, a horizontal equipment cord or patch cord support pathway may not be necessary. Vertical equipment cord or patch cord support pathways are typically used in conjunction with angled patch panels (see Figure 3.33).

Figure 3.33
Angled patch panel



Equipment racks need two vertical cable pathways. One pathway will support the horizontal cable terminated on the rear of the modular patch panels. The other pathway will support equipment cords or patch cords between patch panels and electronics on the front of the equipment rack or cabinet.

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Cable Pathway Support Structures

Overview

This section describes the support structures and hardware associated with backbone and horizontal pathways.

A backbone pathway is the portion of the pathway system that permits the placement of backbone cables between the entrance location and all cross-connect points within the building.

A horizontal pathway is the portion of the pathway system between the HC (FD) in the TR and the telecommunications outlet/connector.

When installing cable pathways, it is important to ensure that the route is verified prior to actually installing the support structures. Fire- and smoke-rated barriers may have to be penetrated, and they must be replaced in compliance with codes, standards, and regulations.

Obstructions (e.g., HVAC ducts, large pipes, and structural beams within the building) may have to be overcome. The ITS installer must be sure that the chosen route will provide a clear path and still maintain appropriate pathway bend radius, which in turn affects the installed cables bend radii.

Conduit

Conduit is primarily used for backbone pathways, but it may also be used as a horizontal pathway. This chapter focuses on the most common conduit types (e.g., electrical metallic tubing [EMT]) with general information regarding other types of conduit.

Materials

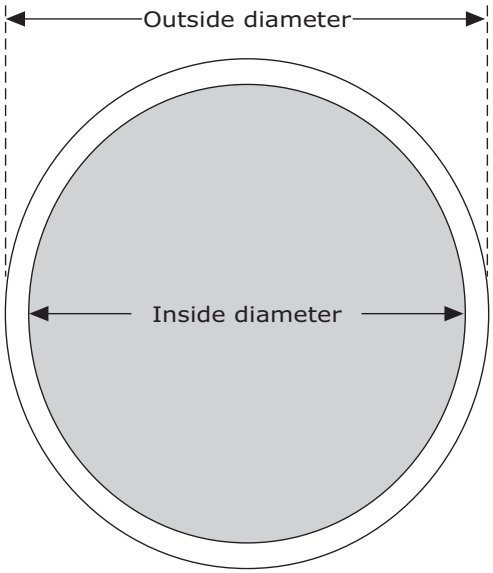
The following types of conduit generally are used inside commercial buildings:

- Electrical metallic tubing (EMT)
- Electrical nonmetallic tubing (ENT)
- Flexible metallic tubing (FMT)
- Intermediate metallic conduit (IMC)
- Rigid metallic conduit (RMC)
- Flexible metallic conduit (FMC)
- Rigid nonmetallic conduit (RNC)
- Others permitted by appropriate electrical codes

Conduit, continued

EMT is available in 16 mm (1/2 trade size) through 103 mm (4 trade size); IMC and RMC are available in 16 mm (1/2 trade size) through 155 mm (6 trade size). Both the OD and inside diameter (ID) of steel conduit are larger than the trade size designation (e.g., 16 mm [1/2 trade size] EMT has an OD of 18 mm [0.7 in], and the ID is about 17 mm [0.67 in]) (see Figure 3.34).

Figure 3.34
Cross section of conduit outside diameter versus inside diameter



NOTE: Conduit trade size is based on nominal inside dimension.

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Electrical Nonmetallic Tubing (ENT) Conduit

BICSI recommends that polyvinyl chloride (PVC) conduit not be used inside commercial buildings. Refer to the AHJ for permitted conduit materials. If the entrance has to be extended past the main entrance room to another ER, a properly sized metal conduit box and metal conduit should be used.

When subjected to extreme temperatures during fires, PVC conduit emits toxic smoke and gases that can cause extensive injury or death to persons attempting to escape the fire. The products of combustion can be severely corrosive to ITS equipment and can disrupt service to critical ITS equipment. PVC conduit can be used under slab-on-grade construction (where codes permit).

Flexible Metallic Tubing (FMT) Conduit

IMPORTANT: Flexible conduit (e.g., metal flex conduit) is not recommended for use with telecommunication cables because of the disadvantages explained below.

During cable pulling, flexible conduit tends to:

- Creep.
- Shift.
- Cause sheath damage to the cable.

Use flexible conduit only in situations where it is the only alternative.

NOTE: If flexible conduit must be used, it shall be limited to 6.1 m (20 ft) and increase the conduit diameter by one trade size. Some manufacturers provide an armored cable assembly with the cabling preinstalled inside of the flexible conduit. Since such integrated cable/pathway design eliminates or sufficiently diminishes the negative features of a flexible conduit listed above, the 6.1 m (20 ft) rule need not be applied.

Electrical Metallic Tubing (EMT)

EMT is a thin-wall metal tubing that does not have threaded ends. It is used widely today in electrical distribution systems and as a pathway for ITS cabling. EMT is supplied in standard 3 m (10 ft) lengths. Each length of tubing is referred to as a section.

Electrical Metallic Tubing (EMT), continued

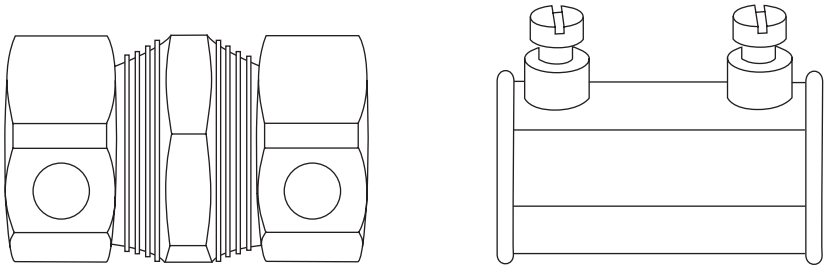
Couplings

EMT uses two types of couplings to connect sections together (see Figure 3.35). Compression couplings are installed by slipping the fitting nut first and then the fitting compression ring onto the conduit. The conduit is then slipped into the main coupling body, and the compression ring is compressed as the nut is threaded and then tightened onto the coupler body. This is accomplished using two pipe wrenches or slip joint pliers.

The other type of coupling is a setscrew coupling. It is installed by inserting the conduit into the fitting and tightening the setscrews with a screwdriver. Both couplings are used extensively throughout the industry.

Be sure conduit ends are filed smooth and securely and fully seated in the coupling or connector. This is important to ensure that the setscrews have room to bite into the conduit for a secure joint. Correct measurement, including length of the elbow legs, is necessary to have sufficient conduit length for secure joints.

Figure 3.35
Electrical metallic tubing couplings



Compression coupling Setscrew coupling

Rigid Metallic Conduit (RMC) and Intermediate Metallic Conduit (IMC)

There are two types of thick-wall metal conduit, RMC and IMC. The wall thickness of RMC is greater than that of IMT, which is greater than that of EMT. RMC and IMC are more rigid than EMT. IMC has an intermediate wall thickness and construction rigidness among the three metal conduits—EMT, IMC, and RMC—hence its name. RMC and IMC are available in 3 m (10 ft) lengths (sections), including a threaded coupler on one end. They are actually just short of 3 m (10 ft).

NOTE: If needed to run 30 m (98 ft) of conduit, it will take slightly more than 10 sections of conduit.

Each section of RMC and IMC is factory threaded on both ends. When a section of this conduit is cut to length, new threads are cut on the end. Compression-type connectors and couplings are available.

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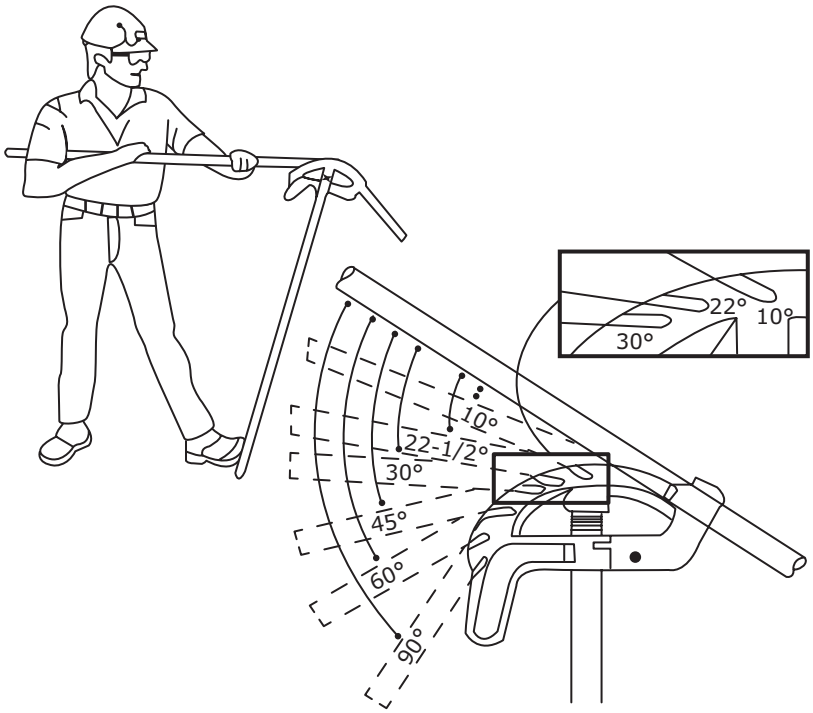
Conduit Elbows and Bends

Factory-manufactured bends are recommended for all types of conduit installations (e.g., EMT IMC, RMC). Bends can be manufactured in the field, but specialized equipment must be used to accomplish the required angle of bend. Field-manufactured bends typically result in an elliptically shaped cross section rather than being completely round (see Figure 3.36).

In the event a field-bend conduit becomes elliptical, it must be replaced or derated to the next smaller size. This is caused by the action of tools used for bending the conduit. A hand bender can be used in the field to bend 16 mm (1/2 trade size) up to 35 mm (1-1/4 trade size).

Conduits are specified by their trade size.

Figure 3.36
Conduit hand bender



If the conduit is 53 mm (2 trade size) or less, the bend radius must be at least six times the internal conduit diameter. Bends are available in standard radii or sweeps. Recommended conduit bends are commercially available beginning at 21 mm (3/4 trade size).

Conduit Elbows and Bends, continued

Conduit bends are readily available in various bend configurations. Elbows and bends of 11.25 degrees, 15 degrees, 22.5 degrees, 30 degrees, 45 degrees, and 90 degrees are available through distributors. These bends are available in all conduit trade sizes. Special radius and long sweeps are available, but they may have to be specially ordered.

If odd bend degrees are needed, various configurations of factory-manufactured bends can be used to accomplish the specific requirements. For example, one 45-degree bend and one 15-degree bend can be coupled together to form a 60-degree bend; two 30-degree bends can be used to accomplish this. However, it is preferable to use one elbow of the proper degree for easier pulling of the conductors.

Long sweeps are available but may need to be obtained by special order. Conduit bends are commercially available with varying leg lengths on each side. A leg is the extension of the conduit bend past the point where the bend stops and straightens out. Most elbows are furnished with a standard leg length for each size.

Nonstandard leg lengths are also available, but they may need to be obtained by special order. Leg lengths may vary from one manufacturer to another. The ITS cabling installer should confirm these lengths to maintain a uniform installation with accurate termination points on the conduits.

Conduit Body

A conduit body is a fitting available in several styles and configurations (see Figure 3.37). The most common styles are the:

- 90-degree bend left, right, or back.
- T (tee) configuration.
- C or straight inline fitting.

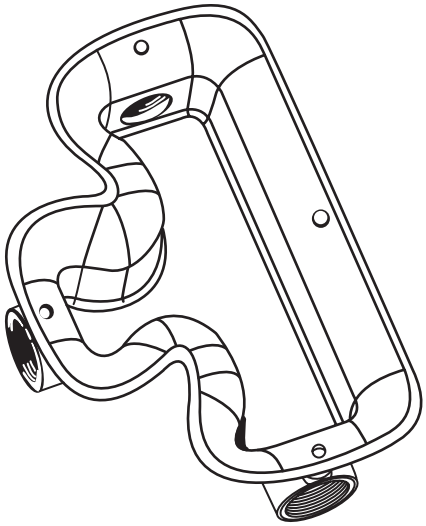
A conduit body (e.g., electrical or telecommunications type) is recognized by its removable cover. The conduit body is a pull point used primarily to give access to and to change the direction of the conduit system. It is important to meet the minimum bend radius requirements when cables are installed into a conduit system and conduit bodies are used to change direction.

The telecommunications conduit body features an internal radius that accommodates a standards-based cable bend radius once cable is installed in the lay position of the conduit body device. Only the telecommunications cabling style conduit bodies should be used in a telecommunications cabling installation (see Figure 3.37).

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Conduit Elbows and Bends, continued

Figure 3.37
Telecommunications cabling style conduit body



In some buildings, a conduit system can furnish cable support and concealment. In such installations, conduit bodies manufactured to provide ample room for telecommunications cables may be used to enable access to the cabling (e.g., C conduit bodies) or to enable access to the cabling with a 90-degree corner (elbow left [LL], elbow right [LR], or elbow back [LB] conduit bodies) in the conduit system.

Conduit bodies designed for use with electrical wiring systems, described in this text as electrical conduit bodies that do not specifically address telecommunications cabling bend radius considerations, are not recommended for use with telecommunications cabling.

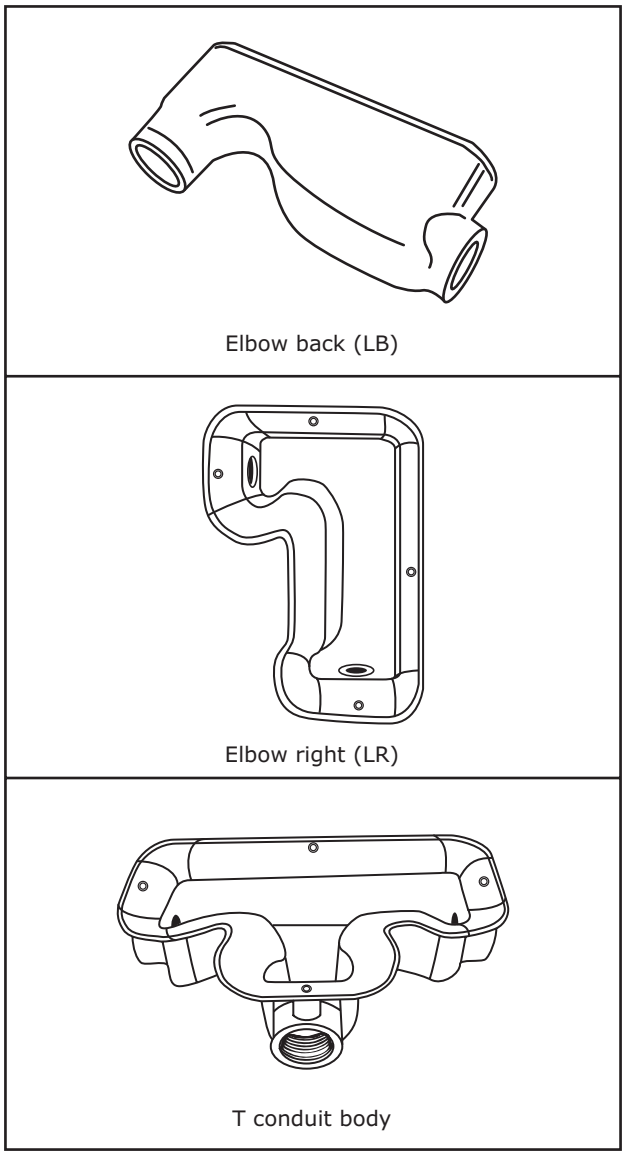
Conduit bodies designed for use with telecommunications cabling systems that provide standards-based internal bend radii are described in this text as telecommunications conduit bodies and may be used where applicable.

ITS installers must consider codes, standards, regulations, and AHJs as well as aesthetics and other customer needs when designing conduit systems with or without the use of telecommunications conduit bodies.

Conduit bodies are available in various types (see Figure 3.38).

Conduit Elbows and Bends, continued

Figure 3.38
Telecommunications conduit bodies



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Placement of Conduit in Pathways

Pathway Preparation

It is important to determine the entire route of a backbone pathway prior to installing the supporting hangers, all-threaded-rod (ATR), or other support mechanisms.

The entire route should be planned ahead of time to ensure that the conduit can be installed without unforeseen obstacles. This is especially true when having to penetrate fire-rated walls and floors. If the penetration cannot be established, then all the work done to install the support hardware may have to be repeated at another location.

Always make penetrations through rated (e.g., smoke, fire, load) walls and floors prior to installing the hangers, clamps, and trapezes. Once the conduit is installed, firestop the penetrations using approved methods.

NOTE: See Chapter 7: Firestopping Practices for approved methods for firestopping.

Support Requirements

Where out-of-the-ordinary heavy loads or abuse is anticipated, ITS installers may choose to add extra supports to assure joints remain secure.

All exposed raceways are to be run as near parallel or perpendicular to walls and ceilings as the ITS cabling installer can achieve.

Do not use raceways as support for equipment. Provide separate support unless otherwise permitted by applicable codes, standards, and regulations.

Install the complete raceway before installing the cables. Be sure a joint is tight and the raceway is securely terminated and held firmly in place.

Cutting Conduit

A hacksaw or band saw should be used to cut conduit. These tools will permit reaming EMT without flaring the ends. A roll-type cutter should not be used on EMT. Be sure to make a square cut. It is best to ream EMT with a tool that is designed for that purpose. This will make fittings easier to install. If other tools are used (e.g., pliers), special care must be taken not to flare the ends. Be sure to measure the exact length of conduit needed.

Conduit Terminations

Backbone conduits should be terminated where they enter or leave a TR or ER. The recommended location for terminating the conduit is in a horizontal plane where the conduit penetrates the wall of the TR or ER. Allow no more than 51 mm (2 in) of conduit and bushing to extend into the room. Conduits should have a bushing installed to reduce cable sheath damage during the pulling operation.

Conduits that enter a TR should terminate near the corners to allow proper cable routing. Terminate these conduits as close as possible to the wall where the backboard is mounted to minimize the cable route inside the room.

Placement of Conduit in Pathways, continued

Conduits shall be equipped with grounding bushings. Grounding bushings are installed on the end of the conduit. With EMT conduit, a setscrew grounding bushing is placed on the end of the conduit and tightened using the appropriate tool.

On IMC and RMC conduits, a grounding bushing is screwed onto the threaded end of the conduit. Tighten the bushing until it is secure. A threadless grounding bushing, which can provide a more convenient means for locating the ground lug, is available. These are installed with setscrews.

Terminate conduits that protrude through the structural floor 25 to 77 mm (0.98 to 3 in) above the surface. This prevents cleaning solvents or other fluids from flowing into the conduit.

Turning conduits down should be avoided, but if necessary, terminate them above the plywood backboard. This allows full usage of the plywood backboard for termination and routing of cabling. If this method is used, channel stock can be used to attach the conduits in a fixed manner to the wall.

Table 3.5 provides guidelines for adapting designs to conduits with bends.

NOTE: Consider an offset as equivalent to a 90-degree bend.

Table 3.5
Adapting designs

If a Conduit Run Requires…	Then…
More than two 90-degree bends	Provide a pull box between sections with two bends or less.
A reverse bend (between 100 and 180 degrees)	Insert a pull point or pull box at each bend having an angle from 100 to 180 degrees.
More than two 90-degree bends between pull points or pull boxes	For each additional bend, derate the design capacity by 15 percent, or use the next larger size of conduit.

No more than two 90-degree bends are allowed in any one-conduit segment. A third bend may be acceptable in a conduit segment without derating the conduit's capacity if any of the following exists:

- The run is not longer than 10 m (33 ft).
- The conduit size is increased to the next trade size.
- One of the bends is located within 305 mm (12 in) of the cable feed end. (This exception only applies to placing operations where cable is pushed around the first bend).

NOTE: In practice, a third bend should not be used unless it is unavoidable.

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Placement of Conduit in Pathways, continued

Securing Conduit Formations

Backbone conduits shall be secured on each end and throughout the entire route to prevent swinging and swaying during the cable placement. When large, high pair-count cables are installed in backbone conduits, the pulling of the cable places significant tension on the conduit. Cable pulling machines, referred to as cable tuggers, are usually employed in this placing operation.

Sometimes the tugger is anchored to the building or attached directly to the conduit. This tension causes swinging and swaying of the conduit and its hangers. Excessive movement of the conduit can cause the hangers to loosen and possibly come free. If this happens, the conduit and its cable could fall to the floor, resulting in damage to the cable, the building, and possibly the ITS cabling installers.

Conduits must be secured at each end in such a manner that they do not move. Cross braces can be used throughout the route to stabilize the conduit(s) and prevent movement. This can be accomplished by the use of conduit clamps, channel stock, or ATR placed at opposing angles (180 degrees opposite from each other). This helps prevent lateral movement of the conduit during placing operations.

Each conduit can be attached to the channel stock with a nationally recognized testing laboratory (NRTL) listed pipe clamp.

NOTE: See Figure 3.28 Conduits on channel stock. If these pipe clamps are equipped with "teeth" that bite into the conduit and the channel stock is not painted, a grounding bushing is not required on every conduit. A single conduit in each run of channel stock can be equipped with a grounding bushing.

The entire section of channel stock can effectively be grounded using a single bushing and bonding conductor wire. An alternative method is to install a listed bonding and grounding (earthing) lug onto the channel stock and then route the bonding conductor wire to the appropriate bus bar (e.g., TMGB, TGB).

The same anchoring mechanisms can be used to secure the clamps and cross braces used to hang the conduits from the building structure.

Hangers

Many different types of hangers are available to support the installation of conduit. Because of this, a limited number of popular options are discussed in this section.

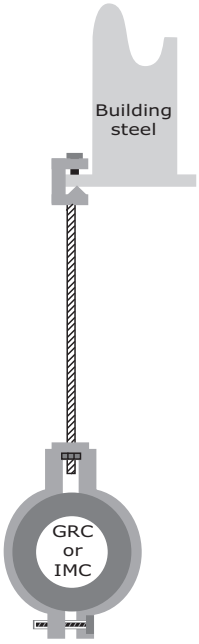
Pipe hangers are used for supporting conduits. The hanger is a pear-shaped device attached to an ATR. An ATR is a straight section of fully threaded round rod stock, and it is available in various lengths and thicknesses.

Placement of Conduit in Pathways, continued

A pipe hanger is suspended from the building structure by an anchor or beam clamp and a section of an ATR. The anchor is installed in the concrete structure of the floor or beam. When concrete is not available and steel trusses are installed in the building, beam clamps can be used to support the ATR and hanger.

The selection of anchors and beam clamps should be determined by the load weight of the conduit and cable to be supported. The ATR is attached to the pipe hanger with nuts and lock washers. The assembly is then capable of supporting the conduit that is installed through the pipe hanger (see Figure 3.39).

Figure 3.39
Pipe hanger



GRC = Galvanized rigid conduit
IMC = Intermediate metallic conduit

Another type of conduit support is a trapeze, and it is made by using two ATRs and a section of channel stock. The ATR is suspended from the building structure and attached to each end of the channel stock using appropriate nuts and washers. The conduits are then attached to the channel stock with pipe clamps and locked in place.

A third type of conduit support is a one-piece conduit hanger. This device is manufactured in such a way that the compression bolt is part of the hanger itself and, when loosened, will not come off the hanger. This type of hanger can be mounted directly to the building structure, red iron, or a specialized hanger mount.

Other types of conduit hangers are available and should be researched by the ITS cabling installer prior to performing the work.

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Stub-Up/Stub-Out Conduits

The terms stub-up and stub-out imply that a section of conduit is used for providing a pathway in a vertical and then horizontal direction from a point of termination. While similar in many ways, they are significantly different from a cabling installation perspective.

Stub-Up Cabling Installation

Stub-ups are usually single sections of small diameter (not less than 21 mm [3/4 trade size]) metallic conduit. They originate at a single- or double-gang box installed in framed wall or paneling. The stub-up continues vertically through the wall cavity where it penetrates the wall cap and stubs up into the ceiling area. It terminates at that point and is usually equipped with a conduit bushing. Sometimes, the stub-up is equipped with a 90-degree bend that is turned back into the room, especially when installed in fire- or smoke-rated walls.

Stub-Out Cabling Installation

Stub-outs are usually short runs of small-diameter metallic conduit. They originate at a single- or double-gang box installed in a framed wall or paneling. The stub-out continues vertically through the wall cavity where it penetrates the wall cap and continues into the ceiling area. In a typical cabling installation, the conduit continues out of the room area and into an adjacent hallway.

The conduit may terminate as it exits the wall of the hallway or may continue to another type of supporting structure (e.g., cable tray, ladder rack). It terminates at that point and is usually equipped with a conduit bushing and sometimes a pull string.

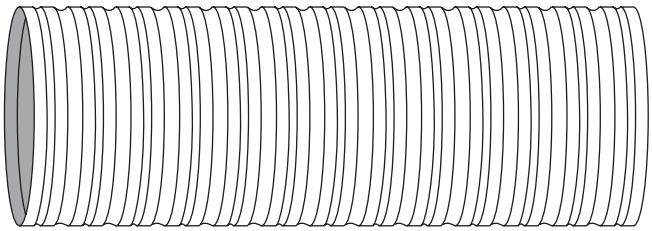
NOTE: Conduit sizes larger than 32 mm (1.26 in) ID are not knockouts on standard receptacle boxes and do not accept box adapters for larger conduits.

Innerducts are available in a variety of colors and in different dielectrical materials (e.g., communications plenum cable [CMP (cable marking as NFPA 70)], communications riser cable [CMR (cable markings as NFPA 70)], low smoke zero halogen [LSZH]) that are suitable for applicable codes, standards, and regulations.

Although usually purchased with a pull rope preinstalled inside for attaching the fiber cable to be pulled, innerducts are available without pull ropes (see Figure 3.40). The pathway of an optical fiber cable must be free of sharp bends and turns. Normally, innerducts are placed inside conduit, through sleeves, or in cable trays. Care should be taken to ensure that the properly fire-rated innerduct is being installed.

Stub-Up/Stub-Out Conduits, continued

Figure 3.40
Innerduct



NOTE: All cables installed within innerduct must have the proper sheath rating according to applicable codes for the area in which they are installed (e.g., CMP, CMR, LSZH).

If the requirement is to place innerducts within a conduit, determine the size and number of innerducts permitted. Conduits and innerducts are sized by the ID.

Placing Innerducts

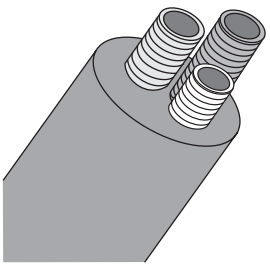
Where optical fiber cables will be used, consider placing three innerducts (two 38 mm [1.5 in] and one 25 mm [1 in]) inside each 103 mm (4 trade size) conduit designated for this purpose to ensure physical cable protection (see Figure 3.41).

An innerduct is a smaller pathway within the conduit and is available in:

- Various diameters (typically 25 to 51 mm [0.98 to 2 in]).
- Various reel lengths.
- Short sections.

Each innerduct should be equipped with a pull cord. Channelized innerducts compartmentalized into separate sections are also available.

Figure 3.41
Four-inch conduit with three innerducts

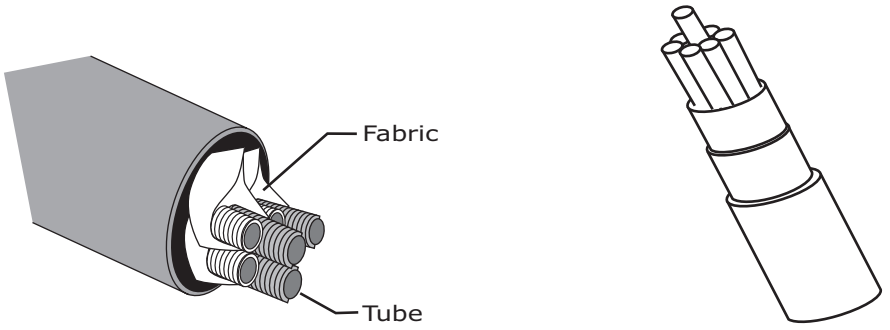


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Stub-Up/Stub-Out Conduits, continued

Usually, 25 mm (0.98 in) innerduct is placed within buildings; however, 32 mm (1.26 in), 38 mm (1.5 in), and 51 mm (2 in) innerducts are available for larger fiber cables. There are two forms of innerducts—tube and fabric type (see Figure 3.42).

Figure 3.42
Two forms of innerduct



Conduit Distribution and Fill Ratios

Conduit may be installed from the work area telecommunications outlet/connector to the TRs in what is usually called a home run. Use caution to ensure that the maximum fill ratio of the conduit is not exceeded. Regardless of code requirements for fill ratio, best practices dictate following these guidelines for ease of pulling. Following fill ratio for firestopping is critical since an overfilled conduit cannot be effectively firestopped.

Conduit Capacity

Table 3.6 provides guidelines and recommendations on conduit fill for balanced twisted-pair cable or coaxial cable, assuming that a straight run of conduit is used and no conduit bends (e.g., 45 degree bend, 90 degree bend) are applied. The table offers conduit sizes ranging from 21 mm (3/4 trade size) to 103 mm (4 trade size).

Stub-Up/Stub-Out Conduits, continued

Table 3.6
Examples of conduit fill based on sample sizing of cables

Trade Size	Metric Designator	Conduit ID mm (in)	Sample Cable OD (mm [in])					
			4.6 (0.18)	5.0 (0.20)	6.0 (0.24)	7.0 (0.28)	8.0 (0.31)	9.0 (0.35)
½	16	15.80 (0.622)	4	3	2 (2[1])	2 (1[1])	1 (1[1])	1 (1[1])
¾	21	20.93 (0.824)	8	7	4	3	2 (2[1])	2 (1[1])
1	27	26.65 (1.049)	14	11	7	5	4	3
1-1/4	35	35.05 (1.380)	24	19	13	10	7	6
1-1/2	41	40.89 (1.610)	33	26	18	13	10	8
2	53	52.50 (2.067)	54	44	30	22	17	13
2-1/2	63	62.71 (2.469)	95	76	53	39	30	23
3	78	77.93 (3.068)	143	116	80	59	45	35
3-1/2	91	90.12 (3.548)	187	151	105	77	59	46
4	103	102.3 (4.026)	239	193	134	98	75	59

[1]All calculations provided in Table 3.6 are based on the industry standard of a 40 percent fill factor for three and more cables in a conduit. Alternative values are provided for 53 percent fill for one cable in a conduit and 31 percent fill for two cables in a conduit. These rules have been established by the NFPA 70, National Electrical Code (NEC).

ID = Inside diameter
in = Inch
mm = Millimeter
OD = Outside diameter

NOTES: The cable fill values offered in Table 3.6 are based on rounded approximations of conduit ID and cable OD. For the most precise cable fill values, it is recommended that you use as many significant digits as available for the conduit ID and cable OD. The conduit ID values presented in Table 3.6 are derived from American National Standards Institute (ANSI) C80.3-2005, American National Standard for Steel Electrical Metallic Tubing (EMT). The calculations used in Table 3.6 to determine cable fill are based on a 40 percent initial fill factor (see exceptions in the footnote to Table 3.6), assuming straight runs with no degrees of bend. These conduit sizes are typical in the United States and Canada, and they may vary in other countries. The metric trade designators and imperial trade sizes are not literal conversions of metric to imperial sizes. Fire and smoke stop assemblies may require different fill ratios.

BICSI does not recommend the use of half inch conduit in ITS installations.

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Stub-Up/Stub-Out Conduits, continued

For cable diameters other than those shown in Table 3.6, use one of the following formulas:

$$N = \text{round_down}\left(\frac{A_{conduit}}{A_{cable}} \times f\right)$$

or

$$N = \text{round_down}\left(\frac{\pi \times \frac{D^2}{4}}{\pi \times \frac{d^2}{4}} \times f\right)$$

or

$$N = \text{round_down}\left[\left(\frac{D}{d}\right)^2 \times f\right]$$

Where:

N	=	Conduit fill, number of cables
A_{cable}	=	Cable cross-sectional area, mm^2 (in^2)
$A_{conduit}$	=	Conduit cross-sectional area, mm^2 (in^2)
π	=	3.14
d	=	Cable outside diameter, mm (in)
D	=	Conduit inside diameter, mm (in)
f	=	Conduit fill ratio

Stub-Up/Stub-Out Conduits, continued

EXAMPLE:

For a 41 mm (1-1/2 trade size) conduit, the conduit fill at a 40 percent fill ratio for 8 mm (0.31 in) cables will be:

$$N = \text{round_down}\left[\left(\frac{40.90\ \text{mm}}{8.0\ \text{mm}}\right)^2 \times 0.4\right] = \text{round_down}\ (26.14 \times 0.4) = \text{round_down}\ (10.46) = 10\ \text{cables},$$

Or

$$N = \text{round_down}\left[\left(\frac{1.610\ \text{in}}{0.31\ \text{in}}\right)^2 \times 0.4\right] = \text{round_down}\ (25.31 \times 0.4) = \text{round_down}\ (10.12) = 10\ \text{cables}.$$

The difference in results between the metric expression (e.g., 10.46 cables) and imperial expression (e.g., 10.12 cables) used in the examples above may be explained because of slight variables in metric to imperial conversions of conduit internal diameter and cable OD.

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Stub-Up/Stub-Out Conduits, continued

Derating Cable Count Because of Conduit Bends

The practice of derating the number of cables pulled into conduit may be considered informative and not normative. The purpose of applying a derating factor is similar to the purpose of considering the use of lubricants in conduit. The higher the conduit's percentage fill, the more friction, resulting in stress that is applied to the cables in the conduit. This cable friction and resulting stress may be amplified when conduit bends occur throughout a section of conduit without a pull point. In the examples below, a 15 percent derating factor was applied to the conduit fill recommendations offered in order to accommodate the effects of friction and resulting cable stress that typically occurs with cabling installation in commercial building premises applications.

The following formula may be used to derate the number of cables in a conduit:

$$CFDR = \text{round_down}\left(\frac{A_{conduit} \times (1 - n \times 0.15)}{A_{cable}} \times f\right) = \text{round_down}\left[\left(\frac{D}{d}\right)^2 \times (1 - n \times 0.15) \times f\right]$$

Where:

CFDR	=	Conduit fill derating factor, number of cables
A_{cable}	=	Cable cross-sectional area, mm^2 (in^2)
$A_{conduit}$	=	Conduit cross-sectional area, mm^2 (in^2)
d	=	Cable outside diameter, mm (in)
D	=	Conduit inside diameter, mm (in)
n	=	Number of conduit bends
f	=	Conduit fill ratio

EXAMPLE:

The derating example is for a 41 mm (1-1/2 trade size) conduit with one 90 degree bend and an 8 mm (0.31 in) OD cable.

The cross-sectional area of conduit and cable is determined using the formula:

$$A = \pi \times d^{2/4},$$

Where:

A	=	Resulting cross-sectional area
π	=	3.14
D	=	Cable outside diameter or conduit internal diameter

Stub-Up/Stub-Out Conduits, continued

Conduit fill derating, in millimeters:

$$CFDR = \text{round_down}\left[\left(\frac{40.90\ \text{mm}}{8.0\ \text{mm}}\right)^2 \times (1 - 1 \times .015) \times 0.4\right] =$$

$$= \text{round_down}\ (26.14\ \text{mm}^2 \times 0.85 \times 0.4) = \text{round_down}\ (8.89) = 8\ \text{cables.}$$

Conduit fill derating, in inches:

$$CFDR = \text{round_down}\left[\left(\frac{1.610\ \text{in}}{0.31\ \text{mm}}\right)^2 \times (1 - 1 \times .015) \times 0.4\right] =$$

$$= \text{round_down}\ (25.3\ \text{in}^2 \times 0.85 \times 0.4) = \text{round_down}\ (8.61) = 8\ \text{cables.}$$

In this example, the cable derating formula resulted in a reduction to eight cables from 10 cables as shown in Table 3.6. The difference in results between the metric expression (e.g., 8.89 cables) and imperial expression (e.g., 8.61 cables) used in the examples above may be explained because of slight variables in metric to imperial conversions of conduit ID and cable OD.

Cable pull force should be monitored closely during the installation to ensure that the manufacturer's cable pull force requirements are not exceeded.

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Ladder Racks and Cable Trays

Materials

Ladder racks and cable trays are available in many sizes and configurations. Some are solid bar stock; others are tubular; while some are manufactured from solid round wire stock. There are enclosed and open cable trays. Ladder racks and cable trays are manufactured from steel and aluminum. Typically, cable trays provide a pathway to house and support cables installed between TRs and from TRs to work areas. They are used to support cables from one wall to another within a TR or ER.

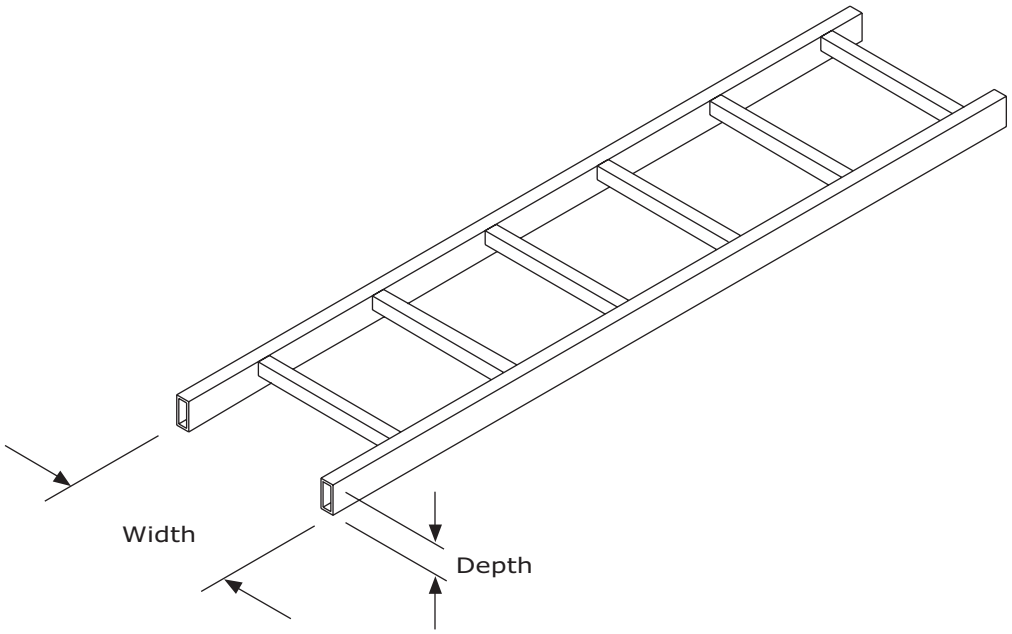
Placing of Ladder Racks and Cable Trays

The following are examples of open tubular and wire mesh ladder racks and cable trays. For both types, a metal bottom can be installed along with a metal cover to convert it to an enclosed system.

Tubular and solid bar ladder rack—In this type of construction, the ladder rack is constructed of tubular stock or solid bar. For tubular ladder rack, the inside of each side rail and cross rung of the tray is hollow (see Figure 3.43). This type is lighter than the solid-bar stock construction and easier to handle in elevated work areas.

Solid stock offers a stronger cabling installation, but in most cases, the tubular stock will provide the weight-loading factor required for most smaller installations. The tubular ladder rack is manufactured with a depth of 38 mm (1.5 in); the width varies from 152 mm (6 in) to approximately 1 m (3.28 ft).

Figure 3.43
Tubular ladder rack

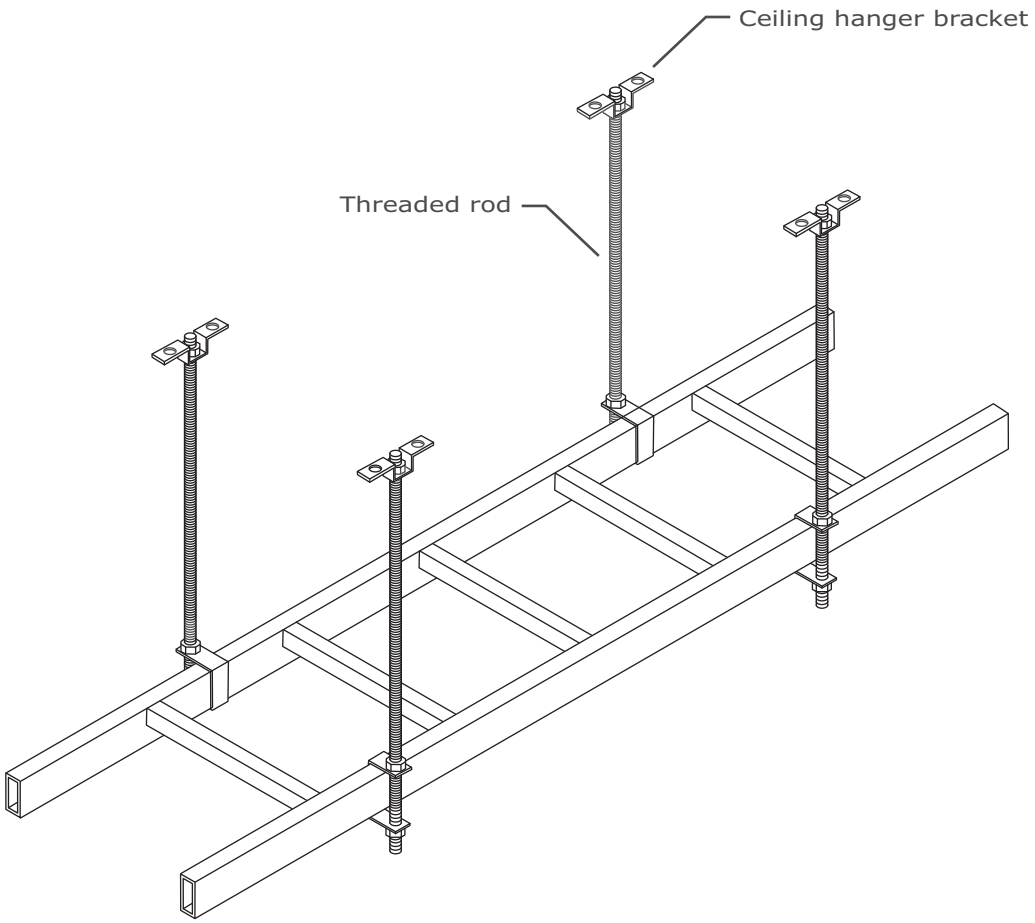


Ladder Racks and Cable Trays, continued

A ladder rack can be wall mounted or supported by the building structure from above using threaded rods and appropriate attachments. The threaded rods shall be installed using properly sized anchors and correct hardware (see Figure 3.44).

Threaded rods are available in various lengths and in a variety of diameters. Select the proper diameter rod required to support the maximum load for which the ladder rack is designed plus future installations. Heavy-duty installations typically use 16 mm (0.63 in [5/8 in]) size rod.

Figure 3.44
Suspended ladder rack



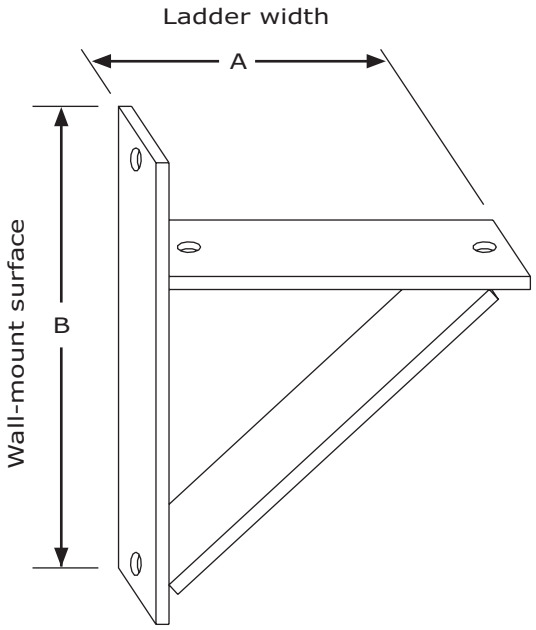
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Ladder Racks and Cable Trays, continued

Wall brackets can support a ladder rack (see Figure 3.45). Wall brackets are first installed on a wall along the route of the ladder rack. The number of brackets and specific spacing interval is dependent upon the load the ladder rack must support.

Prior to installing the wall brackets, install properly sized anchors in order to support the load of the ladder rack and the installed cables. The ladder rack should be designed and installed to support additional cabling beyond the initial requirements.

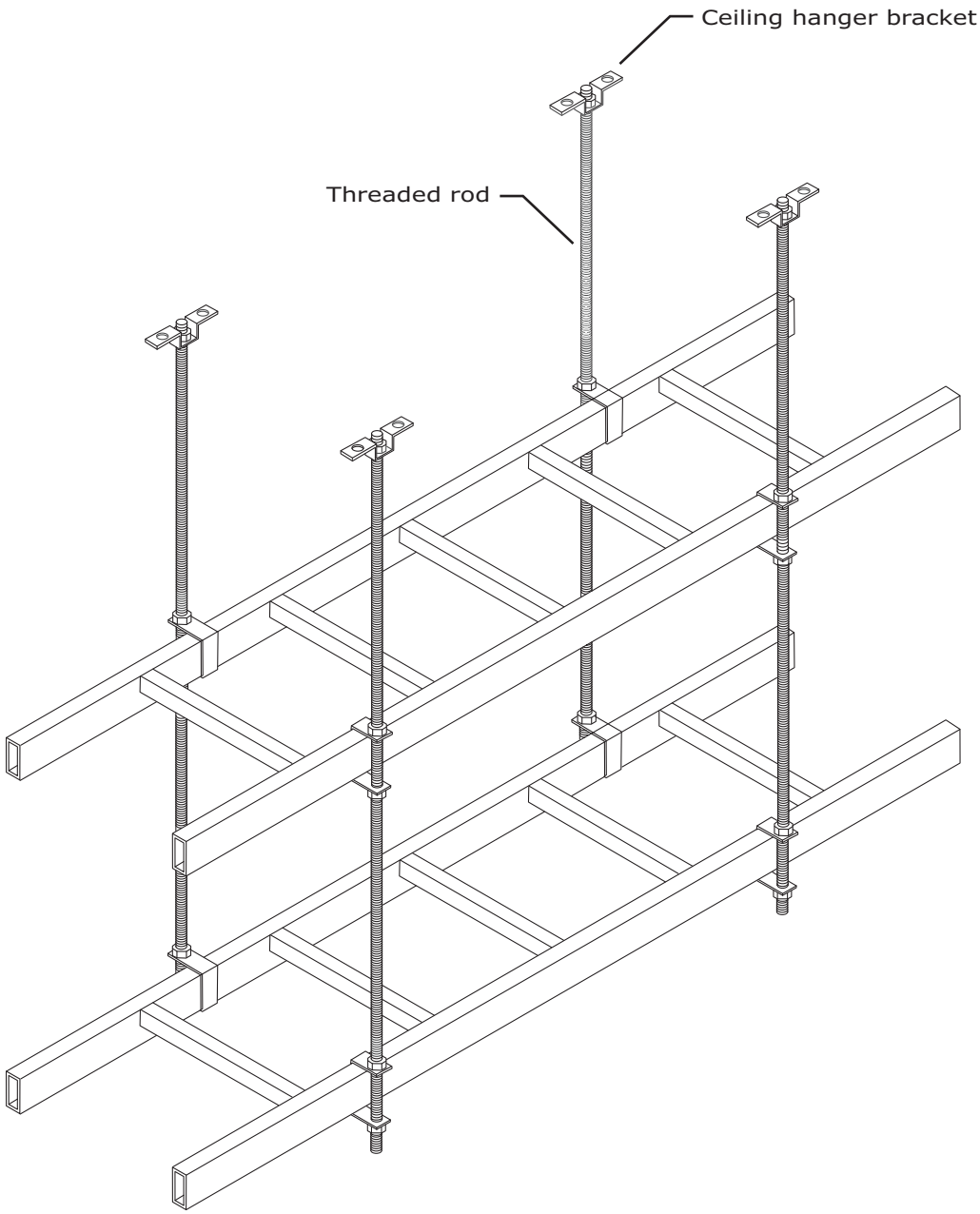
Figure 3.45
Wall bracket



Ladder Racks and Cable Trays, continued

Ladder racks can be installed on one level or on several levels (see Figure 3.46). Corners and changes in the horizontal plane are accomplished using sections of ladder rack cut from standard stock and connected together through proper hardware. Connecting hardware permits all angles, both vertical and horizontal, to be accommodated over the entire route of the ladder rack.

Figure 3.46
Multilevel ladder rack

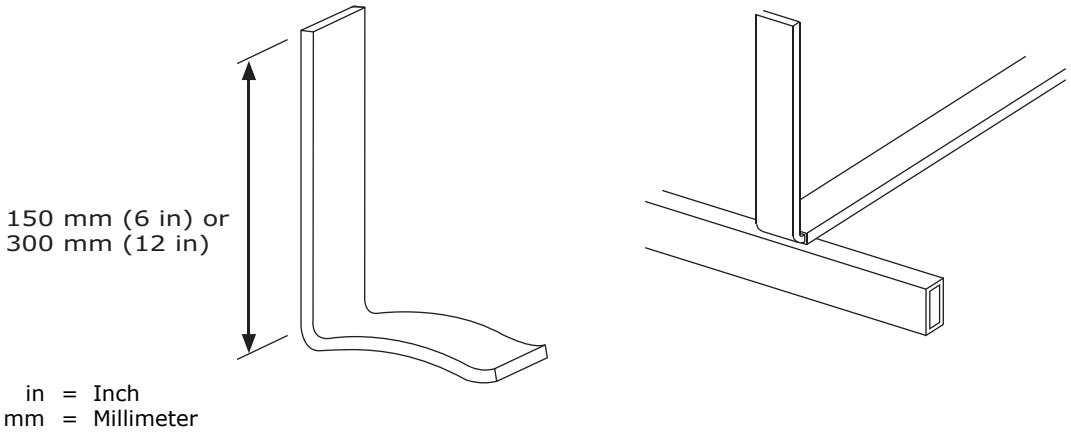


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Ladder Racks and Cable Trays, continued

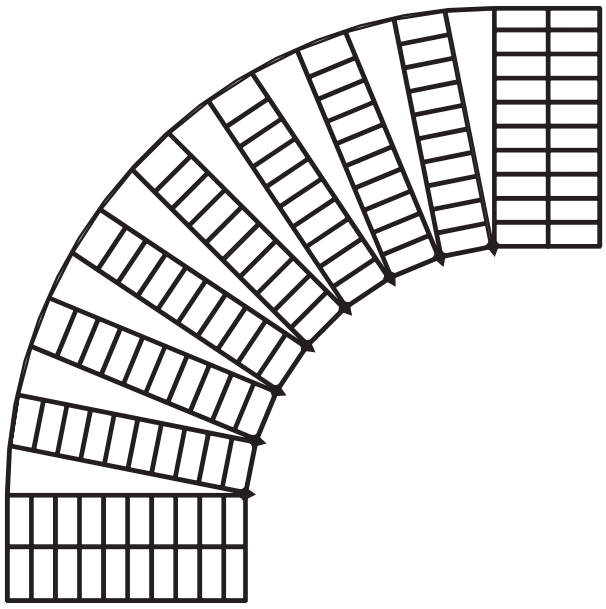
Cable retaining posts are available in 152 to 305 mm (6 to 12 in) lengths to allow additional cables to be installed to a depth exceeding that of the ladder rack (see Figure 3.47). Without these devices, the cable would not be confined by the edges of the ladder rack and may fall from the rack.

Figure 3.47
Cable retaining posts



Rod-stock cable trays are manufactured by using either 6 mm (0.236 in) or 9.5 mm (0.374 [3/8] in) diameter steel rods welded together to form a section of cable tray in the form of a wire grid (see Figure 3.48). It is normally manufactured in three depths—51 mm (2 in), 100 mm (3.94 in), and 152 mm (6 in). It may be ordered in painted, electroplated zinc galvanizing, hot-dip galvanizing, and stainless steel sections. They are available in standard lengths of 3 m (10 ft). The light weight of the rod-stock cable tray is especially helpful when installing in confined areas.

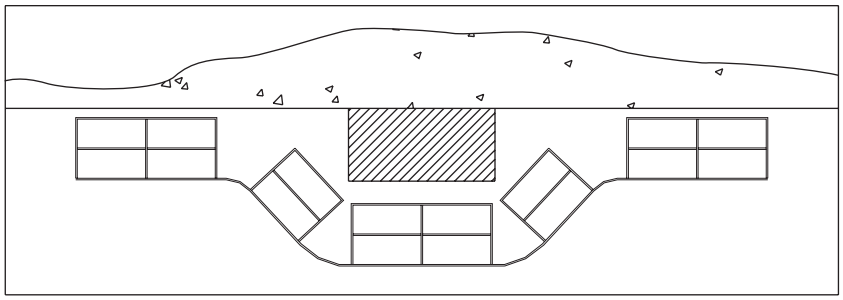
Figure 3.48
Rod-stock cable tray



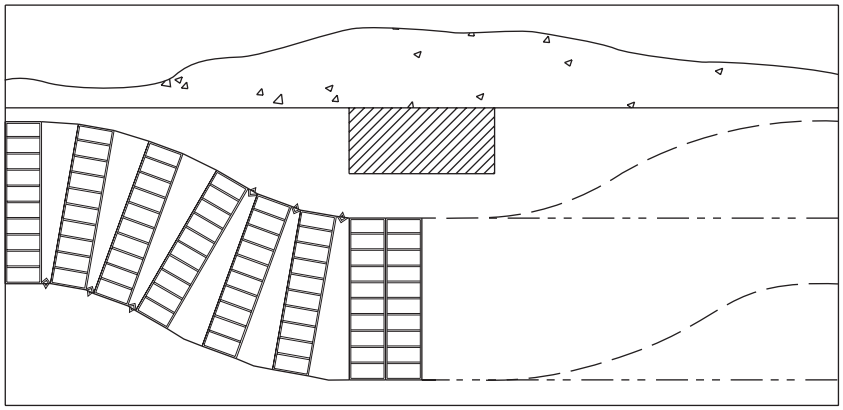
Ladder Racks and Cable Trays, continued

Unlike standard cable trays that require the purchase of fittings for directional changes, the directional transition system can be formed to adjust to changes in elevation and horizontal direction (see Figure 3.49). The accessories required to assemble this type are not as numerous as for a standard cable tray, and the time to create the change is less than standard tray. Installation is accomplished by using light hand tools, power drills, and an offset blade bolt cutter.

Figure 3.49
Directional transition



Easily avoid obstacles in the vertical plane



Easily avoid obstacles in the horizontal plane

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Ladder Racks and Cable Trays, continued

The wire mesh cable tray can be supported using wall brackets or ATRs. When applicable, wall brackets are first installed on a wall along the route of the cable tray. They are installed at intervals, depending on the load the cable tray shall support. Supporting attachment should be applied on a cable tray not more than 0.6 m (2 ft) from the end and on each side of a joint between two sections. Additional supports are required every 1.52 m (5 ft) thereafter. Prior to installing the wall brackets, first install properly sized anchors. It is important to select properly sized anchors, or they will not support the load of the cable tray and the installed cables.

Wire mesh cable trays can be installed on one or several different levels. When more than one level is involved, firestopping between levels may be required. Corners and changes in horizontal level may be accomplished by selective cutting of the rods in the cable tray at specific points using manufacturer's approved cutting tools and connecting together the points cut by the appropriate hardware.

Using the standard connecting hardware, all angles (both vertical and horizontal) can be accommodated over the entire route of the cable tray without having to sever the entire cable tray. Cable trays of all types are required to be bonded per national code whether the cable tray is used for power or low-voltage wiring. Many styles of cable tray joint hardware have been tested for bonding adequacy without the use of a separate copper conductor.

NOTE: Check with the AHJ before cutting wire mesh type trays. Code and listing violations may occur. A listed tray may lose its listing when field modified. This then causes a code violation and can be rejected by the AHJ.

Surface-Mounted Raceway

Surface-mounted raceway is installed on the surface of walls, ceilings, floors, modular furniture panels, and modular furniture. It is available in both metallic and nonmetallic versions. Metallic surface raceway should be bonded and grounded. Some national or local codes and regulations may require bonding and grounding (earthing) of metallic surface raceway when used for power or low-voltage wiring.

Metallic Surface Raceway

This type of raceway is available in many sizes and configurations.

This raceway is available in two sections—a base and a cover. The base is installed on the wall surface using fasteners. The cabling is installed, and then the cover is installed over the top of the cabling. Typically, the cover is held in place by snapping it over the base.

Some metallic surface raceways include bend radius control to ensure compliance with the minimum bend radius requirements of telecommunications cables.

Secure metallic raceway systems are also available in which the covers slide onto the bases at access points, consisting of lockable surface boxes. The covers cannot be removed without access to the boxes.

Metallic surface raceways are available in single and multiple (2-, 3-, or 4-) channel versions.

Surface-Mounted Raceway, continued

Nonmetallic Surface Raceway

Like metallic raceway, nonmetallic raceway is available in many sizes and configurations. Two types of nonmetallic raceway are available:

- One does not feature bend radius fittings.
- One features bend radius fittings.

The primary difference between the two is typically demonstrated in the elbows and fittings used for coupling sections of the raceway together. Nonmetallic raceways, being nonconductive, prevent most of the problems associated with bonding and grounding (earthing) of pathway components.

Nonmetallic surface raceway is available with a single channel or divided channels. When divided channels are required, they are available in 2-, 3-, and 4-channel versions. The dividers used for creating the channels are often removable. Some manufacturers have snap-on dividers that allow easy removal and reinsertion. By flipping the divider back and forth in a 180-degree arc, the attachment to the base will be weakened, allowing the divider to be pulled out of the section of raceway.

This type of raceway is available in two-component sections or a single-component raceway. Some manufacturers refer to the single component versions as a latching duct. This version is manufactured as a single assembly, and once anchored in place, the cover simply snaps onto the opposite sidewall, latching the cover to the base.

Other manufacturers offer a hinged version. The hinged version is a two-piece assembly. One side of the cover is equipped with a round projection that is snapped into a cavity on one side of the base. When closed, the opposite side latches onto the other side of the base.

These low-voltage raceways are available in a range of colors. Most manufacturers offer special colors at additional cost. In most instances, these special orders require additional lead-time for delivery. Some manufacturers allow the raceways to be painted after installation. This increases the difficulty of re-entering the raceway after the paint has cured; therefore, it may not be aesthetically desirable.

NOTE: Raceways rated at 600 volts (V) require a mechanical fastener.

These raceways are available with or without adhesive backing. If adhesive backs are used on a project, be aware that some of the adhesive backing will not fully adhere to all types of wall finishes. The backing is anticipated to hold for a limited time, after which the raceway may fall off the surface to which it was attached. This may necessitate use of an additional adhesive, anchors and screws, or some other type of fastener to ensure the stability of the installation.

Various connectors are available for surface raceway. Splice connectors are used for joining two sections of the raceway in a straight line. Internal, external, and flat elbows are used for changing direction with the raceway. Where joining three sections of the raceway together creates a T, a T cover is used to conceal the joint. End caps are used at the termination of a raceway where a surface-mount box is not used. Conduit adapters, reducers, and ceiling fittings are available for a surface-mounted raceway.

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Surface-Mounted Raceway, continued

Three hand tools are essential for the proper installation of surface raceway—a level, a straight edge, and a ruler. A PVC cutter is used for cutting sections of nonmetallic raceway to the desired length. A compound power miter saw is helpful for cutting difficult angles. With the proper blade, it provides an exact fit between the two sections of raceway. Using this power tool, any angle of cut is obtainable, creating an almost imperceptible joint after the installation of raceway.

Surface-Mount Boxes

Surface-mount boxes are available in a wide variety of shapes and styles. They are typically available in shallow, standard, and deep versions.

These surface-mount boxes are available in a range of colors. Most manufacturers offer special colors at additional cost. In most instances, these special orders require additional lead-time for delivery. Some manufacturers allow the boxes to be painted after installation.

These surface-mount boxes are available with or without adhesive backing. If adhesive backs are used on a project, be aware that some of the adhesive backing will not fully adhere to all types of wall finishes. The backing will hold for a limited time, after which the surface-mount box is anticipated to fall off the surface to which it was attached. This may necessitate use of an additional adhesive, anchors and screws, or some other type of fastener to ensure the stability of the installation.

Some surface-mount boxes are available with separate compartments or barriers, which allow the same box to be used for power and ITS cabling.

Open-Top Cable Supports

Open-top cable supports should provide a wide base to distribute the cables' weight to prevent damage. They are constructed of metal, plastic, or fabric in various configurations for use in environments that may require certain types of dielectrical materials (e.g., CMP, CMR, LSZH). Their use is typically intended to support up to 50 cables between a cable tray and the work area outlets. Sizes are available to support larger quantities of cables; however, it is recommended that larger raceways (e.g., cable tray) be used for installations of more than 50 cables.

NOTE: Do not overload open-top cable supports by using plastic cable ties to retain additional cables.

Open-top cable supports should be installed to maintain a minimum of 77 mm (3 in) clear vertical space above ceiling tiles to allow ceiling tile insertion and removal. They should be installed on a maximum spacing of 1.2 m (4 ft) to 1.52 m (5 ft) centers. These devices shall not be attached to the ceiling grid support system. They should be attached to the building structure.

Additionally, devices (saddles) are available for facilitating the use of existing narrow base bridle rings with category 5e, 6, or other high-performance cable installations.

Support Hardware

Anchors

Many types of anchors are available. The most common anchors are addressed in this section:

- Plastic anchors—Anchors made of plastic represent the most common anchor used throughout the industry. This type of anchor is used to attach almost everything to any type of surface. These anchors are manufactured by screw or bolt size. The diameter and length of the screw determines the choice of anchor.

  When used in masonry or concrete formations, these anchors provide a secure attachment only for light loads.
- Expansion anchors—This type of anchor requires that a hole be drilled into the wall or floor where the attachment is to be made. This can be in framed wall construction, masonry, or concrete construction.
- Toggle bolts (butterfly anchors) —The types of anchors used in a framed wall are sometimes referred to as butterfly anchors (toggle bolts). This occurs because, once installed, they flare out to resemble the wings of a butterfly.

  A framed wall is not a high load-bearing structure, and care should be exercised to prevent overloading.
- Masonry and concrete block anchors—Masonry walls are generally made of brick or concrete block. Bricks can be solid or can have interior cavities. Concrete blocks are similar in that they have interior cavities; however, their cavities are much more expansive than those found in brick.

  The types of anchors used on masonry and concrete block walls are metal anchors that expand when the bolt is installed inside the anchor. This causes the walls of the anchor to expand, forcing them against the wall of the hole and securing the anchor in place.
- Epoxy resin anchors—When high loads are supported by anchors, it may be necessary to install special epoxy resin anchors. These anchors use a chemical bonding agent to prevent them from coming loose under most conditions.

  The same installation methodology should be employed for them as the one used for the expansion anchors in masonry or concrete block walls. However, the addition of a chemical bonding agent will be used to ensure the load rating of the attachment. It is important to follow the manufacturer's instructions. Failure to do so could result in an installation that will not support the designed load.

  Epoxy glues require a chemical reaction in order for the glue to set. Most of these glues form permanent bonds. Reaction time for the glues may vary, depending on the chemical makeup of the agents and the accelerator used to cause the chemical reaction.

  It is important to verify the size hole required for each anchor and to dry fit each anchor into its hole. Keep in mind that the epoxy agent must be applied prior to insertion of the anchor.

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Support Hardware, continued

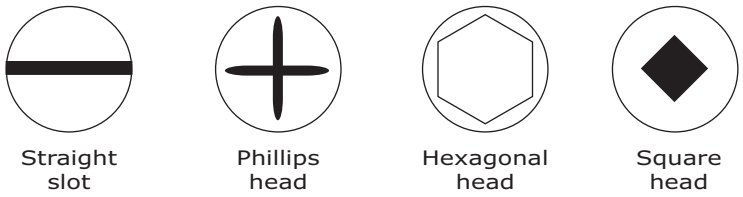
Fasteners

Fasteners are available in many sizes and shapes and have different uses. They can be used in conjunction with many different clamping mechanisms to affix conduit, cables, or other types of hardware to building structures.

Fasteners fall into the following categories:

- Screws—Screws are available in three basic styles: wood, metal, and framed wall screws. All types are available with straight slot, Phillips, square, or hexagonal heads (see Figure 3.50).

Figure 3.50
Screw head types



  - Wood screws—Wood screws are used primarily for insertion into wood products. Examples are wood building studs, plywood, and wood sheathing. They can be installed directly into the wood by hand or with electric screwdrivers. Some types of wood products split when the screw is installed. A pilot hole should be drilled into this type of wood product prior to installation of the screw to prevent splitting.

    The size of the screw indicates its capabilities in fastening power. The larger the load, the larger the screw to handle the load.

  - Metal screws—There are two basic types of metal screws: self-tapping and machine screws.

    The self-tapping screw is a type of screw that has very sharp threads that go all the way from the head to the sharp (pointed) tip of the screw. These sharp threads bite their way into the metal when the screw is inserted and twisted into a hole. This process causes the screw to tap the hole with threads to match the screw.

    Machine screws have threads that are usually finer than self-tapping screws. In addition, they usually have a blunt tip rather than a sharp tip.

    Both types of screws require preparing predrilled holes in the metal surface prior to inserting the screw into the hole. If a machine screw is used, the hole must be tapped to match the threading on the screws.

Support Hardware, continued

– Framed wall screws—Framed wall screws are similar to self-tapping metal screws. They have very sharp threads and points. The threads and points are durable enough to allow the screws to penetrate galvanized metal studs without predrilling. Framed wall screws are available in galvanized and untreated finishes. Galvanized screws can be used outside or in areas where the presence of moisture is likely. Untreated screws should be used inside only.

Most framed wall screws are available with a Phillips head. They can be easily installed with a Phillips driver bit and a power drill or power screwdriver. Framed wall screws can be used to mount equipment on wood or thin sheet metal.

- Bolts, nuts, and washers—Bolts have different thread patterns. Select the nut that exactly matches the bolt diameter and thread pattern. Using a nut that is too large may cause the thread pattern inside the nut to strip out, rendering it useless. Using a nut that has the wrong thread pattern may cause cross threading.

  Cross threading occurs when a thread pattern on a bolt and a nut do not correspond, causing the threads to mismatch when the nut is rotated onto the bolt. While the nut may appear to seat onto the bolt, it is stripping out the thread pattern on the bolt, inside the nut, or both. This will derate the holding power of the assembly and may cause it to fail.

  Bolts and nuts with hexagonal heads are available. Conventional hand tools are used for their installation.

  Washers are available in many types. As a general rule, they fall into lock washers and flat washers. Lock washers are available in two versions—split washers and star washers. Star washers are available with internal stars or external stars.

  A split washer is a round washer that has one point on the washer that has been interrupted, causing it to rise up on each side of the split. In addition, the washer is under tension so that the split is separated, forming jagged edges. When the washer is installed and compressed against the bolt head or nut, the jagged edges bite into the bolt head or nut and resist rotation of either in the opposite direction. This locks the nut or bolt head into place.

  Star washers have manufactured tines. These tines are sharp and very durable. They can appear on the inside or outside edges of the washer. When the washer is installed and compressed against the bolt head or nut, the tines bite into the bolt head or nut and resist rotation of either in the opposite direction. This secures the nut or bolt head into place.

  Flat washers may be round or square. Usually round washers are used because they match the circular pattern of the hole and bolts. The size of the washer depends on the load rating of the assembly. The load rating of the assembly depends on the size of the bolt. Together, they must match to ensure the stability of the installation.

  The area (size) of the washer will vary depending on the job to be performed. When used with wood products, a bigger area prevents the wood from deteriorating around the area where the bolt is installed. When using flat washers with a smaller area on the wood, the area immediately under the washer may become compressed so much that the wood is weakened, causing the assembly to become loose or fail completely. Do not overtighten these assemblies on wood installations.

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Support Hardware, continued

- Specialty fasteners—Specialty fasteners make up a large group of fasteners that are used for a single specific purpose and may require special tools for installation. The most common specialty fastener used in ITS cabling installation is the drive ring. Drive rings are metal nails with metal loops affixed to them. The loop is used for supporting the cable after it has been installed. Drive rings are used with wood structures and may be used with masonry structures along with an anchor.

  Another type of fastener that falls into this category is the bridle ring. Bridle rings are metal rings formed out of galvanized wire stock with one side open. Bridle rings can be obtained with wood screw threads for installation on wood structures or with machine threads for use with beam clamps or pretapped holes in metal structures. Bridle rings are not recommended for support of high-performance cables (e.g., category 5e and above) because of their narrow surface.

  A powder-actuated fastener is a tool used for attaching material to concrete or steel. It uses a nail-type fastener driven by the force of an ignited blank cartridge to drive it into the base material, generally without predrilling the material.

NOTE: These tools require manufacturer training/certification prior to use, and possession of the certificate is required when using the tool. Safety glasses must be worn when using this tool.

Installing Cable Support Systems

Overview

Proper support structures are critically important for the implementation of a cabling system. Cable support systems include the following:

- Plywood backboards, clamps, rings, and/or hangers
- Cable trays and associated support hardware
- Ladder racks and associated support hardware
- Conduits and associated hardware
- Enclosed cabling pathways and associated support hardware
- Open-top noncontinuous cable supports (J-hooks)

In most cases, an ITS cabling installer will install these support structures. Support structures provide a pathway for the cable, thus reducing and eliminating stress that could damage the copper conductors or glass strands inside a cable sheath.

The following steps are general. Additional steps may be required, depending on the size, quantity, and load rating of the individual supporting structures. ITS designers should provide in their design documents all the information that will allow the ITS installer to select the necessary hardware and employ proper methods to correctly install these structures.

Steps—Installing Cable Support Systems

Step	Installing Cable Support Systems
1	Obtain blueprints/specifications/ITS designer's documents for the building structures. • Determine the size, type, and quantity of pathways to be installed. • Determine the proposed route of the pathways between TRs, from ERs to TRs, and from TRs to work areas. • Identify any obstructions along the proposed route, and determine how to overcome them. • If it is necessary to pass through any walls, be prepared to make the required penetration—concrete, concrete block, framed wall, or other wall construction. • When installing cables in a suspended ceiling without permanent pathways, avoid cable paths that may increase obstacles. • Identify the plan to support cable in suspended ceilings and the type of hardware to be installed.

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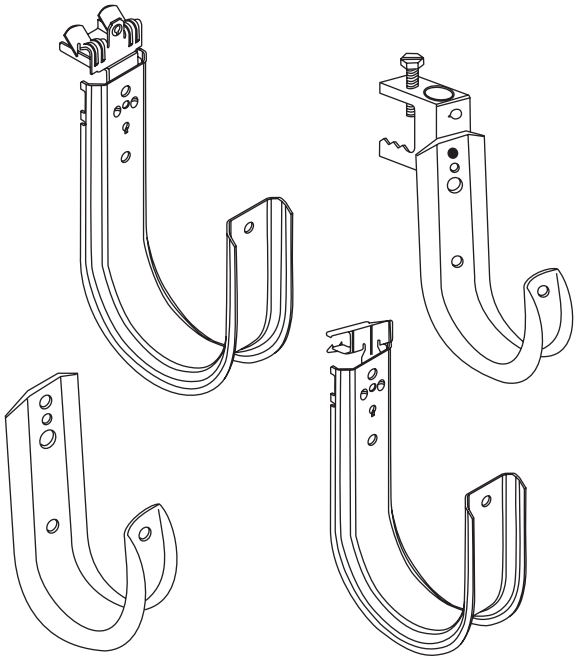
Steps—Installing Cable Support Systems, continued

Step	Installing Cable Support Systems
2	Verify load capacity of the cable support system. • Review the ITS designer's documents. • Determine the weight of individual types and sizes of cable to be installed. • Identify the building structure to ensure a proper attachment of the support system.
3	Verify the adequacy of existing cable support structures. In places where existing supports are to be used, visually examine the supports to determine if they are firmly attached, worn or broken, and capable of bearing extra weight.
4	Verify the accessibility of cable support installation. Examine the: • Area where the building beams are located. • Area where the concrete floor slab above is accessible and usable for installing anchors or other cable supports directly to them. • Paths in all directions from the point of observation to confirm that the pathway is clear for cable supports.
5	Verify the cable separation. For safety and performance purposes, keep power cables physically separated from data and voice cables.
6	Verify the availability of materials and tools. Before beginning an installation of a cable support system, be sure that the required materials, hand tools, and power tools are available. This should include safety tools (e.g., safety glasses, hard hats).
7	Mount D-rings. • Review the ITS designer's drawing and specifications to determine the exact placement, quantity, size, and type of D-rings. • Install the D-rings, working from the top left side of the plywood backboard to the bottom right side of the plywood backboard: – Measure the location of the first D-ring to be installed according to the ITS designer's documents. – Position the D-ring on the backboard, and mark the location of the holes in the D-ring using a pencil. – Using a drill and a bit, predrill the location of the D-ring holes. – Position the D-ring on the backboard, and install a No. 6, 19 mm (3/4 in) sheet-metal screw using a screwdriver. – Install the second No. 6, 19 mm (3/4 in) sheet-metal screw. – Repeat the above steps for each additional D-ring to be installed.

Steps—Installing Cable Support Systems, continued

Step	Installing Cable Support Systems
8	Mount individual cable supporting hardware in structures above the suspended ceiling level (see Figure 3.51).

Figure 3.51
Open-top cable supports (J-hook)



- Determine the open-top cable support size required in each cable path, and lay them out along the cable route.
- Identify the location of the first open top-cable support to be installed.
- Position the open-top cable support at its proper location, and mark the holes for the anchors using a pencil.
- Predrill the holes, and install the correct anchors; depending on the type of structure, a masonry structure will require one type of anchor while metal structures or framed wall will require others.
- Install the anchors.
- Reposition the open-top cable support at the desired location.
- Using the correct screwdriver, install the appropriate screw through the hole in the open-top cable support and into the anchor, securing the open-top cable support to the anchor.
- Repeat the above for the second screw.
- Using the same procedures, install the remaining open-top cable support until all open-top cable supports are installed.

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Steps—Installing Cable Support Systems, continued

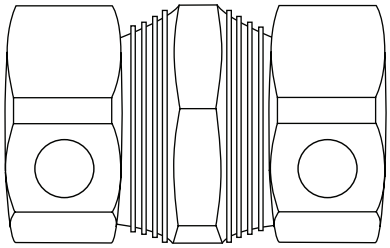
Step	Installing Cable Support Systems
9	Install ladder racks or cable trays. The process of installing ladder racks and cable trays is manufacturer specific because of the many different sizes, types, and configurations. The ITS installer shall consult the manufacturer's specifications and installation guidelines prior to attempting to install these pathways. Be aware that both ladder racks and trays can be installed parallel to and against a wall or suspended from the building structure using ATRs. They can be supported using channel stock or special hanger brackets. Because these pathways are used for supporting both backbone cables and horizontal cables, they are found in most areas of buildings. It may be that other utilities (e.g., HVAC, plumbing, electrical) or structural obstructions will require that the pathway change elevation and direction. Careful planning is important to minimize changes in direction, which can be costly from material and labor perspectives. Penetrations through fire-rated masonry walls are especially challenging to the ITS installer. Firestopping these penetrations requires special knowledge and materials to comply with applicable codes, standards, and regulations. The manufacturers of firestop materials provide detailed instruction on how to install their products to comply with special circumstances. If a situation is identified where the selected firestop manufacturer's technical manual does not contain a certified solution, contact the manufacturer. Provide all the pertinent information regarding the penetration. In most cases, the manufacturer can provide an engineered solution. This engineered solution may move the liability for its design and use from the contractor to the manufacturer. Firestop solutions can be designed in the field using the manufacturer's design specifications.
10	Install conduits. Within buildings, the three most common types of conduits used for telecommunications cabling are: • EMT. • RMC. • IMC. The most common is EMT. RMC and IMC are primarily installed for backbone cables.

Steps—Installing Cable Support Systems, continued

Step	Installing Cable Support Systems
10 cont.	The types of fittings used to connect EMT conduit are:

- Compression couplings (see Figure 3.52). Compression couplings are designed to reduce in diameter to that of the conduit OD when tightened with a wrench. This process increases the friction between the outer wall of the conduit and the inner wall of the coupling to a point where the conduit does not slip or move under normal conditions.

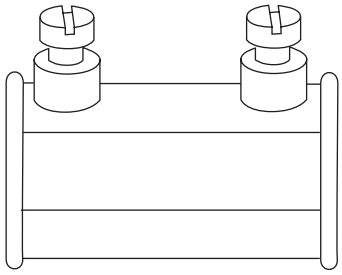
Figure 3.52
Compression coupling



- Install setscrew couplings (see Figure 3.53).

  These couplings are placed over the end of the conduits. They provide little or no friction when installing cables through them. Once the end of the conduits are installed and seated within the coupling, two screws are tightened to attach the conduit to the coupling. The disadvantage to using this coupling is that it can become loose over time, and the conduit can pull away from the coupling.

Figure 3.53
Setscrew coupling

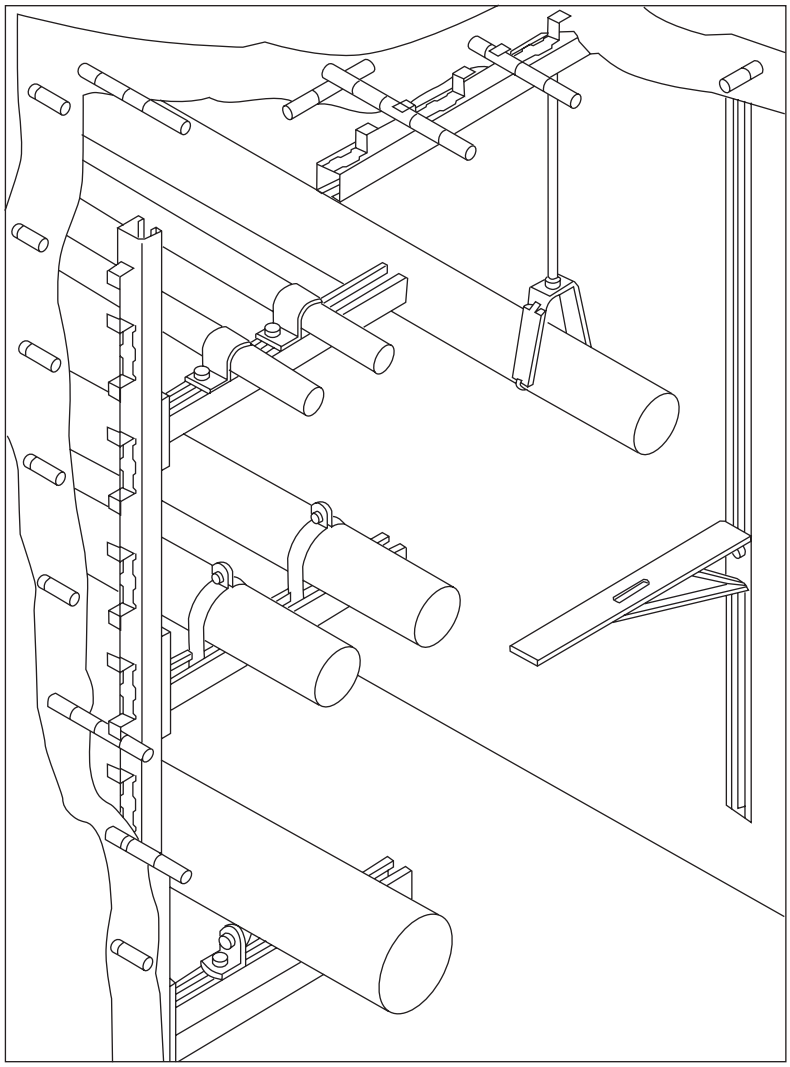


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Steps—Installing Cable Support Systems, continued

Step	Installing Cable Support Systems
11	Install conduit hangers (see Figure 3.54). Conduits are suspended from the building structure using a variety of hangers. These hangers are available in many sizes and types, depending on the type of conduit and method used to install the hangers. Hangers may be attached to ATRs, building steel, masonry walls, and other hangers. The ITS cabling installer should refer to the manufacturer's specifications and use only the correct type and size for the conduit to be installed.

Figure 3.54
Conduit hangers



Steps—Installing Cable Support Systems, continued

Step	Installing Cable Support Systems
12	Complete pathway documentation. It is important to properly document pathway installations in order to identify the cables they house and support. Knowing where a pathway originates or terminates is necessary for determining where cables originate and terminate. Proper identification is especially important for pathways left vacant at the completion of the project. A great deal of time may have elapsed before they are used; however, the team who performed the original installation may not be the same group that performs the additional work. The pathways must be identified on the drawings and should be physically equipped with labels that identify them and state where they originate and terminate. When pathways are installed, an as-built print depicting the ITS installer should provide the routes of the various pathways. The ITS installers should obtain the information contained on these blueprints and transfer it to their work documents. Upon job completion, this information should be contained in the ITS as-built package.
13	Complete general housekeeping. It is important to clean up behind a work operation when installing pathways. Dust and debris harms electronic equipment if an installation is performed within an existing ER. Larger equipment is required to install these pathways, and the materials are bulkier, taking up more space in the hallways and passageways of the building. This causes congestion and, if left in place, can impact the work efforts of other trades. The hangers, associated hardware, anchors, screws, and other materials present a safety hazard to workers and should be properly stored during work operations and upon completion of the day's activities. If an area of work cannot be completely cleaned, safety cones and barricades should be placed to prevent accidental intrusion into the area until the work is completed and the area is cleaned. Keeping a clean workspace reflects on the quality of the work the ITS installation team performs and on the company it represents.

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Installing Bonding and Grounding (Earthing) Infrastructure

Bonding and grounding (earthing) of an ITS cabling project is a significant part of an ITS cabling installer's job. It assists in protecting people and equipment from electrical hazards and provides improved performance of telecommunications cabling systems.

Proper bonding and grounding (earthing) provides protection from overvoltages or accidental connection to foreign electrical voltages or currents. This may include lightning protection systems and related bonding and grounding (earthing) of ITS cabling.

NOTE: Refer to Chapter 4: Bonding, Grounding (Earthing), and Electrical Protection for more in-depth information.

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Chapter 4
Bonding, Grounding (Earthing), and Electrical Protection

Chapter 4 offers important guidelines for bonding, grounding (earthing), and electrical protection and practices to ensure personal safety and code compliance.

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Introduction

Overview

Installing a telecommunications bonding and grounding (earthing) infrastructure is an essential part of an information technology systems (ITS) cabling installer's responsibilities. This chapter provides some background information, including testing verification procedures, that can help the ITS installer make logical and technically sound choices when confronted with a variety of equipment or cabling installations.

References to codes, standards, methods, and practices used in this chapter are derived from documents such as National Fire Protection Association (NFPA) standards 70 (*National Electrical Code*® [*NEC*®]) and 780 (Standard for the Installation of Lightning Protection Systems) and documents published by the American National Standards Institute (ANSI) and the IEEE®.

IMPORTANT: Regions and countries have local and specific requirements relating to bonding, grounding (earthing), and electrical protection that differ from the contents of this chapter.

The information in this chapter is based on the existing references. Special situations (e.g., vaults, electrical power plant facilities, shielded rooms) are not specifically addressed in this chapter.

Every effort has been made to ensure that these recommendations are technically accurate and provide the necessary site and personnel safety. However, local conditions may require additional professional investigations, modifications, or safeguards to meet specific requirements for the:

- Site.
- Equipment.
- Environmental conditions.
- Life, property, and equipment safety.
- Region.

The information contained in this chapter does not replace international, federal, state, local, or other applicable codes, laws, or regulations. Specific applications may contain variables that are beyond the scope of this document. Taking this into consideration, the application of this information cannot guarantee the desired technical results.

Background

Distinct differences exist between the terms bonding and grounding (earthing). Generally speaking, grounding (earthing) is the establishment of a reference for the electrical (alternating current [ac] or direct current [dc]) power source, the electrical equipment, or both. Bonding, however, is the connection intended to safely and effectively equalize the potential differences between two metallic items (e.g., telecommunications grounding busbar [TGB] and cable tray). In the context of this chapter, protection pertains to lightning and surge-related areas.

Safety

A primary responsibility of the ITS installer is safeguarding personnel, property, and equipment from foreign electrical voltages and currents (foreign refers to electrical voltages or currents that normally are not carried by, or expected in, the telecommunications distribution systems).

The results of such disturbances could be:

- Death or injury because of electrical shock.
- Destruction of electronic equipment and property because of electrical fire.
- Malfunction or degradation of components.
- Disruption of work or process.

Avoiding Electrical Shock

The most common electrical shock occurs from inadvertent contact with energized devices or circuits. Accident investigations have identified common conditions that increase the risk of electrical shock, including:

- Touching a faulty or improperly grounded electrical component.
- Standing on a damp floor or earth.
- Having poor clearance and lighting.
- Using or being near conducting material during a lightning storm.

Preventing Electrical Shock

Until verified, always assume that equipment is energized.

Use prudent electrical safety measures (e.g., insulated rubber gloves for personal protection) and appropriate test equipment to verify the presence or absence of dangerous voltages on all exposed:

- Cables.
- Strands.
- Wires.
- Metal.

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Preventing Electrical Shock, continued

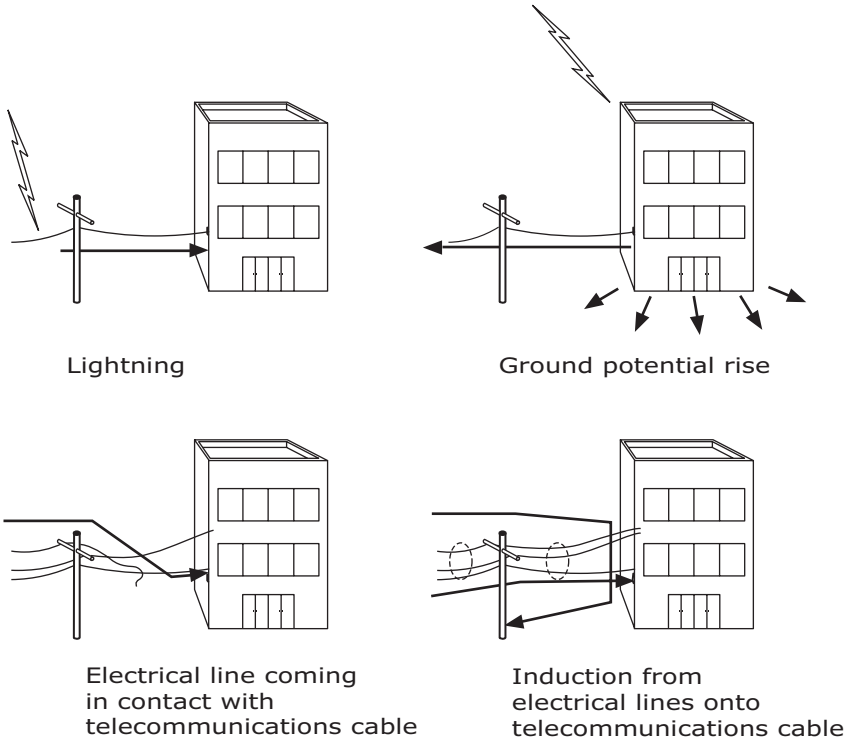
Properly installed ITS cabling is rarely dangerous. During installation, verify that exposed conductors, cable shields, and metal equipment are grounded or free of fault potentials (and otherwise generally safe).

Overall protection must consider:

- Direct lightning strikes.
- Ground potential rise (GPR).
- Contact with power circuits.
- Induction.

Examples of some conditions causing these disturbances are shown in Figure 4.1.

Figure 4.1
Electrical hazards



Planning

The increasing customer requests for personnel and equipment moves and the use of newer, more sensitive, and highly integrated electronic equipment now dictate an environment where electrical protection must be a top priority.

ITS installers are not responsible for engineering the portions of the electrical system related to ac electrical ground faults, structural lightning protection systems, or surge protective devices. ITS installers must be familiar with the basic components and functionalities of these systems. In many cases, ITS installers must incorporate effective bonding, grounding (earthing) and installation procedures for a building or structure that has been in place for years.

Installation Guidelines

The ITS installer must become familiar with the equipment manufacturer's requirements for equipment grounding (earthing). A faulty grounding (earthing) installation may result in damage to expensive equipment and the voiding of the manufacturer's warranty. If the ITS installer finds a conflict among local safety code, BICSI guidelines, and the manufacturer's requirements, the conflict should be resolved with the authority having jurisdiction (AHJ) and the manufacturer's installation guidelines before proceeding.

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Bonding and Grounding (Earthing) Systems

Components

The ITS installer must recognize that three distinct, yet interconnected, grounding (earthing) systems should be in place at every site.

These systems are the:

- AC grounding (earthing) electrode system (also known as the earthing system).
- Equipment grounding system (also known as the equipment bonding system).
- Telecommunications bonding infrastructure.

Because the purpose of each of these systems is unique, one cannot be used in place of one of the other two. Also, the installation requirements, improvement methods, and test methods of the three systems vary greatly.

NOTE: The ITS installer may be responsible for the installation of the telecommunications bonding and grounding (earthing) and the telecommunications circuit protectors.

Although ITS installers are not responsible for the ac grounding (earthing) systems, they should recognize the importance of these interconnected systems. A clear understanding of these systems provides a basis for further training and collaborating with specialists if necessary.

Information Technology Systems (ITS) Installers' Considerations

The installation of the ac grounding (earthing) electrode system is outside the scope of this manual. The ITS installer should, however, identify the type of grounding (earthing) electrode used for the building's ac electrical system for the purpose of ensuring an effective bonding connection for the grounding bus bars and other telecommunications reference points within the telecommunications rooms (TRs).

The ITS installer should ensure that the bus bars within the telecommunications bonding infrastructure are bonded to the building's metal frame (e.g., structural steel) where they are readily available.

NOTE: A wooden structure-type building may have the grounding (earthing) electrode conductor attached directly to the ac power ground located within the nearest ac power panel.

WARNING: The grounding (earthing) electrode conductor is critical to the performance of the electrical power system. Telecommunications personnel should not move, modify, or disconnect any grounding (earthing) electrode conductor without the direct participation of a qualified electrical maintenance person.

Supplemental Bonding Structures

A supplemental bonding structure within an equipment room (ER) or data center is a signal reference grid (SRG), which is often associated with raised flooring.

An SRG may consist of copper conductors (e.g., flat straps, round conductors) that may or may not be fastened to the floor. Although not recommended, the stringers that support the tiles may act as the bonding conductor across the floor's gradient.

An SRG provides a low-impedance path between many cabinets or racks of telecommunications equipment. Typical guidelines specify direct bonding to any conductive path that reaches the grid.

A bonding conductor must be run between the room's associated busbars and to at least two points within the SRG if a raised floor is used within an ER, TR, or data processing center. This will ensure that an equipotential plane exists between the SRG and the bonding and grounding (earthing) infrastructure for the building.

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Telecommunications Bonding Infrastructure

Overview

The overall purpose for the telecommunications bonding infrastructure is to equalize potentials between metallic surfaces predominantly in the event of lightning, ac electrical system faults, electromagnetic induction, or electrostatic discharge.

There are many ways to achieve the goal of an equipotential plane. The ITS installers of the telecommunications infrastructure must examine the site and give practical consideration to a variety of options that are available to them. The following sections are intended to act as a practical guide to assist the ITS installer in offering effective, technically sound bonding and grounding (earthing) solutions. These sections use generally accepted industry terminology.

Bonding System Practices

Overview

Telecommunications bonding practices are generally easy to apply once the intent of the bonding connections is understood. Bonding conductors are not designed to intentionally carry ac ground fault current or lightning stroke current. However, they are installed so that voltages may be equalized when those events occur.

NOTE: The practices outlined for small systems and large systems discussed further in this section should be used as a guide.

Small Systems

In small ERs and entrance facilities (EFs), the bonding and grounding (earthing) begins at the telecommunications main grounding busbar (TMGB), which must be referenced to the nearest approved grounding (earthing) electrode (e.g., typically made available by the qualified electrical maintenance person).

The ground connection terminals on the installed equipment (e.g., protector panels, private branch exchange [PBX] cabinets) are usually directly connected to the closest approved grounds (typically made available by the qualified electrical maintenance person).

All exposed cable must be directly terminated at the associated protectors. Any exposed cable shields are bonded directly to the closest:

- Protector.
- Protector’s ground terminal.
- Approved protector ground.
- Approved grounding (earthing) electrode connection.

Bonding System Practices, continued

Beyond this, the equipment manufacturer's guidelines must be followed (see Figure 4.2). Typically, a bonding conductor is installed directly between the protector's ground (earthing) source and the PBX (or other equipment) ground terminal.

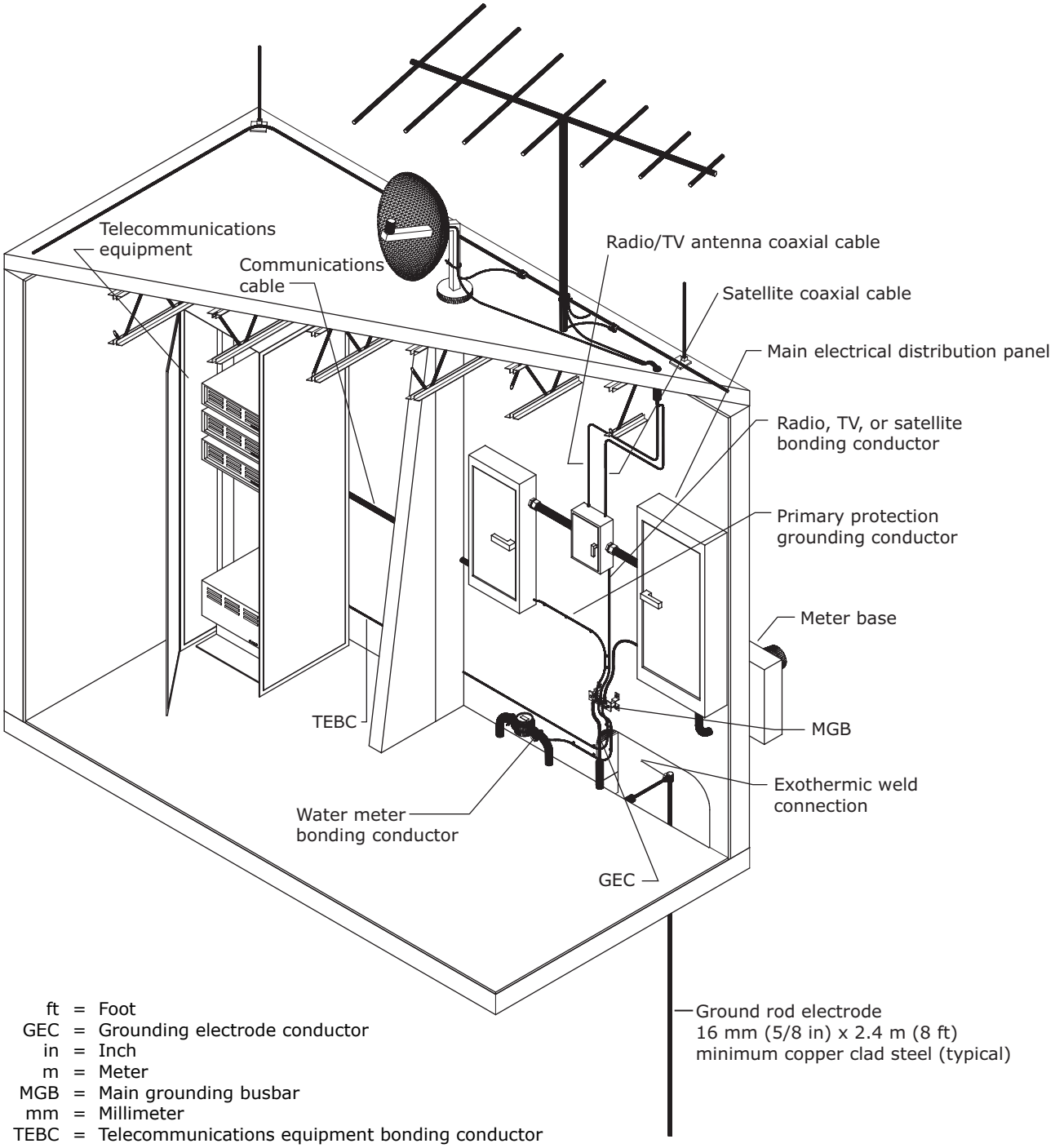
If the protector and PBX are collocated and rely on the same approved ground, then the bonding conductor may not be needed.

NOTE: Figure 4.2 only shows the bonding and grounding (earthing) infrastructure. A bonding connection must be made to the equipment grounding busbar located in the nearest ac electrical panel board (e.g., main service entrance panel board, branch circuit panel board).

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Bonding System Practices, continued

Figure 4.2
Recommended small system bonding and grounding (earthing)



ft = Foot
GEC = Grounding electrode conductor
in = Inch
m = Meter
MGB = Main grounding busbar
mm = Millimeter
TEBC = Telecommunications equipment bonding conductor

Bonding System Practices, continued

Large Systems

In a large system, the installation of the bonding and grounding (earthing) infrastructure can be very complex when compared with a smaller system that only requires a few conductors to bond the limited amount of connections required. In the case of a larger building, multiple busbars are used where multiple ERs, TRs, and EFs exist (see Figure 4.3).

Often, confusion stems from the obvious need for placing multiple grounding busbars throughout the facility, which sometime leads the ITS installer to explore methods to bond them all together. Practically speaking, however, each TGB or TMGB must have an effective bonding connection to the nearest approved building grounding (earthing) electrode and the equipment grounding (earthing) system (e.g., ac branch circuit panel board's equipment grounding busbar). This will minimize voltage differences between the telecommunications grounding (earthing) infrastructure and the ac grounding (earthing) systems during lightning, electromagnetic interference (EMI)/radio frequency interference (RFI), and ac electrical fault conditions.

The telecommunications bonding and grounding (earthing) infrastructure originates at the service equipment (power) ground and extends throughout the building.

It includes the following major components:

- Bonding conductor for telecommunications (BCT)
- Telecommunications main grounding busbar (TMGB)

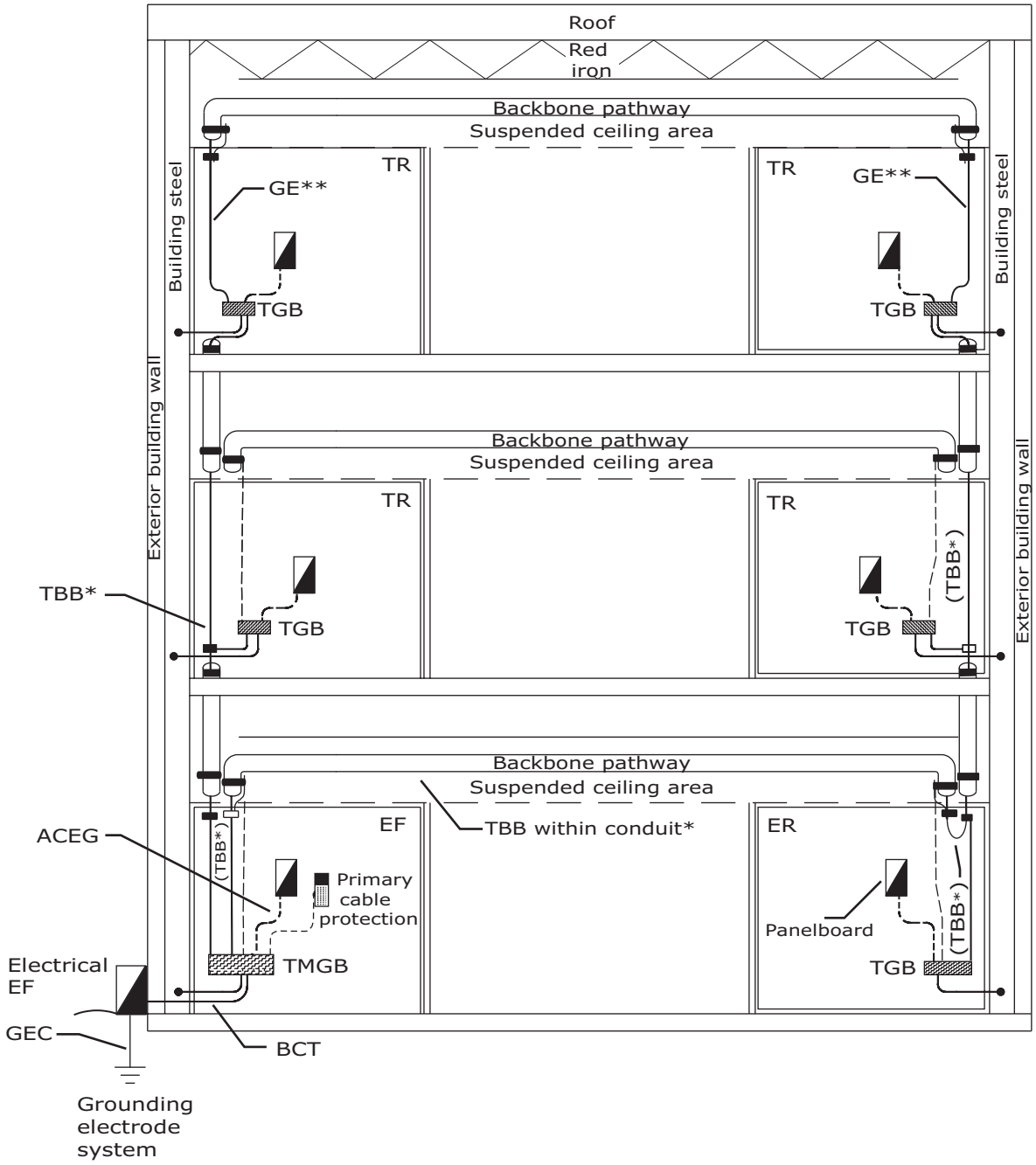
It may also include:

- Telecommunications bonding backbone (TBB).
- Telecommunications equipment bonding conductor (TEBC).
- Telecommunications grounding busbar (TGB).
- Grounding equalizer (GE).

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Bonding System Practices, continued

Figure 4.3
Large system arrangement options



ACEG = Alternating current equipment ground
BCT = Bonding conductor for telecommunications
EF = Entrance facility
ER = Equipment room
GE = Grounding equalizer
GEC = Grounding electrode conductor
TBB = Telecommunications bonding backbone
TGB = Telecommunications grounding busbar
TMGB = Telecommunications main grounding busbar
TR = Telecommunications room

NOTE: All ferrous metal enclosures must be bonded at both ends regardless of length when containing a bonding conductor.

Entrance Facility (EF)

Bonding Conductor for Telecommunications (BCT)

The earthing reference for the telecommunications bonding infrastructure is dependent (via the BCT) on the ac grounding (earthing) electrode system's physical and electrical characteristics.

The BCT bonds the electrical system's grounding (earthing) electrode system to the TMGB. Unless this bonding connection is made within 6.1 meters (m [20 feet (ft)]), the impedance of this conductor, because of its length, may limit its effectiveness.

Telecommunications Main Grounding Busbar (TMGB)

The TMGB serves as the dedicated extension of the building ac grounding (earthing) electrode system for the telecommunications infrastructure. It serves as a central attaching point for all equipment and other busbars within the building (see Figure 4.4).

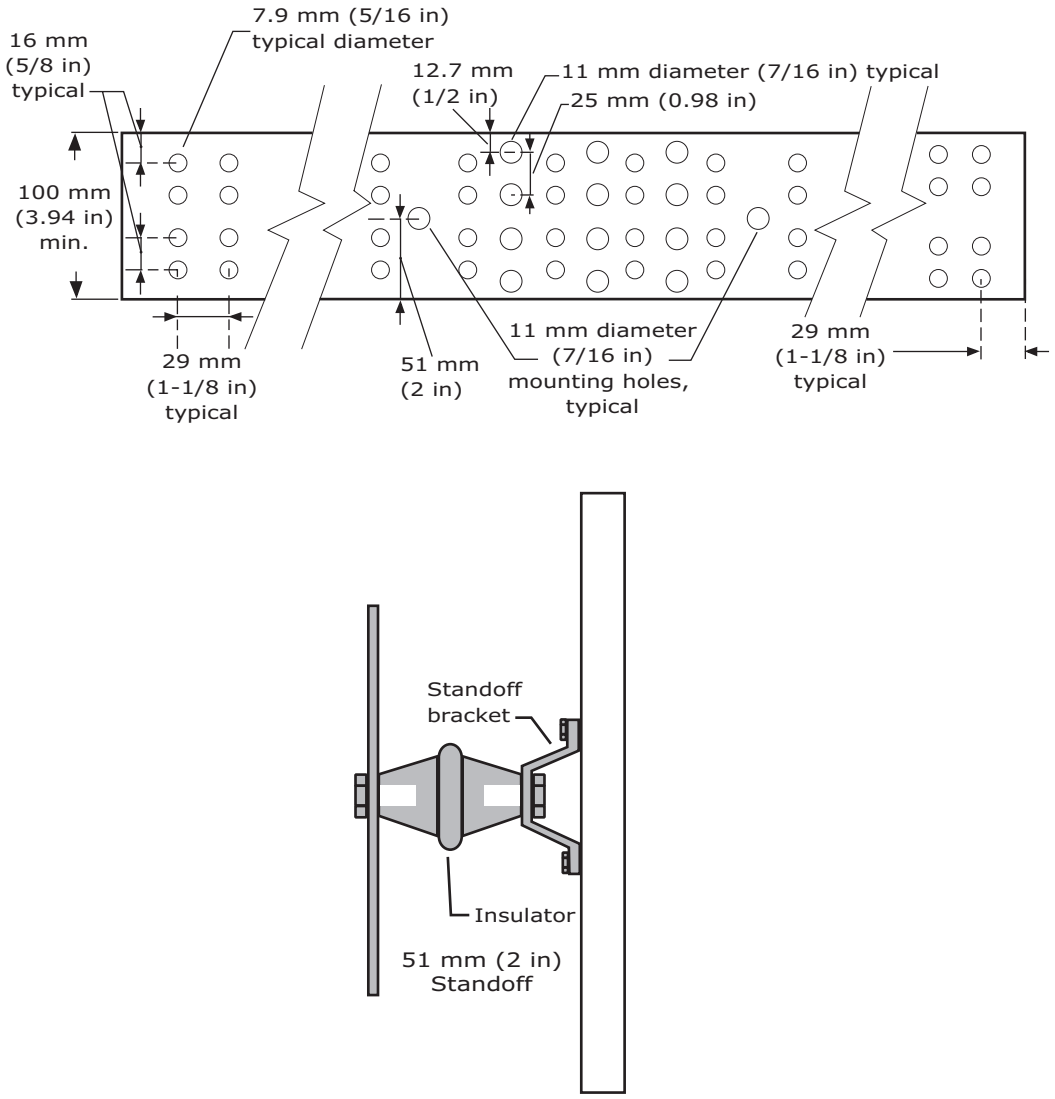
When connecting to the busbars, larger backbone conductors should be bonded using the larger holes and two-hole lugs. The TMGB should:

- Be directly bonded to the commercial power service equipment ground.
- Be located in the telecommunication entrance facility (EF) but shall be placed to minimize the length of the BCT that bonds the TMGB to the building's grounding (earthing) electrode.
- Be located in the EF for the bonding of protector terminals and cables with metallic shields.
- Be positioned adjacent to the protectors and directly between the protectors and the approved building ground for protector operation.
- Be designated for protectors and must safely carry lightning and power fault currents.
- Be located to minimize bonding conductor lengths.
- Serve equipment within the same room or space.
- Be positioned so that ITS cabling will generally follow the related bonding conductors. Close proximity can help with EMI.
- Provide a minimum of 51 millimeters (mm [2 inches (in)]) clearance behind the busbar when mounted.
- Have an isolated mount to avoid unwanted potentials on the busbar.

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Entrance Facility (EF), continued

Figure 4.4
Telecommunications main grounding busbar example



in = Inch
mm = Millimeter

In addition to the BCT, two supplemental bonding connections may exist for the ITS installer:

- Where building steel is available in the EF, the TMGB should be bonded to the nearest structural steel column provided that its bonding effectiveness has been verified via two-point bonding testing.
- A bonding conductor should be routed between the TMGB and the nearest effective grounded ac electrical branch circuit panel board provided that a low ground impedance of the panel board has been verified with a ground impedance tester.

Entrance Facility (EF), continued

Additional Bonding Connections to the Telecommunications Main Grounding Busbar (TMGB)

Many different connections to the TMGB can be made. These include bonding connections to:

- Primary and secondary surge protectors.
- Cable trays.
- Ladder racks.
- Equipment racks.
- Branch circuit panel boards.
- Power conditioning equipment.
- Cable sheaths.
- Battery racks.
- Entrance and other conduits.

Additional busbars may be required when systems are larger and require more connections than the TMGB can accommodate. When additional busbars are installed in the same space as the TMGB or in remote ERs or TRs, they are referred to as TGBs. While the use of TMGBs is restricted to only one per building, there may be as many TGBs as needed.

Equipment Room (ER)

Equipment Room (ER) Telecommunications Grounding Busbar (TGB)

A TGB is the grounding (earthing) connection point for telecommunications systems and equipment in the area served by an ER or TR.

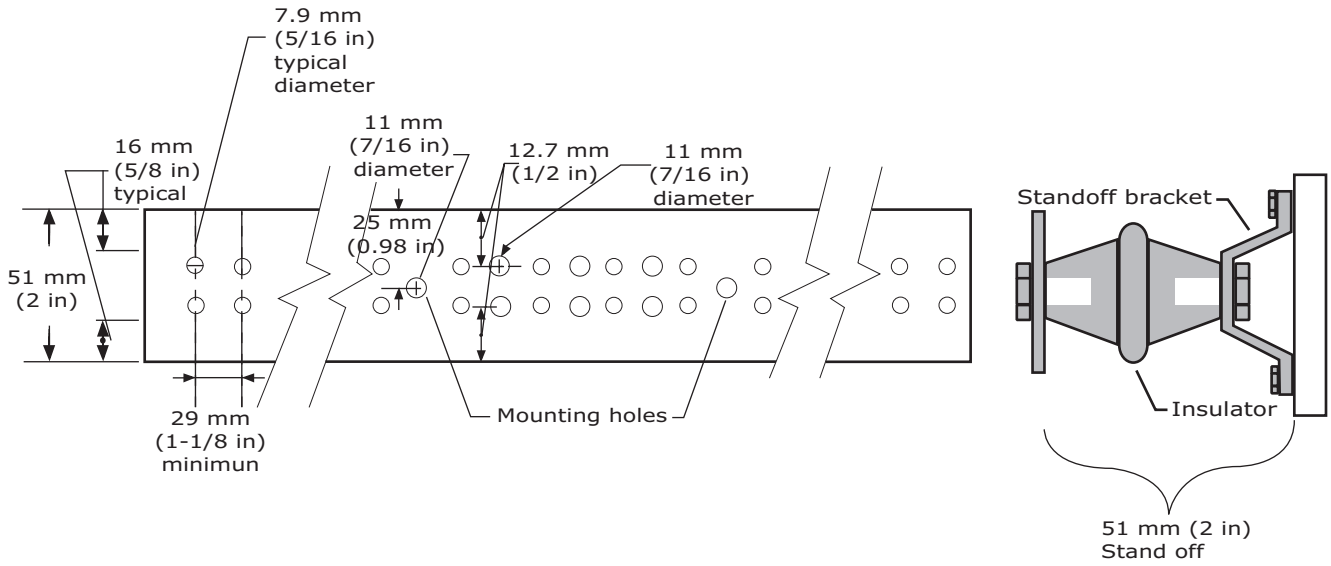
The TGB should be mounted providing a minimum 51 mm (2 in) clearance to avoid unwanted potentials on the busbar (see Figure 4.5).

As with the TMGB, the TGB should be capable of accommodating bonding conductors that originate at various equipment and metallic surfaces and allow for future growth.

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Equipment Room (ER), continued

Figure 4.5
Telecommunications grounding busbar example



in = Inch
mm = Millimeter

The TGB should be referenced to the equipment ground terminal of the ac electrical panel board(s) serving telecommunications equipment in the ER to equalize potentials between them. This connection is important because it equalizes the potentials during lightning, electrostatic discharge, and EMI conditions. This panel board, known as a branch circuit panel board, may reside in the ER. The TGB should also be bonded to the nearest accessible structural steel member, whether it is a horizontal or vertical beam, if available.

WARNING: Connections to an ac panel board ground should be installed by qualified electrical installers.

Telecommunications Room (TR)

Like the ER, the bonding infrastructure for the TR will depend on the referencing of its TGB.

Telecommunications Room (TR) Telecommunications Grounding Busbar (TGB)

The TGB within the TR should follow the same designs and installation guidelines specified in the ER section above.

Telecommunications Room (TR), continued

Referencing the Telecommunications Room (TR) Telecommunications Grounding Busbar (TGB)

The TGB should be referenced to the equipment ground terminal of the nearest ac electrical panel board to equalize potentials between them. This connection is important because it will equalize the potentials during ac electrical system fault, lightning, electrostatic discharge, and EMI conditions. This ac panel board, also known as a branch circuit panel board, may reside in the ER. The TGB should also be bonded to the nearest structural steel member, whether it is a horizontal or vertical beam, if available.

WARNING: Connections to an ac panel board ground should be installed by qualified electrical installers.

Telecommunications Bonding Backbone (TBB)

A TBB is a copper conductor that interconnects the TMGB to TGB. It is intended to equalize potentials between TRs on multiple floors of a building with an ultimate connection to the EF's TMGB. The TBB should be an insulated, stranded copper conductor. The TBB is recommended as a primary bonding design and should be incorporated to accommodate the needs of the site.

Older buildings, however, may not have the facilities for this type of conductor installation. As a secondary consideration, some latitude must be given for the ITS installers to rely on the existing ac electrical distribution (structural steel and ac panel boards) to provide an effective reference. In lieu of installing the TBB between the floors in this case, a bonding conductor should be provided from the TGB in each TR to structural steel (if accessible) and the nearest ac electrical panel board.

WARNING: Connections to an ac panel board ground should be installed by qualified electrical installers.

Grounding Equalizer (GE)

A GE is a minimum 6 American wire gauge (AWG [4.1 mm (0.16 in)]) insulated, stranded copper conductor intended to equalize potentials between TRs on the same floor of a structure. For example, the Telecommunication Industry Association (TIA) J-STD 607 recommends that this connection be made on every third floor and the top floor of multistory structures.

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Telecommunications Equipment Bonding Conductor (TEBC)

The TEBC connects the TMGB/TGB to the equipment racks/cabinets. The TEBC shall be a continuous copper conductor that is sized for a minimum 6 AWG [4.1 mm (0.16 in)] insulated, stranded copper conductor.

The TEBC shall be exothermically welded or connected using a compression style or exothermic style two-hole lug to the connection point on the TMGB/TGB.

NOTE: All bonding conductors shall maintain a minimum bending radius of 203 mm (8 in). The angle of a bend shall not be less than 90 degrees.

Bonding Equipment, Racks, and Cabinets

Grounding (earthing) through the equipment ac power cord does not meet the intent of the National Electrical Contractors Association NECA/BICSI standard 607 (currently under development). It is intended that the ac power ground path and the telecommunications ground path offer redundant and specific ground paths for the equipment.

While the ac-powered equipment typically has a power cord that contains a ground wire, the integrity of this path to ground cannot be easily verified. Rather than relying on the ac power cord ground wire, it is desirable that equipment be grounded in a verifiable manner as described in the standard.

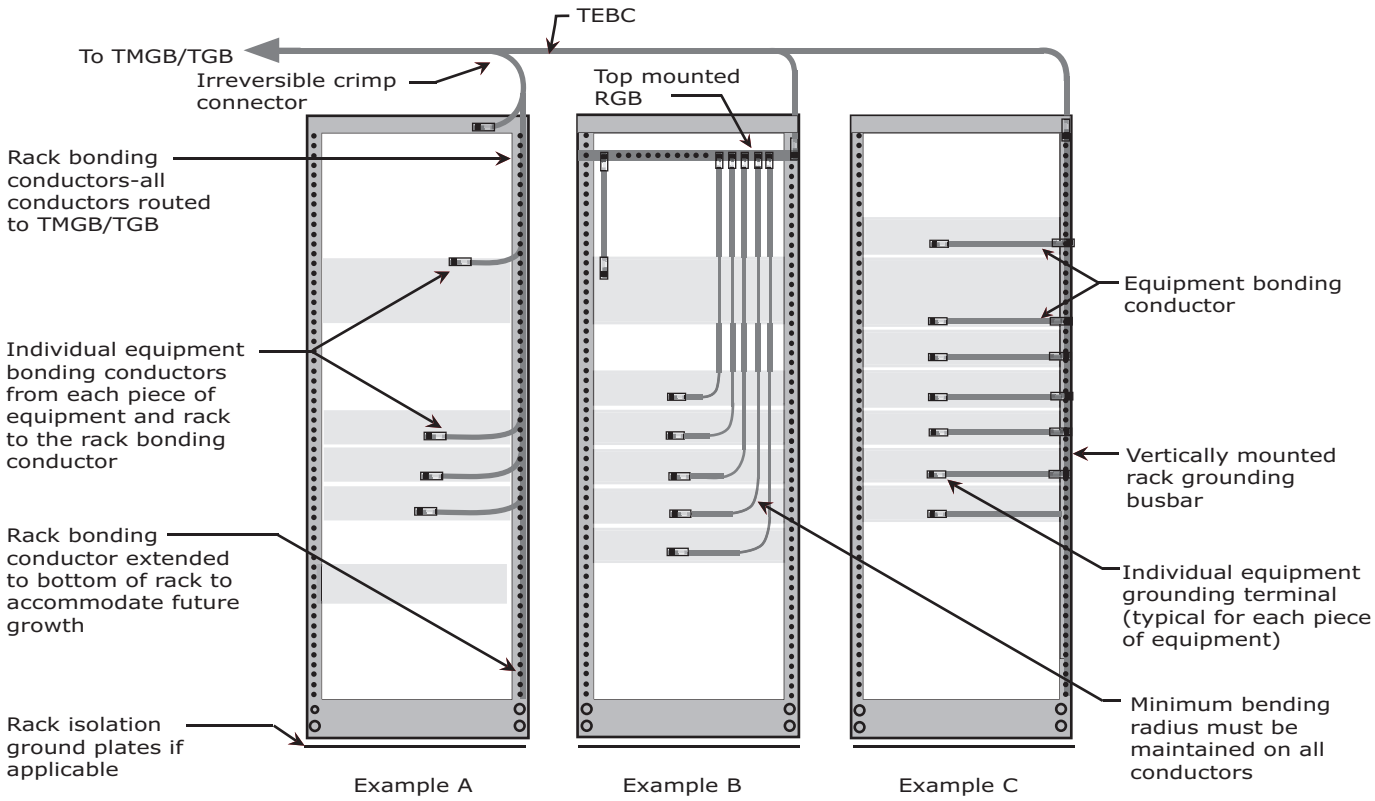
Electrical service power is routed in close proximity to the structural members of equipment cabinets and racks. Accordingly, every structural member of a cabinet or rack should be grounded to prevent a safety hazard in the event that some member makes contact with a live power feed. This grounding (earthing) condition is achieved by ensuring that there is electrical continuity throughout the structural members of the cabinet or rack.

Bonding Equipment, Racks, and Cabinets, continued

There are three methods to bond the equipment located in the equipment rack or cabinet to the telecommunications bonding system (see Figure 4.6).

NOTE: Many types of equipment do not require individual bonding conductors and, as such, do not have an attachment point for bonding conductors. Equipment that does not have attachment points for bonding conductors may be bonded either through the equipment rail or the ac power cord. Refer to the manufacturer's documentation for guidelines.

Figure 4.6
Example of three methods to bond racks to ground



RGB = Rack grounding busbar
TEBC = Telecommunications equipment bonding conductor
TGB = Telecommunications grounding busbar
TMGB = Telecommunications main grounding busbar

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Bonding Equipment, Racks, and Cabinets, continued

Example A

Example A attaches the equipment to a rack bonding conductor (RBC) that extends from the equipment rack/cabinet to the TEBC using an irreversible compression connector sized to match the conductor gauges or a nationally recognized testing laboratory (NRTL)-listed grounding block.

NOTE: In a single rack or cabinet environment, an RBC is not required; the TEBC will serve this purpose.

The TEBC is then bonded directly to the TMGB/TGB. This example illustrates that there is multiple cutting and stripping of the RBC as well as the addition of multiple irreversible compression connections.

Example B

Example B utilizes a horizontal rack grounding busbar located at the top or bottom of the equipment rack/cabinet. Each piece of equipment in the rack/cabinet is bonded directly to the horizontal rack grounding busbar through a unit-bonding conductor. The horizontal rack grounding busbar is then bonded to the telecommunications equipment-bonding conductor through an RBC using an irreversible compression connector sized to match the conductor gauges.

NOTE: In a single rack environment, an RBC is not required; the TEBC will serve this purpose.

The TEBC is then bonded directly to the TMGB/TGB. This example illustrates that unit-bonding conductors may be longer and adds to the complexity of cable management.

Example C

Example C utilizes a vertical rack grounding busbar that runs almost the entire length of the rack/cabinet. The equipment is then bonded to the vertical rack grounding busbar via a short unit-bonding conductor. The vertical rack grounding busbar is then bonded to the TEBC via an RBC using an irreversible compression connector sized to match the conductor gauge.

NOTE: In a single rack environment, an RBC is not required; the TEBC will serve this purpose.

The TEBC is then bonded directly to the TMGB/TGB. This example illustrates that unit-bonding conductors can be very short, and the connection to the grounding busbar does not require stripping of insulation and the use of irreversible compression connections.

Bonding Connections

Unnecessary connections or splices in bonding conductors should be avoided. Where necessary, an approved connection should be used and positioned in an accessible location.

The bonding or grounding (earthing) conductor shall be connected to the grounding (earthing) electrode by exothermic welding, listed lugs, listed pressure connectors, listed clamps, or other listed alternatives.

Typical connections are made using:

- Bolts or crimps (e.g., connectors, clamps, lugs)—Where possible, irreversible compression-type connections and two-hole lugs should be used. Listed hardware should always be used.
- Exothermic welding—A molecular bond of metals is commonly applied to:
  - Connections to, and within, the ac grounding (earthing) electrode system.
  - Locations requiring minimal maintenance.
  - Parts of grounding (earthing) systems that are subject to corrosion or that must reliably carry high currents.
  - All connections that are buried (e.g., outdoor ground rods, rings).
  - Bonds to structural steel.

All bonding connections should follow the manufacturer's installation guidelines.

Installing Bonding Connections

Ideally, the conductor will be fully seated inside the connector barrel or extended 3 mm (1/8 in) beyond if the connector is a set-screw, pass-through style. Some crimp style connectors may have inspection holes that are used to visually ensure that the conductor is fully inserted into the connector during assembly and later during subsequent inspections.

IMPORTANT: Care must be taken not to nick the conductors when preparing the conductors for termination. High-voltage faults will arc across nicked conductors and possibly cause a fire. Nicked conductors are also subject to breakage when the conductor is flexed at the nicked lactation.

When connectorizing an insulated conductor, the insulation should be removed using an appropriate tool. This will ensure that the conductor is not nicked and the edge of the insulation is neat and close to the barrel of the connector where the conductor enters the lug. The insulation should be flush with the connector, but may have a maximum of 3 mm (1/8 in) of conductor exposed between the insulation and the connector. This provides a uniform installation that maintains the aesthetics of a professional installation.

Inspection of Bonding Connections

The integrity of bonding connections cannot always be easily determined because of:

- Distance.
- Access.
- Other parallel bond connections that often exist.

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Bonding Connections, continued

Visual inspection can usually reveal problems such as:

- Loose connections.
- Corrosion.
- Physical damage.
- System modifications.

During any service work, the ITS installer should visually inspect the bonding connections.

If service personnel are not expected to return to the site, the customer should be advised:

- That specific telecommunications bonding should be reinspected regularly.
- When alteration or damage occurs.

In some cases, approved grounds are accessible only to a licensed electrician. The customer and responsible personnel should be consulted.

Testing the Integrity of Bonding Connections

Two-point bonding measurements should be performed using an earth grounding (earthing) resistance tester configured for a continuity test. The test should be performed between any two conductive surfaces where bonding exists.

The recommended maximum value for the bonding resistance between these two points is 0.1 ohms (100 milliohms). Consult the meter manufacturer's operation instructions for safety precautions, specific usages, and displayed data interpretation.

Lightning Exposure for Outside Plant (OSP)

Lightning exposure cannot always be accurately examined. The ITS installer must consider codes, standards, and site records when evaluating a site for exposure.

Exposure basically refers to an outdoor telecommunications cable's susceptibility to electrical power system faults or to lightning or other voltage and current transients. A cable is considered electrically exposed if any of its branches or individual circuits is exposed.

Interbuilding circuits are considered to have a lightning exposure unless one or more of the following conditions exist:

- Circuits in large metropolitan areas where buildings are close together and sufficiently high to intercept lightning.
- Interbuilding cable runs of 42.7 m (140 ft) or less, directly buried or in underground conduit. (The shield or conduit must be bonded to the building's ac grounding [earthing] electrode system at each end. This is another simplified zone of protection as well as proper bonding practice.)
- Areas having an average of five or fewer thunderstorm days per year and earth resistivity of less than 100 ohmmeters.

Telecommunications Circuit Protectors

Overview

Various codes cover telecommunications circuit protection, a primary responsibility of the ITS installer. The basic functions of protectors are:

- Arresting surges or overvoltages (diverting them to ground) that come from exposed circuit pairs.
- Protecting against sustained hazardous currents that may be imposed.

The primary protector shall be located as close as practicable to the point at which the cable enters the building. Therefore, in installations requiring a primary protector, the OSP cable is not to extend beyond a set distance into the building from the point of entry. Seek local AHJ approval for these requirements.

There are three types of telecommunications circuit protectors:

- Primary protectors—These are intended for application on exposed circuits. These must be installed as near as possible to the point at which the exposed cables enter the building, and the grounding conductor must safely carry lightning and power fault currents.
- Secondary protectors—These may not be required by codes, but they are typically used for additional protection behind primary protectors. In addition to voltage protection, this type must protect against sneak current. Sneak current can be caused by:
  - Power faults, which are too low in voltage to operate primary protectors.
  - Station equipment that will draw excess current and overheat station wire.
  - Induction from power lines.
- Data and fire alarm protectors—These modules are more sensitive with a lower fault threshold because they do not have to allow for the 90 volts (V) associated with a telephone's ring voltage. Though not required by codes, these modules must perform primary protection against lightning transients. They do not have the ability to protect against power faults. These should be used according to the manufacturer's guidelines.

There can be some overlap in function with the available products. The ITS equipment manufacturers should be consulted for specific applications. The following rules generally apply:

- A primary protector is required where a circuit is exposed to electrical power faults and lightning. Other protector types are not qualified for protection under these conditions.
- Where a circuit is exposed to lightning surges, a primary protector or a data/alarm protector is required as dictated by equipment manufacturers.
- Where sneak currents are hazardous, a secondary protector or primary protector with secondary protection is required (as directed by equipment manufacturers). Some primary protectors can include basic secondary protector function (sneak current protection).
- ITS equipment manufacturers may include additional protection functions, sometimes called enhanced protection, for specific applications.

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Primary Protector Terminal Installation Design Considerations

Important installation considerations include the following:

- Primary protectors must be installed immediately adjacent to the exposed cable's point of entry. The associated grounding conductor must be routed, as straight as possible, directly to the nearest ground approved by the AHJ.
- A noncorrosive atmosphere is required for long-term reliability.
- When a protector is installed in a metal box, bond the box with an approved bonding conductor directly to the protector ground.

WARNING: Do not locate primary protectors near any hazardous or easily ignitable material.

An exception to the minimum 6 AWG [4.1 mm (0.16 in)] bonding conductor are smaller EFs. It is required to determine the minimum-size conductor for the protection unit based on the anticipated current flow from the number of conductor pairs and the distance of the protector terminal from the ground source.

The following conductor sizes are based on the assumption that the protector terminals will be located up to 6.1 m (20 ft) away from the electrodes (see Table 4.1).

Table 4.1
Copper grounding conductor capacity

Number of Pairs	Minimum Capacity
1–2	12 AWG [2.1 mm (0.083 in)]
3–6	10 AWG [2.6 mm (0.10 in)]
> 6	6 AWG [4.1 mm (0.16 in)]

AWG = American wire gauge
in = Inch
mm = Millimeter

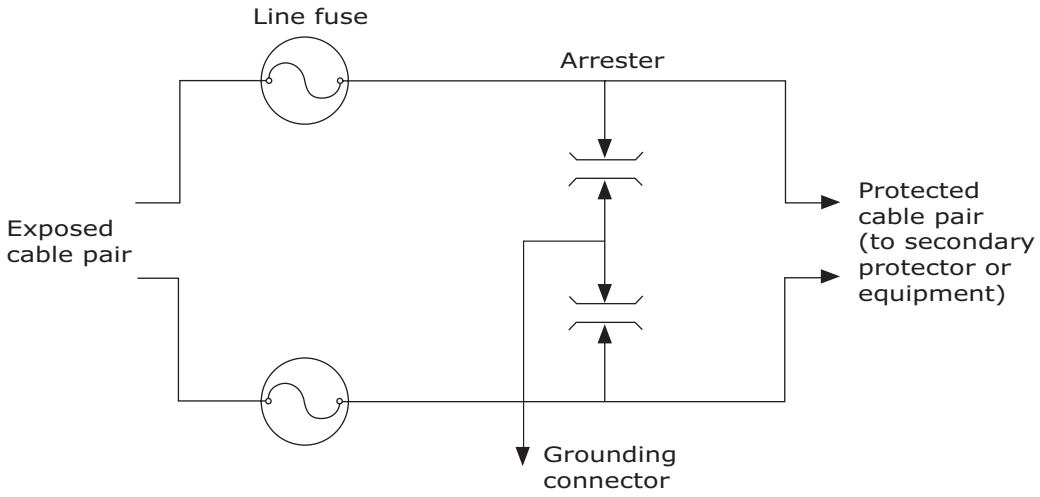
NOTE: Some codes allow the conductor to be as small as 14 AWG [1.6 mm (0.063 in)]. It is safer to use the AWG sizes of 12, 10, and 6, as outlined above, when installing protection terminals.

Primary Protectors

Two types of primary protectors are fused (typical) and fuseless (legacy). In the event of extended overcurrent situations, the exposed side must fuse open without damaging the ground conductor or indoor circuit. The fused type accomplishes this with an integral line fuse (see Figure 4.7).

The fuseless type must be installed with fine-gauge fuse wire (acting as a fuse link) on the exposed line side (provided by the manufacturer). Both types will operate the same way when installed. This type of protection is designed for sustained large surge currents. Reaction time is very long, usually measured in microseconds or milliseconds. This type of protection is for conductors and not for equipment. Fuseless conductors shall be two gauges smaller than the main conductor.

Figure 4.7
Fuse protection



Manufacturers use many different components to implement protection functions. The following components are typical for primary protectors.

Carbon Blocks (Legacy)

Carbon blocks are the original protectors. An air gap between carbon elements is set to arc at about 300 V to 1000 V and conducts surge current to a grounding conductor. When the surge current finally drops low enough, the arc stops and the protector resumes its normal isolation of ground.

A fail-safe function causes carbon blocks to short permanently to ground when an extended hot surge or permanent fault current overheats them. They are typically installed as pairs and are the lowest cost option; however, carbon blocks tend to wear out quickly under extreme conditions and can cause leakage and noise in voice circuits. These devices have relatively slow reaction times, usually in excess of 15 nanoseconds (ns).

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Primary Protectors, continued

Gas Tubes (Typical)

Gas tubes are arresters that operate the same as legacy carbon blocks, arcing over a gap to a grounding conductor. They have a wider gap because of special gas and, therefore, a higher reliability. They have tighter tolerances on arc breakdown voltage and are typically set to arc at a lower voltage, providing better protection than legacy carbon blocks.

Another type of gas tube, the dual-gap, provides a common arc chamber that grounds both wires of a pair together and minimizes metallic surges that would otherwise occur from individual arrester operation. Gas tubes have reaction times of between 10 and 15 ns.

Solid State (Typical)

Solid state arresters rely on high-power semiconductor technology. They are fast acting and well balanced, and they do not deteriorate with age below a rated maximum surge current. Reaction times for these types of units are 3 to 5 ns with clamping voltages of 150 V to 300 V.

Secondary Protectors

Secondary protectors are required to coordinate with lightning transient and power-fault requirements of primary protectors. In some cases, secondary protectors may include one of the previously described arrester components. For this reason, cost-effective secondary protection is typically available as an option on primary protectors. Secondary protectors must handle sneak currents. The components for sneak current are different from those used for primary protection.

Heat Coil (Legacy)

The coils detect sustained low-level current by heat. The heat melts a spring-loaded shorting contact that permanently shorts the line to ground, requiring manual inspection and replacement.

Sneak Current Fuse

A sneak current fuse opens the station circuit wiring under sustained low-level current, requiring manual inspection and replacement. This fusing is on the station side of the arresters and should not be confused with the primary protector line fusing.

Positive Temperature Coefficient (PTC) Resistors

Positive temperature coefficient (PTC) resistors are used in place of a sneak current fuse and will limit sustained current as they heat. They do not require replacement after the sneak current fault is cleared.

Enhanced Protection

Electronics often require protection when clamping voltages are 90 V or lower with a peak reaction time of 1 to 2 ns.

Enhanced protection uses additional components to provide protection that is typically suited for specific low-voltage data circuits. In most cases, equipment manufacturers have designed such protection into their equipment, but they may prefer to use available external protectors.

In some cases, these protectors can substitute in a primary protector panel for special applications of individually exposed circuits.

In other cases, protectors may be qualified for use in office locations where the protected station or terminal is powered or behind primary protectors.

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Appendix: Bonding, Grounding (Earthing), and Electrical Protection Standards and Testing Procedures

International Bonding, Grounding (Earthing), and Electrical Protection Standards

Table 4.2 shows some valuable references for the ITS installer.

Table 4.2
International bonding, grounding (earthing), and electrical protection standards

References	Description
Alliance for Telecommunications Industry Solutions (ATIS)	ATIS writes many standards that have been adopted by ANSI. ATIS Committee T1, Working Group T1.E1, is currently developing a standard, *Grounding and Bonding Telecommunications Equipment in Central Offices and Similar Type Facilities*. ATIS Committee T1 also produces the following applicable standards: • ANSI T1.311, *American National Standard for Telecommunications—DC Power Systems—Telecommunications Environment Protection.* • ANSI T1.313, *American National Standard for Telecommunications—Electrical Protection for Telecommunications Central Offices and Similar Type Facilities.*
ANSI J/STD-607-A	ANSI J/STD-607-A covers grounding and bonding requirements for telecommunications applications within commercial buildings. This does not replace *NEC*® requirements, but it provides additional standards for bonding and grounding (earthing). It covers only bonding and grounding (earthing) and relies on other standards for the many other important protective measures.
ANSI/TIA/EIA-568-C.1-2	*Commercial Building Telecommunications Cabling Standard, Part 1: General Requirements, Addendum 2, Grounding and Bonding Specifications for Screened Balanced Twisted-Pair Horizontal Cabling* specifies additional requirements for grounding (earthing) and bonding of installed screened balanced horizontal cables and connecting hardware used within a commercial building environment.
CENELEC EN 50174	This is a three-part European planning and installation standard for information technology cabling. Its scope includes safety, planning, electromagnetic compatibility considerations, quality assurance, installation practices, documentation, administration, and repair and maintenance.
CENELEC EN 50310	This standard addresses the application of equipotential bonding and earthing in buildings with information technology equipment.

International Grounding (Earthing), Bonding, and Electrical Protection Standards, continued

Table 4.2, continued
International bonding, grounding (earthing), and protection standards

References	Description
CSA C22.1-02	The Canadian Standards Association (CSA) publishes *Canadian Electrical Code (CE Code) Part 1,* the *CEC Handbook,* and a number of coordinated product test standards. These are comparable to the *NEC* (based on the same system grounding and protection methods), but the two codes are not identical.
IEEE 1100	*IEEE Recommended Practices for Powering and Grounding Electronic Equipment* also is known as the *IEEE Emerald Book.*
NFPA 70 (*National Electrical Code® [NEC®]*)	The National Fire Protection Association, Inc. (NFPA) publishes NFPA 70, commonly known as the *National Electrical Code (NEC)*, which has numerous sections containing relevant information. The *NEC* provides minimum requirements for safeguarding personnel, equipment, and property. A useful reference is the expanded version the *National Electrical Code Handbook* (it is the same code but has additional explanatory comments). *NEC* Chapter 8, Communications Systems, covers general requirements for grounding, bonding, and protecting low-voltage communications equipment. *NEC* Article 250, Grounding covers electrical power circuits and low-voltage control and signaling circuits. Although the electrical power grounding requirements do not directly apply to communications circuits, it is important to be familiar with such requirements and methods since they must be coordinated with the communications protection. The same familiarity is important for other typical electrical systems as covered in *NEC* Articles 645, 725, 760, 770, 810, and 820. Much of this chapter is based on the 2005 edition of the *NEC* although many local jurisdictions still require adherence to earlier editions. In some situations, more stringent requirements are needed to ensure adequate electrical protection and/or proper system reliability.

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International Grounding (Earthing), Bonding, and Electrical Protection Standards, continued

Table 4.2, continued
International bonding, grounding (earthing), and protection standards

References	Description
NFPA 780	*Standard for the Installation of Lightning Protection Systems* covers requirements for lightning protection systems. These systems intercept and divert direct lightning strikes that occur to the premises. Although such systems are not typically the responsibility of an ITS installer, there are requirements for separation and common bonding with telecommunications equipment. This code also provides a lightning tutorial, addresses zone of protection, and discusses situations that are useful for the ITS installer to understand.
Safety standards	For the United States, there are many Underwriters Laboratories Inc.® (UL®) safety standards that specify manufactured product tests for safety under various conditions (e.g., electrical exposure, capacity, physical handling and installation, moisture). Of particular interest are: • UL 96, *Lightning Protection Components.* • UL 96A, *Installation Requirements for Lightning Protection Systems.* • UL 467, *Grounding and Bonding Equipment.* • UL 497, 497A, and 497B, three standards that cover communications circuit protectors. • UL 1449, *Standard for Transient Voltage Surge Suppressors.* For example, in the United States, UL is an independent national recognized testing laboratory (NRTL) and tests products according to their application or purpose. Lists of such tested products are made available for insurance underwriting and for site inspection. The products are termed Listed For The Purpose. In all cases, equipment must have a visible marking or label identifying it as listed.

International Grounding (Earthing), Bonding, and Electrical Protection Standards, continued

Table 4.2, continued
International grounding (earthing), bonding, and electrical protection standards

References	Description
Safety standards	Occupational Safety and Health Administration (OSHA) now registers other independent testing laboratories to allow for competitive services, and many different markings can now be found (e.g., CSA®, Factory Mutual [FM], Intertek ETL, MET). Devices, components, and systems that have been tested and listed should be acceptable (or approved) to local inspectors or other local authorities. There are similar test requirements in other countries although this varies by country. (Canada has a wide range of CSA standards; the United Kingdom has British Standards Institution [BSI] standards; Australia has Australian standards; and the European Community is establishing common standards.)
Telcordia™ Technologies (Bellcore)	Telcordia publishes many standards that specify protection devices for telecommunications switching centers (central offices).

Recommended Testing Procedures and Criteria

Typically, it is not the ITS installer's responsibility to perform the verification of the ac grounding (earthing) electrode system quality. This is the responsibility of a qualified testing technician.

BICSI recommends that the tests be performed to evaluate the bonding connections between the telecommunications busbars and the ac grounding (earthing) electrode system. This testing should be performed after the cabling and grounding (earthing) infrastructure are installed but prior to end-use equipment installation.

Measuring the bonding resistance between two points reveals high-resistance connections that could elevate potentials on equipment frames during lightning or ac system fault conditions.

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Recommended Testing Procedures and Criteria, continued

True Root Mean Square (rms) Alternating Current (ac) Measurements

Measuring the ac current on bonding conductors may reveal unwanted presence of the ac current flow. A reading of 0 ampere is the best possible reading for any bonding conductor. However, all sites have bonding conductors that exhibit some value greater than 0 ampere.

Some of the typical reasons are:

- Induction of ac and dc currents.
- Faulty wiring.

As a guide, the recommended maximum ac or dc current value on any bonding conductor should be less than 1 ampere. The acceptable ac and dc current levels may change, depending on the equipment needs. If the current levels exceed 1 ampere, further investigation is warranted.

Two-Point Bonding Measurements

This test is performed using an earth grounding resistance tester that is configured for a continuity test. An earth ground tester generates a test ac current that is manufacturer specific and less susceptible to the influences of dc current. As a result, it is more accurate than the standard volt-ohm-milliammeter (VOM).

The test is performed by connecting the meter leads between the nearest available grounding (earthing) electrode (e.g., structural steel column) and the busbar in the EF or TR. The recommended maximum value for the bonding resistance between these two points is 0.1 ohm (100 milliohms). In telecommunications central office facilities, the acceptable resistance between any two points may be less than 100 milliohms, possibly 50 milliohms.

For testing outdoor grounding (earthing) rings, a polyvinyl chloride (PVC) enclosure is placed over the top of a ground rod so that the enclosure top is level with the earth. The buried ground rod has a grounding conductor exothermically welded to the rod and the conductor ends near the earth level. This is so the conductor can be reached within the enclosure to attach the testing gear lead.

NOTE: Before performing the two-point bond test, the technician should be qualified with proper utilization of the equipment.

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Chapter 5
Copper Structured Cabling Systems

Chapter 5 explores copper cable structured cabling systems and focuses on global best practices for pulling, splicing, terminating, testing, and troubleshooting balanced twisted-pair cable.

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Information Technology Systems (ITS) Cables and Connecting Hardware

Introduction

The information in this chapter provides BICSI® best practices based on industry standards. BICSI best practices may be more or less stringent than the industry standards that apply in a given geographic area. The information technology systems (ITS) installer is required to have a good working knowledge of applicable ITS standards.

ITS standards provide a comprehensive set of requirements and recommendations for the use of balanced twisted-pair cabling and coaxial cabling in the horizontal and backbone distribution subsystems.

Two types of balanced twisted-pair cabling are recognized and recommended for use in the horizontal cabling system:

- 4-Pair unshielded twisted-pair (UTP)
- 4-Pair screened/shielded twisted-pair

Screened/shielded cabling is available in many forms, including:

- Shielded twisted-pair (STP).
- Screened twisted-pair (ScTP).
- Foil twisted-pair (FTP).
- Overall unshielded twisted-pair with foil screened twisted-pair (U/FTP).
- Overall braid screen with foil screened twisted-pair (S/FTP).

The horizontal cabling is the portion of an ITS cabling system that extends from the work area telecommunications outlet/connector to the horizontal cross-connect (HC [floor distributor (FD)]) in the telecommunications room (TR) or telecommunications enclosure (TE).

The horizontal cabling includes horizontal cables, telecommunications outlet/connectors in the work area, connecting hardware that forms the HC (FD), and equipment cords, patch cords, or cross-connect jumper wires located in the TR or TE. It may include multi-user telecommunications outlet assemblies (MUTOAs) and transition points (TPs) or consolidation points (CPs). ITS installers must be aware of the various types of cabling that are available for installation and maintenance. Each type and configuration has specific uses and defined methods that must be employed during installation. Although this section focuses on horizontal cabling, backbone cabling is also identified.

The horizontal cabling provided to each individual work area shall consist of telecommunications outlet/connectors connected to a 4-pair 100-ohm balanced category 5e/class D minimum (category 6/class E or higher recommended) cable. If specific applications require other types of cabling (e.g., 75-ohm coaxial), the other types may be installed in addition to the cabling listed above. To determine the suitability of the cabling types listed above for specific applications, consult systems suppliers, equipment manufacturers, and systems integrators.

Introduction, continued

Several performance categories for 100-ohm balanced twisted-pair horizontal cabling are available. Both cable and connecting hardware categories are specified in applicable standards. The connecting hardware and equipment cords, patch cords, or cross-connect jumper wires used for a horizontal cabling segment must be rated in the same category/class as the cable or in a higher category/class.

Communications Cables Listing

Listings for telecommunications cables and pathways for interior building installations are based on their characteristics when exposed to fire (see Table 5.1). Many codes, standards, and regulations related to this subject are used throughout the world. The cable marking types presented in Table 5.1 do not represent a cable substitution hierarchy. Please refer to applicable codes, standards, and regulations for such cable substitution hierarchy.

The ITS installer and distribution designer should seek and respect guidance from the authority having jurisdiction (AHJ) for the fire-rated performance of all cabling and containment products.

Table 5.1
Commonly used balanced twisted-pair cable fire rating designations

Cable Marking	Type
CMP	Communications plenum
CMR	Communications riser
CMG	Communications general
CM	Communications
CMX	Communications, limited
CMUC	Undercarpet communications
LSZH (LSF)	Low smoke zero halogen (low smoke and fume)

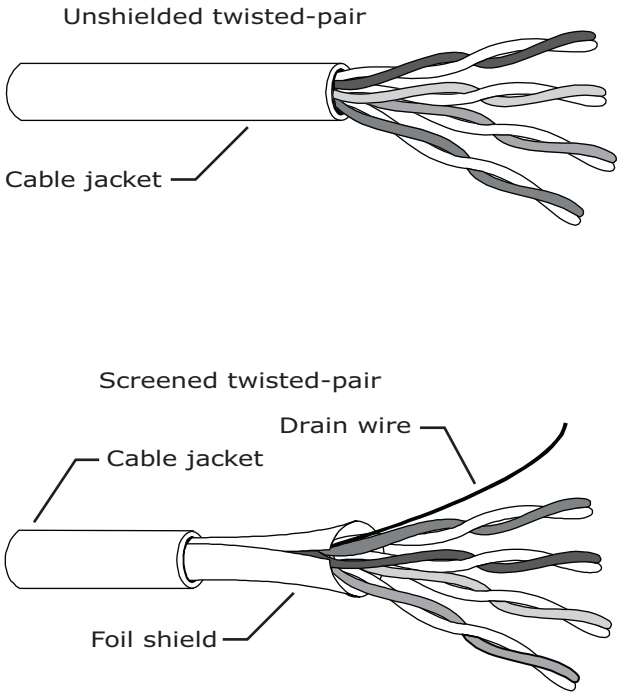
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Four-Pair Balanced Twisted-Pair Cable

Balanced twisted-pair cable may be used to support many types of services, including voice and data cabling, electronic safety and security (ESS) systems, building automation systems (BAS), audiovisual (AV) systems, and other types of telecommunications systems (see Figure 5.1). Balanced twisted-pair cable has the following characteristics:

- Composed of insulated conductors twisted together to form circuit pairs
- Provides support for noise cancellation techniques through conductor twisting
- Generally has a characteristic impedance of 100 ohm (± 15 ohm)
- Conductor sizes 22 American wire gauge (AWG [0.64 millimeters (mm [0.025 inches (in)])]) to 24 AWG [0.51 mm (0.020 in)]
- Overall sheath or jacket on each cable, which is designed for the environment where it is intended to reside

Figure 5.1
Balanced twisted-pair cables



Four-Pair Balanced Twisted-Pair Cable, continued

To improve information throughput, significant performance changes have been made to balanced twisted-pair cables. The ITS installer must consider the relevant aspects of cable performance defined in the standards for the appropriate cabling category/class during installation and testing.

Balanced twisted-pair cabling performance is described using a scale based on classes or categories defined by International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC), and Telecommunications Industry Association (TIA), respectively.

ISO defines component performance by the term category and cabling link or cabling channel system performance by the term class, which is short for classification. While category 5e/class D is the minimum acceptable performance for network cabling, category 6/class E or higher is recommended.

Specifications for several performance levels of balanced twisted-pair cable and associated connecting hardware are shown in Table 5.2.

Table 5.2
Balanced twisted-pair cabling channel performance

ISO Category/Class	TIA Category	Frequency
Category 3/class C	Category 3	16 MHz
Category 5/class D	Category 5e	100 MHz
Category 6/class E	Category 6	250 MHz
Category 6_A/class E_A	Category 6_A	500 MHz
Category 7/class F	N/A	600 MHz
Category 7_A/class F_A	N/A	1000 MHz

ISO = International Organization for Standardization
MHz = Megahertz
N/A = Not applicable
TIA = Telecommunications Industry Association

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Four-Pair Balanced Twisted-Pair Cable, continued

Multipair Backbone Cables

Multipair backbone balanced twisted-pair cable is also specified in performance categories.

The categories are:

- Category 3/class C (specified up to 16 megahertz [MHz])
- Category 5e/class D (specified up to 100 MHz)

Backbone Cabling Channel Length Limitations

The backbone cabling length limitations of balanced twisted-pair cabling are applications dependent. Table 5.3 features a listing of all applications classes, the frequency range of interest for each, and examples of applications that operate within each class. The following applications classes listed in Tables 5.3 and 5.4 are based on the channel specifications of the applications and are used as the basis for the backbone cabling channel length limitations.

Table 5.3
Applications classes

Applications Class	Frequency Range	Example Applications
Class A	up to 100 kHz	Basic telephony systems
Class B	up to 1 MHz	ITU-T Rec. I.430, I.431, ISO/IEC 8802-3
Class C	up to 16 MHz	10BASE-T
Class D	up to 100 MHz	1000BASE-T
Class E	up to 250 MHz	1000BASE-T
Class E_A	up to 500 MHz	10GBASE-T
Class F	up to 600 MHz	10GBASE-T
Class F_A	up to 1 GHz	10GBASE-T

GHz = Gigahertz
IEC = International Electrotechnical Commission
ISO = International Organization for Standardization
ITU-T = ITU-Telecommunication Standardization Sector
kHz = Kilohertz
MHz = Megahertz

For guidance on backbone length limitations, refer to Table 5.4.

Four-Pair Balanced Twisted-Pair Cable, continued

Table 5.4
Maximum supportable distances for balanced twisted-pair cabling applications

	Applications Classes							
Cabling Categories/Classes	Class A	Class B	Class C	Class D	Class E	Class E_A	Class F	Class F_A
Category 3/class C	2 km (6562 ft)	200 m (656 ft)	100 m (328 ft)	–	–	–	–	–
Category 5e/class D	3 km (9842 ft)	260 m (853 ft)	160 m (525 ft)	100 m (328 ft)	–	–	–	–
Category 6/class E	3 km (9842 ft)	260 m* (853 ft)	160 m* (525 ft)	100 m* (328 ft)	100 m (328 ft)	–	–	–
Category 6_A/class E_A (9842 ft)	3 km (853 ft)	260 m* (525 ft)	160 m* (328 ft)	100 m* (328 ft)	100 m* (328 ft)	100 m (328 ft)	–	–
Category 7/class F (9842 ft)	3 km (853 ft)	260 m* (525 ft)	160 m* (328 ft)	100 m* (328 ft)	100 m* (328 ft)	100 m* (328 ft)	100 m (328 ft)	–
Category 7_A/class F_A	3 km (9842 ft)	260 m* (853 ft)	160 m* (525 ft)	100 m* (328 ft)	100 m* (328 ft)	100 m* (328 ft)	100 m* (328 ft)	100 m (328 ft)

* Extended length limitations of higher categories/classes of cabling remain a subject of future study.

ft = Foot
km = Kilometer
m = Meter

NOTE: For operating temperatures above 20 °C (68 °F), backbone cabling length should be reduced by 0.2 percent per °C for screened cabling. For unscreened cables, backbone cabling length should be reduced by 0.4 percent per °C for temperatures ranging from 20 °C to 40 °C (68 °F to 104 °F) and 0.6 percent per °C for temperatures ranging above 40 °C to 60 °C (104 °F to 140 °F).

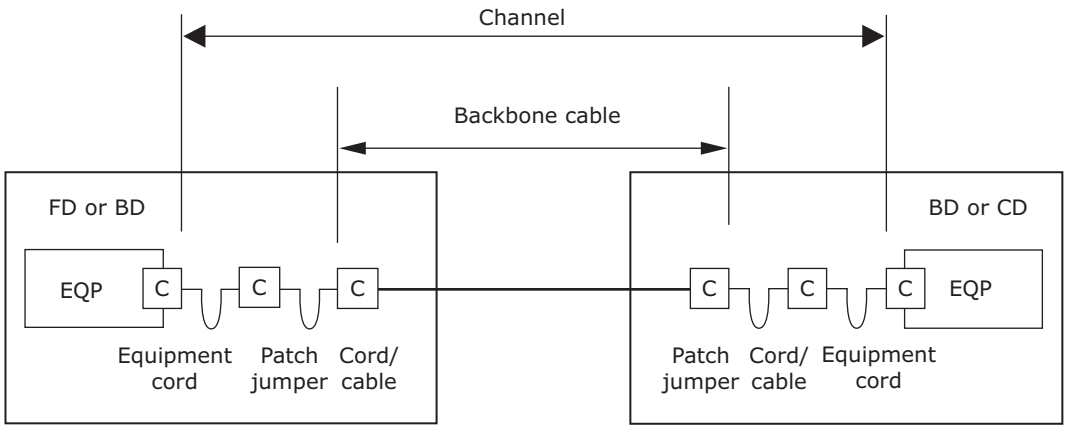
Applications limited by propagation delay or delay skew may not be supported if channel lengths exceed 100 meters (m [328 feet (ft)]).

Backbone cabling consists of the backbone cables, HCs (FDs), intermediate cross-connects (ICs [building distributors (BDs)]), main cross-connects (MCs [campus distributors (CDs)]), mechanical terminations, and patch cords or jumpers used for backbone-to-backbone cross connection. Backbone cabling includes cabling within buildings and between buildings (see Figure 5.2). The term “mechanical terminations” refers to all optical fiber and balanced twisted-pair terminations of cable to connectivity, including optical fiber splicing and balanced twisted-pair splicing. These mechanical terminations are noted in Figure 5.2 using the capital letter C.

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Four-Pair Balanced Twisted-Pair Cable, continued

Figure 5.2
Backbone cabling model



BD = Building distributor
C = Cabling connection (e.g., plug-socket, wire-connector)
CD = Campus distributor
EQP = Equipment (e.g., switches, servers, voice over Internet protocol [VoIP])
FD = Floor distributor

Color Codes

Color codes have been developed to enable the ITS installer to quickly identify any pair within a balanced twisted-pair cable.

ITS installers must be able to identify individual pairs within the cable and the individual conductors within each pair. In telephony, individual conductors are referred to as tip and ring conductors. Each pair has a tip and a ring conductor, or a positive and negative conductor, respectively.

The colors used to identify tip conductors are different from the colors used to identify ring conductors. There are five colors associated with tip conductors, and there are five different colors associated with ring conductors (see Table 5.5).

When two conductors are paired, two different colors identify the pair number. There are 25 possible color combinations when the five tip and five ring color codes are mixed. However, two tips or two rings are never used to make a pair.

Four-Pair Balanced Twisted-Pair Cable, continued

Table 5.5
High pair-count cable, color-coded pairs

	Ring Conductors				
Tip Conductors	Blue 1st Pair	Orange 2nd Pair	Green 3rd Pair	Brown 4th Pair	Slate 5th Pair
White (1–5)	1	2	3	4	5
Red (6–10)	6	7	8	9	10
Black (11–15)	11	12	13	14	15
Yellow (16–20)	16	17	18	19	20
Violet (21–25)	21	22	23	24	25

The tip colors are white, red, black, yellow, and violet. There are five pairs within a tip color. Tip colors indicate in which group a pair is located (e.g., white indicates the pair group is 1, 2, 3, 4, or 5, and black indicates that it is pair group 11, 12, 13, 14, or 15).

NOTE: The tip color does not identify a specific pair number until the combination of the tip and ring colors are matched.

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Four-Pair Balanced Twisted-Pair Cable, continued

The ring colors are blue, orange, green, brown, and slate. The ring color identifies the position of the pair within the group of five tip possibilities (e.g., blue is the 1st pair; green is the 3rd pair within the tip group).

To identify the pair number, the tip and ring colors must be viewed together (e.g., the white/blue pair is actually a white tip and a blue ring). White indicates the pair is between pairs 1 and 5 while blue indicates it is the 1st pair of the group.

NOTE: In another example—the black/brown pair—black indicates pairs 11 to 15 while brown indicates the 4th pair. The 4th pair is the 14th pair in the binder group.

The standard color code can be used to identify up to 25 pairs without duplicating any pair color combinations.

For cables with more than 25 pairs, the first group of 25 pairs is formed into a bundle and has a colored binder (tape or thread) placed around the bundle. Additional bundles (25 pairs) have their own unique colored binder. The colored binder wraps follow the same color code as the individual pair color code. They are referred to as binder groups or binders.

The white/blue binder group is the first and contains cable pairs 1 to 25; the white/orange binder group is the second and contains cable pairs 26 to 50; and the red/blue binder group is the sixth and contains cable pairs 126 to 150.

This system of 25-pair binder groups works for a cable containing up to 625 pairs of cable (25 binders times 25 pairs per binder = 625 total pairs); however, the system stops at 600 pairs. The violet/slate binder group is not used. On some smaller cables (100 pairs or less), the manufacturer may mark the binders by the ring color only since it can be assumed that the tip color is white. See Table 5.6 for a list of pair and binder groups.

When cable exceeds 600 pairs each, 600 pairs (24 binders) are wrapped in a colored super binder. The colored super-group binder denotes 600 pairs. The color code changes from the normal tip/ring identifiers to a simple tip color (e.g., white indicates 1 to 600 pairs; red indicates 601 to 1200 pairs).

Four-Pair Balanced Twisted-Pair Cable, continued

Table 5.6
High pair-count cable, color-coded pairs, and binder groups

Pair			Binder Group	
Number	Tip	Ring	Color	Pair Count
1	White	Blue	White-Blue	001–025
2	White	Orange	White-Orange	026–050
3	White	Green	White-Green	051–075
4	White	Brown	White-Brown	076–100
5	White	Slate	White-Slate	101–125
6	Red	Blue	Red-Blue	126–150
7	Red	Orange	Red-Orange	151–175
8	Red	Green	Red-Green	176–200
9	Red	Brown	Red-Brown	201–225
10	Red	Slate	Red-Slate	226–250
11	Black	Blue	Black-Blue	251–275
12	Black	Orange	Black-Orange	276–300
13	Black	Green	Black-Green	301–325
14	Black	Brown	Black-Brown	326–350
15	Black	Slate	Black-Slate	351–375
16	Yellow	Blue	Yellow-Blue	376–400
17	Yellow	Orange	Yellow-Orange	401–425
18	Yellow	Green	Yellow-Green	426–450
19	Yellow	Brown	Yellow-Brown	451–475
20	Yellow	Slate	Yellow-Slate	476–500
21	Violet	Blue	Violet-Blue	501–525
22	Violet	Orange	Violet-Orange	526–550
23	Violet	Green	Violet-Green	551–575
24	Violet	Brown	Violet-Brown	576–600
25	Violet	Slate	25th binder is not used.	

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Four-Pair Balanced Twisted-Pair Cable, continued

High pair-count cable (more than 4 pairs) is generally used for backbone service and is often referred to as multipair cable.

Balanced twisted-pair cable pairs are color-coded and are usually attached to assigned positions on connecting hardware.

Methods of terminating balanced twisted-pair cable include:

- Insulation displacement contact (IDC)—The specified termination.
- Insulation piercing contact (IPC).

NOTE: Screw terminal connectors are not recommended for telecommunications cabling.

Balanced twisted-pair patch cords or equipment cords:

- May have stranded conductors for added flexibility.
- That are stranded are allowed to exhibit 20 to 50 percent more attenuation than solid conductors.
- Shall meet the same performance rating as the horizontal cabling in use (with the possible exception of insertion loss).
- Usually have 8-position, 8-contact (8P8C) connectors on the ends.
- Must be balanced twisted-pair construction.

If using stranded conductor cable, ensure that the connectors are designed for these stranded conductors and include conductor color codes in accordance with applicable standards (see Table 5.7). The wrong kind of connectors may damage the wire and constitute a faulty connection.

Table 5.7
Color codes for 100-ohm balanced twisted-pair patch cables

Pair	Identification	Conductor Color Code—Option 1	Conductor Color Code—Option 2
Pair 1	Tip	White-blue (W-BL)	Green (G)
	Ring	Blue-white (BL-W)	Red (R)
Pair 2	Tip	White-orange (W-O)	Black (BK)
	Ring	Orange-white (O-W)	Yellow (Y)
Pair 3	Tip	White-green (W-G)	Blue (BL)
	Ring	Green-white (G-W)	Orange (O)
Pair 4	Tip	White-brown (W-BR)	Brown (BR)
	Ring	Brown-white (BR-W)	Slate (S)

NOTE: Option 2 is a legacy telecommunications color code.

Four-Pair Balanced Twisted-Pair Cable, continued

Horizontal Cabling Selection

To support voice and data communications in commercial, industrial, and residential buildings, a minimum of two recognized cables must be terminated to two telecommunications outlet/connectors at individual work area locations. The two telecommunications outlet/connectors at each work area allow support for multiple telecommunications applications at the desk.

The horizontal cabling provided to each individual work area shall consist of telecommunications outlet/connectors connected to:

- 4-Pair 100-ohm balanced category 5e minimum (category 6 or higher recommended).
- Any one of the following (depending on the anticipated needs of work area occupants):
  - 4-Pair 100-ohm balanced category 5e minimum (category 6 or higher minimum recommended).
  - Two or more strands of 50/125 micrometer (μm) multimode (e.g., OM2 minimum) or 62.5/125 μm multimode (e.g., OM1 minimum) optical fiber cable (laser optimized OM3 minimum recommended).
  - Two or more strands of singlemode (e.g., OS1 minimum) optical fiber cable.

NOTE: Telecommunications outlet/connectors that serve an individual work area may be located in one or more faceplates. If specific applications require other types of cabling (e.g., 75-ohm coaxial), the other types may be installed in addition to the cables listed above. To determine the suitability of the cabling types listed above for specific applications, consult systems suppliers, equipment manufacturers, and systems integrators.

The 4-pair cables used in voice and data networks follow a common format for their construction. The balanced twisted-pair color identification for each wire in all four pairs is determined according to the applicable standard for the cabling system being installed.

Crossover of wires and pairs must be completed outside of the fixed cabling (e.g., equipment cords that attach the passive cabling to the active equipment). The cable jacket or sheath is made from a polymer, which exhibits certain characteristics when exposed to fire that will determine its applicability for the environment where it is to be used.

The outside diameter (OD) of 4-pair cables will vary according to the type of cable. These cable types include solid conductors for horizontal and backbone cabling, solid or stranded conductors for equipment cord or patch cord assemblies, and screened, shielded, or unshielded constructions.

The cable sizes range from 4 mm (0.15 in) OD to 9 mm (0.35 in) OD. When passing different cable types and sizes through mechanical firestop assemblies, the cable OD will be critical for maintaining fill ratios to support the firestop system integrity.

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Four-Pair Balanced Twisted-Pair Cable, continued

When installing 4-pair cables, the manufacturer's data sheet will provide details of the maximum pulling tension for installation along with two sets of bend radii—one for installing (under load) and one for dressing in cables (no load). The installation bend radius is often overlooked, but in some respects, it is the most critical.

Four-pair balanced twisted-pair cables are also vulnerable to damage at the time of installation (e.g., through neglect when sharp edges along pathways are exposed). Other trades often do not understand or respect the delicate nature of 4-pair cabling treading on or routing other services alongside the 4-pair cables.

Undercarpet Cable

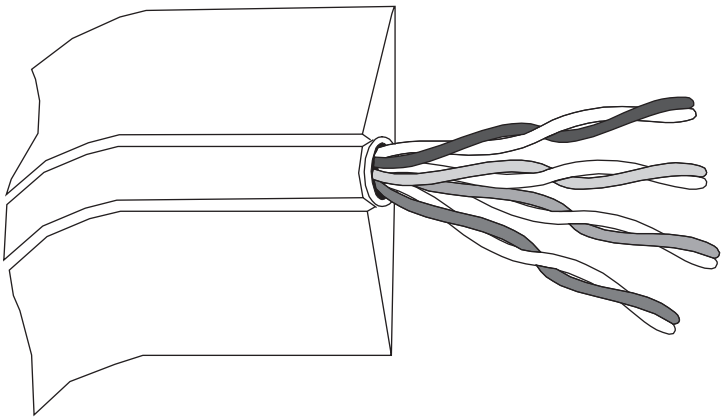
Another form of balanced twisted-pair cable is undercarpet cable (see Figure 5.3). Undercarpet cable should not be the ITS installer's first choice. It is not recommended because of its:

- Susceptibility to damage.
- Limited flexibility for moves, adds, or changes (MACs).

When using undercarpet cable, an ITS installer should avoid:

- High traffic areas.
- Heavy office furniture locations.
- Undercarpet power cable.

Figure 5.3
Undercarpet cable



Cable terminations will involve 4-pair cable from a TP to a work area outlet.

Undercarpet Telecommunications Cable (UTC)

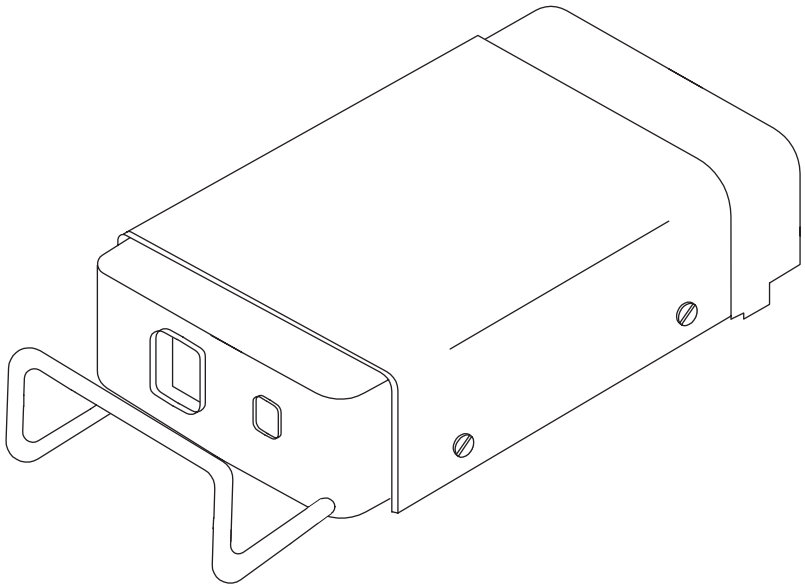
Undercarpet telecommunications cable (UTC) is a flat, low-profile cable designed to be installed directly on the surface of a floor and covered with carpet or carpet tiles (see Figure 5.4). UTC is available in:

- Unshielded pairs.
- Screened/shielded pairs.
- Coaxial.

While it is not recommended that UTC be used, UTC may be specified in situations where the installation of other cable alternatives is not feasible. The ITS installer should coordinate with the ITS designer to define a specific zone distribution layout and to determine the location where the shorter sections of UTC interconnect to the standard horizontal cable media. The interconnection point between horizontal cabling and UTC is a TP.

TPs should be located in a position to limit the length of the UTC, generally less than 10 m (33 ft). A floor monument may be used as the housing for the work area outlet (see Figure 5.4). This monument must be positioned to meet the user's specific needs and in a manner to provide a pathway to the TP. Flat power cables should be installed before the UTC, and the ITS installer must be sure to cross over the power feeds at right angles.

Figure 5.4
Floor monument for undercarpet telecommunications cable



Specific design limitations with UTC that can prohibit its installation are that:

- The media may not be capable of meeting the high performance standards required for the job.
- The environment may not be suitable (e.g., damp location).
- The surface preparation of the flooring may not be adequate to support the installation.

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Screened/Shielded Twisted-Pair Cable

Screened/shielded twisted-pair cable is becoming more widely used as the requirements for high performance applications demand greater protection for signals from outside noise sources. Although screened/shielded cabling may be more expensive than UTP, screened/shielded cabling offers a higher immunity to electromagnetic interference (EMI) and may also be used in areas susceptible to radio frequency interference (RFI).

The construction of screened/shielded cables differs significantly from one manufacturer to another. These cable types feature a number of different configurations of braid/mesh screen, foil shield, or a combination of braid screen and foil shield.

Screened/shielded cabling is very effective at significantly reducing emissions from the captive balanced twisted-pairs while featuring good immunity to undesirable sources of EMI and RFI.

When foil is used, an optional drain wire may be used inside the cable adjacent to the conductive side of the foil screen. Cable manufacturers do not always employ this practice when placing a foil over each individual pair within the cable.

Cabling system manufacturers provide details of their installation and termination practices to maintain the integrity of the cabling system performance. Proper installation practices vary by manufacturer.

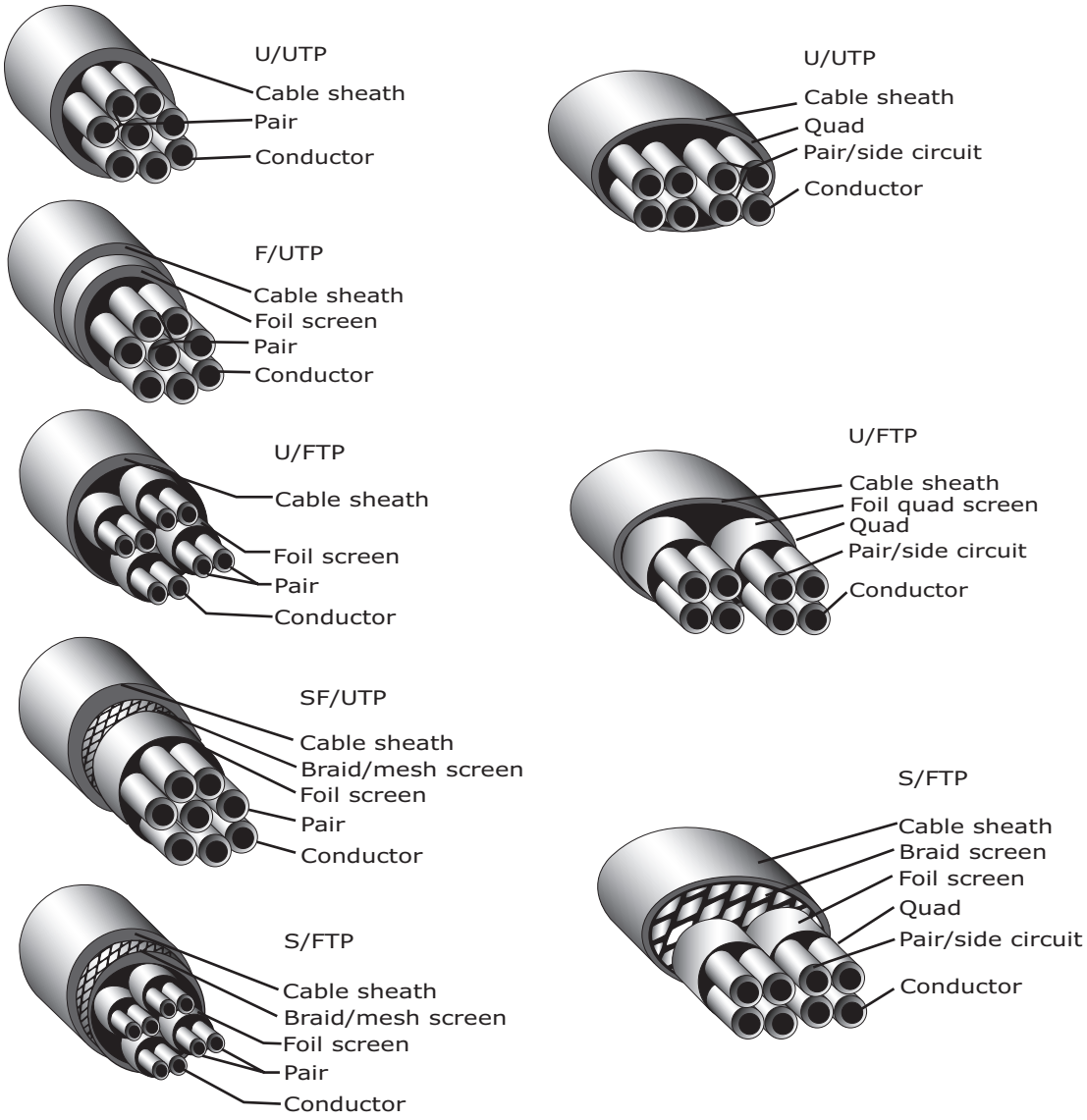
Two common screened/shielded cable types include:

- Overall foil screened with unshielded twisted-pairs (F/UTP) also known as ScTP.
- Braid/mesh screen surrounding individually S/FTP.

See Figure 5.5 for examples of screened/shielded and unshielded balanced twisted-pair cable designs.

Screened/Shielded Twisted-Pair Cable, continued

Figure 5.5
Screened/shielded and unshielded balanced twisted-pair cable design examples



F/UTP = Overall foil screened with unshielded twisted-pair
S/FTP = Overall braid screen with foil screened twisted-pair
SF/UTP = Overall braid and foil screened with unshielded twisted-pair
U/FTP = Overall unshielded twisted-pair with foil screened twisted-pair
U/UTP = Overall unshielded twisted-pair with unshielded twisted-pair

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Screened/Shielded Twisted-Pair Cable, continued

Screened/shielded cables:

- Have a characteristic impedance of 100 ohm (± 15 ohm).
- Have four pairs of 22 AWG [0.64 mm (0.025 in)] to 24 AWG [0.51 mm (0.020 in)] solid conductors.
- May have a lower twist rate for each pair versus that for a UTP cable.
- Feature a number of different configurations of braid/mesh screen, foil shield, or a combination of braid/mesh screen and foil shield.
- Often have drain wire for bonding to ground (earth).
- Have similar electrical performance characteristics as the UTP equivalent category or class of cabling.
- May be used where additional protection from EMI or RFI is desired.

Screened/shielded patch cords/equipment cords:

- May have stranded or solid conductors for flexibility.
- May be constructed with 26 AWG [0.41 mm (0.016 in)] stranded wire conductors, which are allowed to exhibit up to 50 percent more attenuation when compared with 24 AWG [0.51 mm (0.020 in)] sized solid conductors.
- Shall meet the same transmission performance criteria as the horizontal cabling in use (with the possible exception of insertion loss).
- Usually have connectors with a metal screen/shield around the plug and outlet housing.
- Must be balanced twisted-pair construction.

Connecting Hardware

Overview

Connecting hardware is a mechanical device (e.g., plug, jack) attached to the end of a cable or to a piece of equipment. Connecting hardware is often referred to as a connector. When two connectors are mated, electrical signals (in copper systems) or light impulses (in fiber systems) can be transferred from one cable or piece of equipment through the connectors to the other cable or other piece of equipment.

Connectors are as essential to the integrity of an ITS network as is the cable itself. Together, the cable, the connectors, and the active equipment devices form the telecommunications channel through which information moves.

The connector provides the physical attachment from the media to:

- An active ITS device (e.g., transmitter, receiver, transceiver).
- A passive ITS device (e.g., patch panel to patch panel).

Along a cable path, connections can contribute to the loss of signal (insertion loss) from transmitter to receiver. The role of the connector is to provide a coupling mechanism that keeps loss to a minimum.

Some of the key factors in establishing a good connection and minimizing loss of signal include:

- Fit—The attachment must be sufficiently secure to prevent the connectors from separating unintentionally.
- Alignment—The device must provide the physical alignment necessary to properly complete the link.
- Functionality—The connection must provide efficient transfer of electricity from cables to connectors.
- Configuration—Connectors must be designed specifically for the media and the devices being connected.

Durability is demonstrated by the connectors' ability to withstand hundreds of insertion and withdrawal cycles without failing. This is calculated as mean time between failures (MTBFs).

Most connectors are classified as "male" and "female." In general, outlets or jacks are female connectors, and plugs are male connectors.

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Types of Outlet Interfaces

Suitable connecting hardware must be used to ensure proper signal transmission. The ITS installer must ensure that the connectors being installed are designed specifically for the media being connected. Various types of outlet interfaces are currently used within the industry as shown in Table 5.8.

Table 5.8
Outlet interfaces designed for media to be connected

Media	Outlet Interface
Balanced twisted-pair	8P8C connector (screened/shielded or unshielded)
Coaxial	BNC series connector F series connector N series connector

8P8C = 8-position, 8-contact
BNC = Bayonet Neill-Concelman

Additional connectors used to interconnect electronic equipment are:

- Telco 50-pin connectors.
- D-subminiature connectors.

Twisted-Pair Connectors

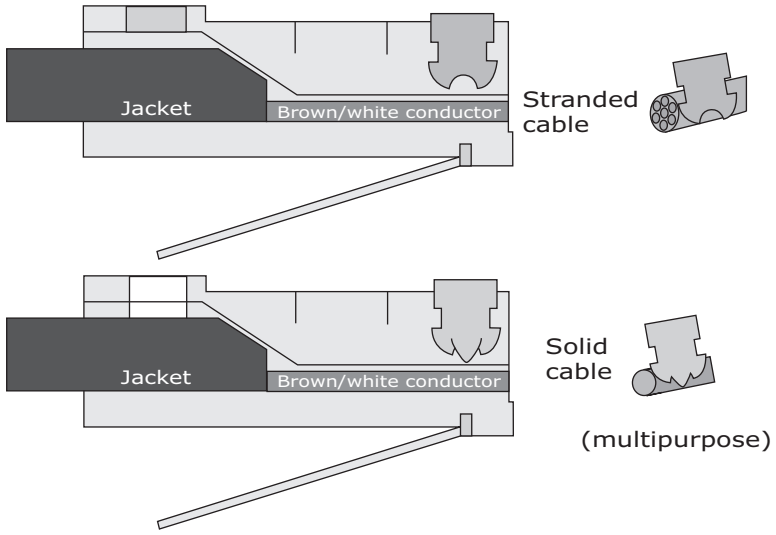
Twisted-pair cable requires IDCs. An IDC connection permits the termination of an insulated conductor without stripping insulation from the conductor. As the insulated conductor is inserted between two or more sharp edges of the contact, the insulation is displaced, allowing contact to be made between the conductor and the connector terminal. Connectors have IDCs designed for solid conductors or IPCs designed for stranded conductors as well as contact terminations having universal contacts that accept either stranded or solid conductors.

Types of Outlet Interfaces, continued

Modular plug contacts for stranded conductors are designed as a single blade intended to penetrate the conductors' insulation and insulation piercing connection and slide between the individual conductor strands (see Figure 5.6). This type of contact cannot be used with a solid conductor because it has no strands to slide between; the solid conductor may be nicked or broken if this type of contact is used. Nicked conductors soon break from fatigue and can become nonfunctional or subject to intermittent opens (no electrical pathway).

NOTE: It is rare to achieve a reliable connection using a connector designed for stranded cable on a solid conductor.

Figure 5.6
8-position, 8-contact modular plug, stranded/solid



Modular plug contacts for solid conductors are designed with three fingers that penetrate the insulation on both sides of the conductor. The fingers provide an electrical connection by trapping the conductor between the fingers.

Some manufacturers market solid-conductor modular plug contacts as multipurpose connectors capable of terminating both stranded and solid conductors. These connectors work well for solid conductors. However, the connectors do not always provide a connection as reliable as the single-bladed contact when used with a stranded conductor.

Some manufacturers market universal modular plugs capable of terminating both stranded and solid conductors.

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Types of Outlet Interfaces, continued

AT&T developed the universal service order code (USOC) system for the identification of parts and services delivered within its service areas. The Federal Communications Commission (FCC) adopted the USOC system that related to some of the interface jacks used for connecting various devices to the public telephone network. Designations (e.g., RJ-21X) were used to define the physical connector as well as, in some cases, how the physical connector was to be wired.

The specific codes as adopted in part by the FCC are:

- RJ—Registered jack.
- C—Flush- or surface-mount jack.
- W—Wall-mount jack.
- X—Complex or multiline connector.

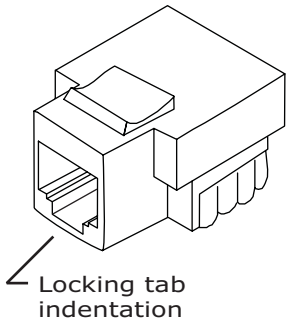
The following are the three common modular connectors used in ITS:

- 4P4C—4-position, 4-contact connectors are used primarily for telephone handset cords.
- 6P6C—6-position, 6-contact connectors are used primarily for telephones and modem line cords.
- 8P8C—8P8C connectors are used for ITS and patch cords.

NOTE: See Appendix B: Network Interfaces and Demarcation Points in the United States in BICSI's *Telecommunications Distribution Methods Manual*.

Modular jacks are designed to connect balanced twisted-pair cables to equipment via equipment cords. The cables are terminated on the rear of the jack while the connector's front provides access for the equipment cord via the modular 8P8C plug (see Figure 5.7).

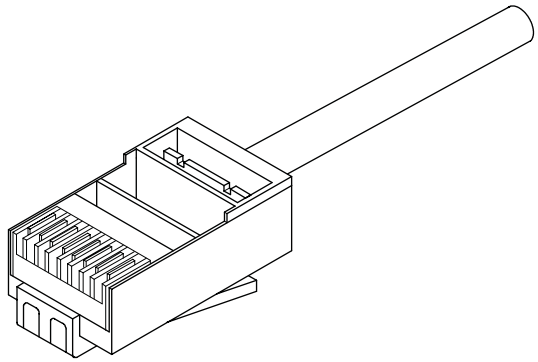
Figure 5.7
8-position, 8-contact modular jack



Types of Outlet Interfaces, continued

An 8P8C modular connector shall be utilized for 4-pair cable termination. Modular plugs and connectors are available in various sizes and shapes (keyed/non-keyed). The number of positions (8P) indicates the connector's width while the number of contacts (8C) installed into the available positions indicates the maximum number of conductors the connector can terminate. See Figure 5.8 for an example of a non-keyed 8P8C modular plug.

Figure 5.8
8-position, 8-contact modular plugs non-keyed



Telephone system manufacturers may supply line cords composed of 6P2C plugs with a 2-conductor cable. This can be a problem if the ITS installer tries to use these cords on another type of equipment that requires more than one pair of conductors.

Twisted-pair connectors may be 8P8C modular jacks or plugs and are designed to:

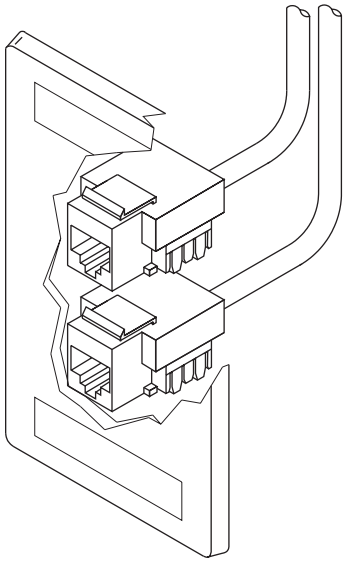
- Terminate 100-ohm, 4-pair, 22 AWG [0.64 mm (0.025 in)] to 24 AWG [0.51 mm (0.020 in)] cable.
- Support up to 1000 MHz, category 7_A/class F_A standards.
- Use IDC terminations.

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Types of Outlet Interfaces, continued

The jack should be installed with the contact pins up and the locking tab indentation down. When viewed from the front, the pin numbers run from left to right consecutively 1-8. Figure 5.9 shows twisted-pair work area horizontal cables mated to twisted-pair outlet connectors on a faceplate.

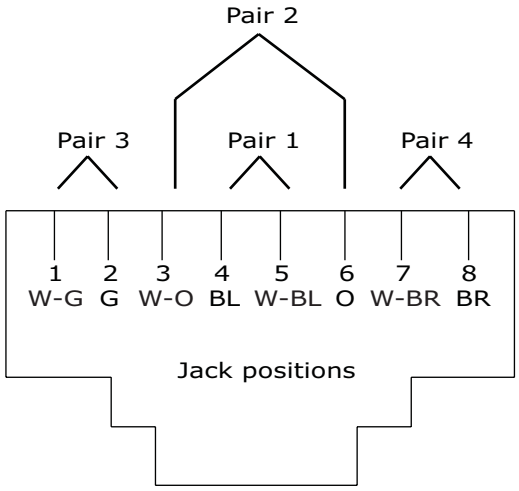
Figure 5.9
Telecommunications outlet and connectors



Types of Outlet Interfaces, continued

Modular jacks are capable of accepting pin assignments compatible with all known data applications operating over 100-ohm twisted-pair cable. These are shown in Figure 5.10.

Figure 5.10
Preferred 8-position, 8-contact jack pin/pair assignments T568A



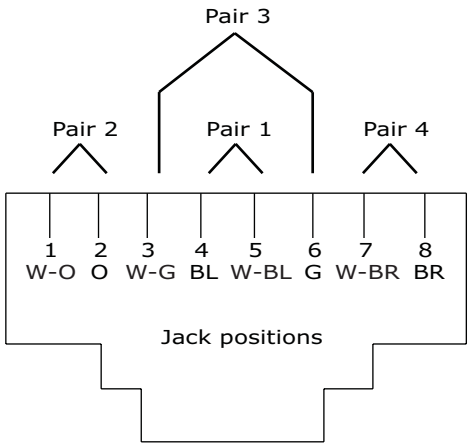
BL = Blue
BR = Brown
G = Green
O = Orange
W = White

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Types of Outlet Interfaces, continued

Certain 8-pin cabling systems may require the designation of T568B for optional pin/pair assignments. The optional 8-position assignments are shown in Figure 5.11.

Figure 5.11
Optional 8-position, 8-contact jack pin/pair assignments T568B

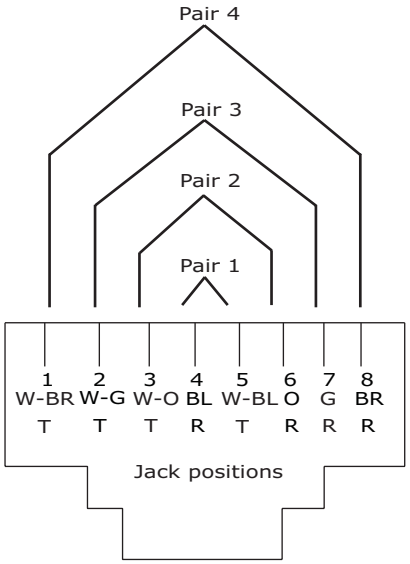


BL = Blue
BR = Brown
G = Green
O = Orange
W = White

Types of Outlet Interfaces, continued

A legacy pin/pair assignment for telephony is designated as USOC (see Figure 5.12). USOC pin/pair assignments are not suitable for network cabling applications but may still be in use to support analog telephony applications.

Figure 5.12
Legacy 8-position, 8-contact jack pin/pair assignments universal service order code



BL = Blue
BR = Brown
G = Green
O = Orange
R = Ring
T = Tip
W = White

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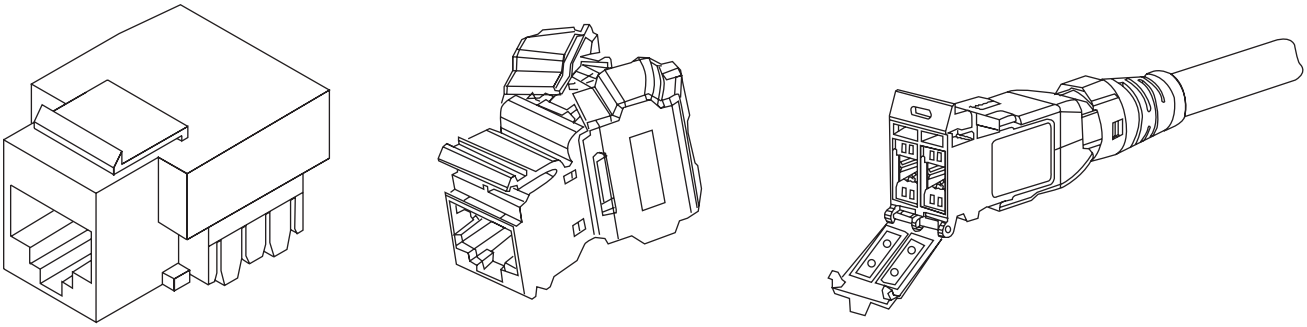
Types of Outlet Interfaces, continued

Screened/Shielded Twisted-Pair Connectors

Screened/shielded cabling installations require a shielding element associated with every component of the cabling system. Screen/shield continuity is maintained from the first connector in the TR to the work area outlet through the user's equipment cord and to the equipment's chassis ground. A metal screen/shield typically surrounds each modular jack. The cable's drain wire, if present, and the foil screen must be attached to the connector's screen/shield.

Screened/shielded patch cords and equipment cords must be used to extend the screen/shield from the shielded modular jacks (see Figure 5.13). Each cord consists of a solid or stranded screened/shielded cable with a screened/shielded modular plug on each end. Each plug has a metal shield surrounding it. The cable's drain wire, if present, and the foil screen must be bonded at every connection.

Figure 5.13
Balanced twisted-pair modular jack



Unshielded connector Shielded connector Category 7_A connector

An 8P8C shielded modular connector is utilized for 4-pair screened/shielded cable. When prepared and terminated properly, the connector ensures a good connection and will serve to reduce electrical interference from external sources.

Outlets or jacks are female connectors while plugs are male connectors. Shielded connectors are 8P8C modular jacks or plugs that are:

- Designed to:
  - Terminate 100-ohm, 4-pair, 22 AWG [0.64 mm (0.025 in)] to 24 AWG [0.51 mm (0.020 in)] cable.
  - Support up to 1000 MHz, category 7_A/class F_A standards.
  - Use IDC terminations.
- Be covered by a metallic screen/shield.
- Be connected to the screen/shield and drain wire (if present).

Types of Outlet Interfaces, continued

Overall Braid Screen with Foil Screened Twisted-Pair (S/FTP) Cabling Connectors

The S/FTP cabling connectors approved for use with category 7/class F and category 7_A/class F_A cabling include those defined in applicable standards listed in the reference section of this chapter (see Figures 5.14-5.18 for examples).

Figure 5.14
4-Pair screened/shielded twisted-pair cable example

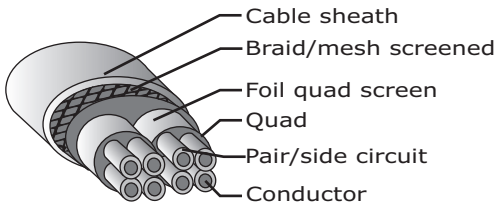
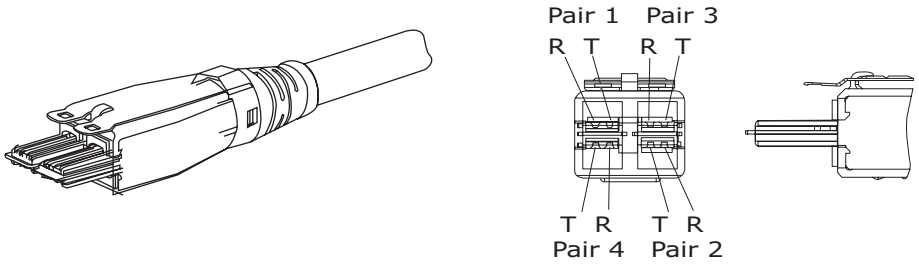
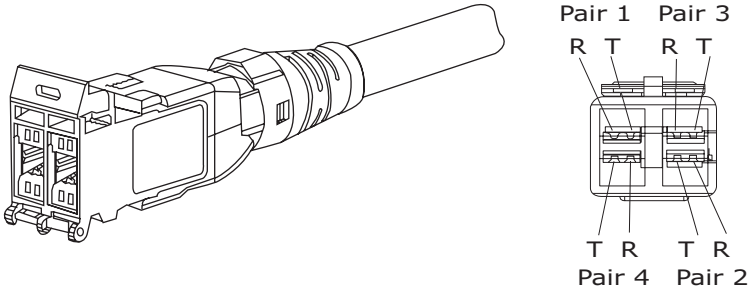


Figure 5.15
4-Pair screened/shielded twisted-pair connecting hardware (plug) example



T = Tip
R = Ring

Figure 5.16
4-Pair screened/shielded twisted-pair connecting hardware (outlet) example



T = Tip
R = Ring

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Types of Outlet Interfaces, continued

Figure 5.17
4-Pair screened/shielded twisted-pair connecting hardware (plug components) example

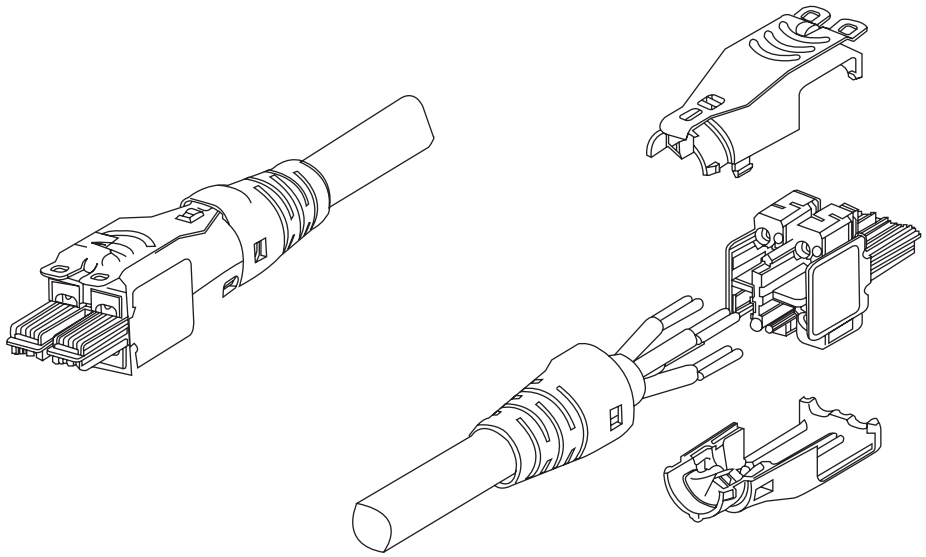
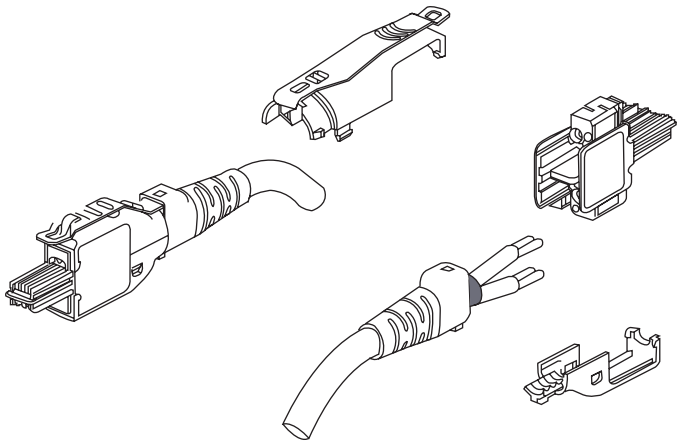


Figure 5.18
2-Pair screened/shielded twisted-pair connecting hardware (plug components) example



Matching Connectors to Media Type

Table 5.9 shows the industry-standard connectors specified for different types of cable.

Table 5.9
Cabling specifications related to application standards

Standard	Minimum Category/Class	Maximum Distance	Topology Logical	Topology Physical
10BASE-T	Category 3/class C or higher	100 m (328 ft)	Bus	Star
100BASE-TX	Category 5e/class D or higher	100 m (328 ft)	Bus	Star
1000BASE-T	Category 5e/class D or higher	100 m (328 ft)	Bus	Star
10GBASE-T	Category 6_A/class E_A or higher	100 m (328 ft)	Ring	Star

ft = Foot
m = Meter

NOTE: The 8P8C modular connectors are the type used in the standards and IEEE® specifications.

Under IEEE 802.3, the first set of numbers describes the amount of information or megabits per second (Mb/s) the segment can support.

The term BASE describes the number of signals on the media at the same time. BASE refers to baseband, which has only one carrier channel that restricts the media to a single signal, thus monopolizing the media's entire bandwidth during the transmission. This differs from a broadband transmission where multiple signals can co-exist in the media by using different frequencies (e.g., community antenna television [CATV]).

If the last designator is a letter and not a number (as in 10BASE-F or 10BASE-T), the letter represents the media. For example, the F represents fiber, and the T represents twisted-pair. Both types of media are in the standards with strict distance limitations (e.g., twisted-pair cannot exceed 90 m [295 ft] when used for data transmission).

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Coaxial Cable

The predominant coaxial cables are Series-6, Series-11, and Series-59. These video cables have a characteristic impedance of 75 ohm. There may be special backbone applications where a larger diameter cable is specified. While the termination procedures may be similar, special attention must be paid to the manufacturer's specific instructions for termination and connectors.

Coaxial cable is unbalanced and consists of a centered inner conductor insulated from a surrounding outer conductor and an overall jacket. Coaxial cable (commonly referred to as coax) is used for computer networks, CATV, and video systems. Historically, coaxial cable was designated as radio grade (RG) cable. Coaxial cables used in broadband applications are now referred to as Series "X" cables. RG cables were originally military specifications utilizing a solid dielectric whereas series cables have a foamed dielectric. The "X" designates the construction of the cable with such factors as:

- Center conductor diameter.
- Center conductor being solid or stranded.
- Dielectric composition.
- Outer braid percent of coverage (e.g., 80 percent or 95 percent coverage).
- Impedance.

Screw-on and hex crimp coaxial connectors are not recommended for commercial building installations and should be avoided because of their performance characteristics. Although convenient, these connectors can result in intermittent problems that can be difficult to troubleshoot.

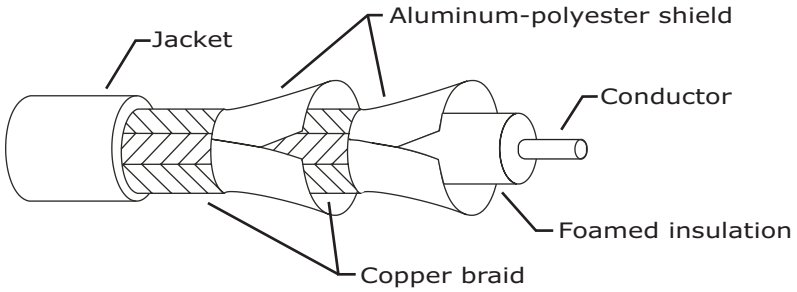
Coaxial Cable, continued

Series-6 coaxial cable is used for video, CATV, and security cameras (see Figure 5.19).

Series-6 has a:

- Characteristic impedance of 75 ohm.
- Coated foil shield over the dielectric to shield against high frequencies.
- Braided shield over the coated foil to shield against low frequencies.
- Solid-center conductor.
- F or Bayonet Neill-Concelman (BNC) connector.

Figure 5.19
Series-6 quad shield coaxial cable



Series-11U is used in video backbone distribution. It has less signal attenuation than Series-6, making it the preferred choice for longer runs.

Series-11U has a:

- Characteristic impedance of 75 ohms.
- Coated foil shield over the dielectric to shield against high frequencies.
- Braided shield over the coated foil to shield against low frequencies.
- 18-14 AWG [1.0 mm (0.039 in)-1.6 mm (0.063 in)] solid or stranded center conductor.
- F or N connector.

Coaxial cables of each series are available in a variety of configurations—jacket types, shield configurations, bandwidths, and attenuations. A coaxial cable cannot be selected by simply identifying the physical size (series); a full understanding of the application is necessary.

Many supply houses and most manufacturers offer consultation services to assist in the selection of the cable best suited to the needs of the job.

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Coaxial Cable, continued

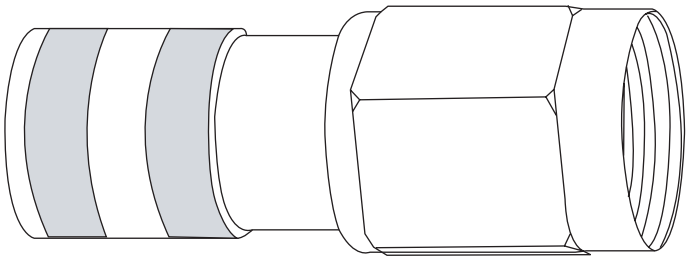
Coaxial Connectors

Either male or female connectors can be attached to coaxial cable; however, most installations use male connectors on cable ends. Purchase coaxial patch cables with connectors already attached if possible.

F Coaxial Connectors

F connectors do not have center pins. Instead, the connector uses the solid center conductor of the cable as a center pin. For this reason, F connectors cannot be used with cables that have a stranded center conductor (see Figure 5.20).

Figure 5.20
One-piece crimp-style F connector



F connectors are:

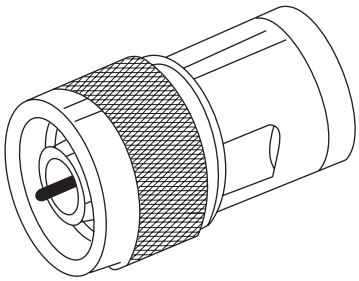
- Economical.
- Used for connecting Series-59, Series-6, and Series-11 coaxial cable to video, CATV, and security cameras.
- The most widely used connector for residential cable service.
- Available as one- or two-piece connectors. One-piece connectors have built-in crimp sleeves or compression components. Two-piece connectors have separate crimp sleeves that must be crimped over the outer braid. The one-piece compression connectors are gaining favor because of their higher bandwidth capabilities for satellite and broadband cable installations.
- Required since the use of a special tool compresses the connector longitudinally rather than the traditional hex collar crimp.
- Available as a screw-on connector. These types are not recommended for commercial use.

Coaxial Cable, continued

N Coaxial Connectors

N connectors are used in data, radio, and video applications (see Figure 5.21). The connector consists of a threaded coupling nut similar in design to an F connector except it is larger.

Figure 5.21
N connector

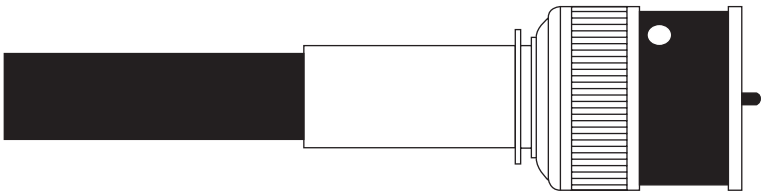


N connectors have a center pin that must be installed over the cable's center conductor. The N male connector uses a threaded outer collar to mate with the female connector.

Bayonet Neill-Concelman (BNC)

Named for its designers, the BNC connector has been in use since the 1940s (see Figure 5.22). BNC connectors have a center pin that must be installed over the cable's center conductor and are used with RG59 (75 ohm) coaxial cable.

Figure 5.22
Bayonet Neill-Concelman connector (hex crimp)



Three types of BNC connectors are common:

- Crimp
- Three piece
- Screw-on (not recommended for commercial applications)

Crimping requires a special tool but no solder. The three-piece connector may require crimping or solder to hold the conductor to the center pin. The proper tool is especially important for obtaining an effective crimp on the sleeve of the connector.

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Installing Cable

Overview

Placing cable is an important part of a successful installation. In addition to pulling techniques, the ITS installer must be familiar with industry standards and codes as well as the system's overall design. This section highlights tasks and procedures common to all ITS cabling installation projects and describes specific types of cable installation.

Common Project Procedures

Cabling installation encompasses a variety of pathways, cable types and sizes, pulling methods, and tools. Every project combines these items in a unique way to meet the customer's requirements. However, some elements are common to all cabling installation projects:

- Knowledge of industry standards and codes
- Understanding of the project design
- Project planning
- Systematic and consistent methods employed
- Safety procedures
- Firestopping methods
- Job wrap-up tasks

There are several cable installation factors that should be considered. These include:

- Pulling tension.
- Bend radius.
- Physical damage.
- Cable organization/orientation in pathway.
- Cable conditioning—Cables should be conditioned for temperature within the manufacturer's guidelines prior to pulling.

Standards and Codes

All installations must adhere to electrical, fire, and building codes and should follow industry standards. Knowledge of national and local codes, an understanding of cabling installation standards, BICSI best practices, and manufacturer's specifications are critical to the success of the project.

Understanding the Customer's Design

As part of the planning process described in Chapter 10: Planning and Project Management, the ITS installer should review the cabling installation drawings, specifications, and scope of work (SoW) prior to starting the project. Knowledge of the overall design requirements, including the types, sizes, and routes of both media and pathways, will help the ITS installer determine the tools and procedures needed to install cable.

Media

The majority of new construction and renovation projects involve the installation of copper and/or optical fiber cabling. This cabling supports many different kinds of technology applications, including:

- Voice communications.
- Data communications.
- Video systems.
- CATV systems.
- Power over Ethernet (PoE).
- Voice over Internet protocol (VoIP).
- Other building information systems (e.g., monitoring, fire alarm, security, paging, audio).

There are two types of cabling installation—horizontal and backbone. Horizontal cable is installed between the TRs or TEs and the work area telecommunications outlet/connector. Backbone cabling is used to interconnect TRs, TEs, equipment rooms (ERs), and entrance facilities (EFs).

Cable is susceptible to damage during pulling. Exceeding the maximum pulling tension of the cable may adversely affect the transmission characteristics of the cable. The maximum pulling tension of 4-pair, balanced twisted-pair cable shall be 110 Newtons (N [25 pounds-force (lbf)]). For other cable types, manufacturers' pulling tension guidelines shall be followed. The maximum pulling tension for cable is typically expressed in units of Newtons or pounds-force. The Newton is a metric measure of force equal to 105 dynes or 4.45 lbf. To convert a Newton force to a pound force, divide it by 4.45. For example, a maximum pulling tension of 100 N converts to approximately 22.5 lbf.

The minimum bend radius of 4-pair cable shall be four times the cable diameter. For other cable types, manufacturer cable bend radius guidelines shall be followed.

Physical damage to the cable jacket of insulated conductors must be avoided. Stretching, kinking, excessive spiraling, and other forms of cable damage may adversely affect the cable transmission performance. Always communicate with personnel at the payout end of the reel or box to assure a smooth pull.

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Understanding the Customer's Design, continued

Pathways

Like media, pathways are classified as horizontal, intrabuilding, and interbuilding backbone pathways.

NOTE: See Chapter 3: Cabling, Pathways, and Spaces for details on pathways.

Horizontal pathways are typically provided for the installation of cabling between TRs or TEs and work areas. Intrabuilding backbone pathways normally provide access for backbone cabling between TRs and TEs whereas interbuilding backbone pathways connect buildings.

Building designs use several types of horizontal pathways, including:

- Conduit—Conduit may be installed from the work area telecommunications outlet/connector to the TRs in what is usually called a home run. Use caution to ensure that the maximum fill ratio of the conduit is not exceeded. Regardless of code requirements for fill ratio, best practices dictate following these guidelines for ease of pulling. Following fill ratio for firestopping is critical since an overfilled conduit cannot be effectively firestopped.
- Cable trays—Cable trays are often used to provide a means of support for large quantities of horizontal cable or high pair-count backbone cables.
- Open-top supports—These devices are often used when conduit and cable trays are not available or appropriate (e.g., for individual horizontal cable runs serving a work area). These devices shall not be attached to the ceiling grid support system. They should be attached to the building structure.

  NOTE: Structural steel (red iron), roof support, or other building structures should only be used with an appropriate supporting hook, ring, or clamp designed to support the weight of the cables installed and to protect the cable after placement. Cable should not be placed within the framework of structural steel (red iron).

Backbone pathways may consist of sleeves that connect the spaces or rooms used for backbone cables. If these spaces are stacked (located one above the other), interfloor sleeves are typically provided. In the event a room is not stacked, a home run conduit method may be used.

Project Planning

After reviewing the cabling installation documents to determine what is required on the project, the ITS installer can prepare for the job. The following precable-pulling tasks are essential:

- Determine controls to ensure that consistent methods are used in placing each type of cable.
- Ensure that correct lengths and types of cable are readily available.
- Ensure that the appropriate labels are available.
- Identify and obtain appropriate cabling installation system components, equipment, and supplies.

  NOTE: See Pulling Cable Setup in this chapter for additional information.

- Identify locations for accessing and pulling the cable.
- Determine the staffing required, and assign tasks to team members.
- Obtain equipment that allows ITS installers to communicate with each other.

NOTE: Special consideration should be given to installation requirements for preconnectorized cables utilizing pulling eyes.

Pull Strings

Pulling cable through a conduit requires some type of pulling device attached to the cable that precedes it through the conduit. That pulling device is a pull string or rope.

Methods for installing the pull string or rope through the conduit include:

- Fish tape—A fish tape is a steel or fiberglass wire rigid enough to be pushed all the way through the conduit or, in longer runs, to a pull box. It is used to retrieve the pull string or rope from the far end.
- Air-propelled devices, including:
  - A vacuum on one end and a foam ball (rat) attached to a pull string on the other end.
  - A compressed air bottle or mechanical blower used to propel a pull string attached to the propellant object.

Other devices can be purchased or set up on the job.

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Project Planning, continued

The installation of pull strings for cable pulls in an open ceiling and walls may be different from those used with conduit. Various ways are used to pass the pull string through the pathway, including:

- A tool used to extend the reach across building structures. These tools include:
  - Fish tape.
  - Fiberglass poles.
  - Telescoping poles.
  - Expanding rods.
- Drop chain or fish chain for use inside walls.
- Remote-controlled appliances attached to the pull string.

For all of these methods, it is essential that the cables have a straight and smooth path.

In many projects, the ITS installer will have to pull backbone balanced twisted-pair cable with high pair counts. A 2400-pair, 24 AWG [0.51 mm (0.020 in)] backbone cable could weigh as much as 46.3 kilograms per meter (kg/m [21 pounds per foot (lb/ft)]). As a result of this weight, use a pull rope and attachment device of sufficient strength to pull the cables.

The recommended cable slack, once cables are in place, is listed in Table 5.10.

Table 5.10
Recommended cable slack

Location	Service Slack
Work area 4-pair cables	305 mm (12 in) minimum slack after termination
TR/ER 4-pair	Farthest corner via the pathway plus floor to ceiling
TR/ER multipair	Length of backboard plus floor to ceiling
TE	2 m (6.6 ft) stored outside the enclosure

ER = Equipment room
ft = Foot
in = Inch
m = Meter
mm = Millimeter
TE = Telecommunications enclosure
TR = Telecommunications room

Project Planning, continued

Verification of Cable Lengths and Types

Balanced twisted-pair cable arrives from the distributor in boxes or on reels. When reels are received, the cable may have been taken from a larger reel and spooled onto a smaller reel. Cable reels may be steel, plastic, or wood; they should be returned to the factory if possible.

The size of the reel depends on the size and quantity of the cable. High pair-count cable can be loaded onto reels that are up to 2 m (6.6 ft) high and 1.5 m (4.9 ft) wide.

When high pair-count cable is received at the work site, verify the cable length. Although cable is shipped from the manufacturer with a cable run label that indicates the length of the cable, do not take this measurement for granted.

Sometimes a distributor has not verified the cable length after spooling it from a large to a smaller cable reel, and it may be too short or too long. Inspect both ends of the cable, if practicable, to verify the footage markings on the outer jacket and compute the actual length of the jacket. This is an accurate method for verifying cable length.

When the nominal velocity of propagation (NVP) is properly set for the cabling under test, the use of a time domain reflectometer (TDR) will provide an accurate reading of electrical cable length.

High pair-count cables should be ordered with a factory-equipped pulling eye. If this is not possible, install a field assembled pulling eye prior to placing the cable.

Cable Bend Radius

All cables have a minimum bend radius that must be maintained both during the pulling process and after the cable is installed so as to not damage the cable. Prior to beginning the pull, verify controls are in place that will ensure that the minimum bend radius limits will not be exceeded for all cables.

Cable Bend Radius Guidelines

The minimum cable bend radius must be controlled at all times during the installation. Additional tools (e.g., pulleys, wheels) or additional personnel may be needed to maintain the proper bend radii during the pull.

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Project Planning, continued

Tools and Equipment

The physical weight of backbone cable often requires special tools and installation apparatus to assist the ITS installers. For vertical pathways, cabling is more easily pulled from the top down than from the bottom up because gravity helps with the pull. This is the preferred method if the reels of cable can be moved to the top floor.

Sometimes the reels are too large to fit through doors, or there is limited floor loading or elevator capacity. When necessity demands it, backbone cable is pulled from the bottom up.

In both cases, special cable-handling devices may be required, including:

- Winches.
- Cable reel brake.
- Temporary take-up devices.
- Bullwheels.
- Pulleys.
- Mesh grips.
- Mule tape (pull ropes).

The type of equipment needed depends on the direction of the pull. If pulling from the bottom up, a winch may be needed. If pulling from the top down, a reel brake may be needed. A reel brake is a device used to control the rate of removal (payout) of a cable from a cable reel.

Locations for Accessing and Pulling Cable

Determine if a loading dock, forklift, or other mechanical device is available to off-load large cable reels at the delivery site. While many delivery trucks are equipped with lift gates, some larger reels cannot be handled in that manner.

The ITS installer must make plans for locations to store cable that is awaiting placement and have a method for moving cable reels from the storage point to the pulling location. This includes a pathway suitable for the material and its conveyance (e.g., wide doorways and elevators equipped to handle the weight and room to set up reel supports, pulleys, and associated equipment).

Project Planning, continued

Telecommunications Equipment

Communications with coworkers is an essential part of every cable placement. Each person involved in the pull should have a designated responsibility. Everyone should be prepared to alert the person in charge of pulling the cable about possible safety concerns, problems, and situations that are wasting time or materials.

Cable must not be allowed to twist, kink, or bind during placement. Eliminate excessive spiraling. If these conditions arise, the pull must be stopped and corrective action must be taken.

Communication in this instance consists of two major components—the means to communicate (e.g., radios, intercoms, other electronic devices) and a commonly understood set of commands.

Terms such as “back,” “forward,” and “the other way” can mean completely different things to people standing apart on a work site. Ensure that the placement crew agrees upon a standard set of commands, the methods to be employed, and the responsibility of each person for communications.

Safety Procedures

The safety of everyone involved is important, including the building occupants, cabling team members, and other contractors working on the work site.

ITS installers must participate in their company safety programs, follow company policies and practices, and be capable of providing basic first aid. To help ensure a safe installation, the cable puller must follow safety procedures in several areas.

NOTE: See Chapter 2: Safety Procedures for more detailed information.

Clear Designation of Work Areas

Before work begins, it is important to secure the area to restrict access to authorized personnel only. Safety cones, yellow tape, and folding A-frame signs may be used for this purpose. If the area of work is near a door or hallway corner, the markers should give oncoming pedestrians adequate advance warning of a hazard. In addition, work areas should never be left unattended if they present a hazard (e.g., open floor systems or open ceiling systems with open access panels or equipment). Remove caution markers as soon as the work is complete. If the markers are left and people realize the work is finished, the warnings may be ignored. This could cause an accident in the future when a real danger exists.

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Safety Procedures, continued

Proper Use of Tools and Equipment

All tools must be examined regularly to ensure that they are in safe working conditions. Cabling installation involves a variety of tools and equipment that prevent safety risks. To help prevent accidents, manufacturers require users to be certified for use of certain tools (e.g., powder-actuated tools). However, even a simple tool can present a safety risk. For example, hand tools must be checked to ensure that wooden or plastic handles are free of splinters, sharp-edged cuts, or other surface damage that could injure an ITS installer's hand.

IMPORTANT: Carefully follow the manufacturer's instructions when mounting, securing, and using potentially dangerous mechanical equipment for cable pulling (e.g., winches, cable wheels, cable brakes). Do not set up or operate this equipment without first receiving adequate training.

Protective Clothing and Equipment

Personal protective equipment (PPE) decreases the ITS installer's risk of injury. This equipment includes:

- Headgear (e.g., hard hat) to protect against falling or flying objects, electric shock, and striking the head.
- Eye protection (e.g., full face shield, goggles, safety glasses) when working with batteries, powder-actuated tools, and optical fibers. Eye protection is necessary when working in a crawl space, above a dropped ceiling, or above eye level.
- Breathing protection (e.g., respirator, filter mask) when harmful dust, gas, smoke, chemical vapor, or other pollutant is present at the work site.
- Protective footwear on work sites where the feet could be injured by falling objects, rolling carts, or stepping on sharp objects. Wear rubber-soled shoes when working near electrical power cabling and equipment. Some work sites do not allow the use of steel-toe shoes. The ITS installer must be aware of any such requirements.
- Protective gloves when performing any work that has the potential for hand or forearm injuries.
- Hearing protection while working in the vicinity of loud noises.
- Well-fitting clothing to protect from minor cuts and materials that could irritate the skin (e.g., fiberglass). Do not wear loose clothing that could get caught on tools, surroundings, or operating machinery.

Safety Procedures, continued

Identification of Potential Hazards

Installing cable inside a building can be hazardous and requires extra safety precautions. The cabling installation team should identify potentially hazardous areas before beginning work. The presence of electrical wires and electrical equipment is probably the most common environmental hazard faced by the ITS installer.

Treat all electrical circuits as if the circuits are live (energized) even after the circuits have been turned off. Cable pullers must be especially careful in situations where electrical circuits or equipment may be contacted blindly as when fishing conduits and wall. Do not use metal fish tape in a conduit if the exit point is unverified.

Other sources of potential hazards include dust and debris when working in floor and ceiling systems, exposure of optical fibers to the skin and eyes, asbestos, and chemical hazards.

Firestopping

Building codes and standards provide strict requirements for sealing, or firestopping, penetrations through fire- and smoke-rated walls, floors, partitions, and ceilings. Approved methods and materials must be used to reduce the chance of spreading fire, smoke, and toxic gases throughout a building.

All firestopping solutions are a combination of firestop materials, holding devices, packing materials, and other devices that make up a listed (approved) system. Use an approved system to properly firestop a penetration. Contact an appropriate firestop manufacturer for any situations that are not specifically addressed by the manufacturer's listed methods.

NOTE: See Chapter 7: Firestopping Practices for additional detailed information.

Job Wrap-Up

Every cabling installation has several tasks that should be done after the cable is pulled. The ITS installer must:

- Label the new cables.
- Update the building floor plans.
- Clean the work site.

Before pulling the cable, a temporary label should be placed on each end that conforms to the labeling scheme to be used on the project. The label should identify the cables so that ITS installers will be able to identify the cables for termination.

Labels shall be placed so that they are readily readable with minimal disturbance to the cables. These temporary labels will later be removed and replaced with permanent machine-generated labels on all cables, faceplates, and patch panels.

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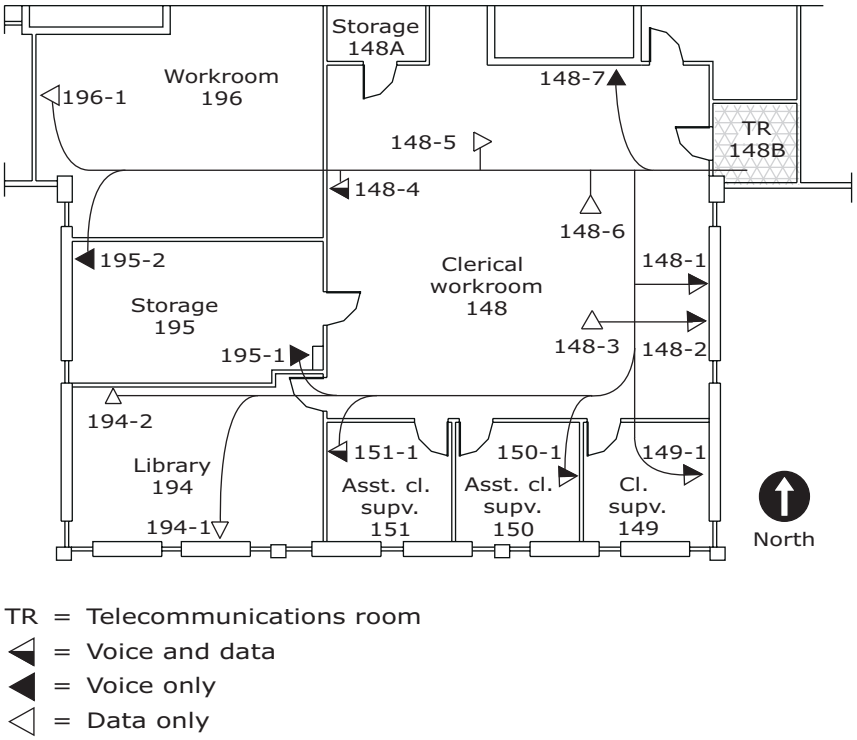
Job Wrap-Up, continued

The building plans or blueprints are the record of what is in the building. After an installation is complete, the cabling contractor must usually submit as-built plans, sometimes called record drawings, to the general contractor and building owner. These plans are a lasting record of cable information that documents the placing of cables (see Figure 5.23).

On the building floor plans, the ITS installer must provide the following cable information:

- Show clearly what types of cables were installed.
- Document the origination and termination point of each cable.
- Show clearly on the floor plans which pathway (e.g., conduit, cable tray) was used.

Figure 5.23
Example of marked job floor plans with common symbols



Several cleanup tasks should be performed in each area of the work site after the cable is pulled. Keeping a work site clean:

- Prevents development of safety hazards.
- Reflects on the professionalism of the ITS installer and the cabling installation company. Work areas should be left in the same or better condition than when work began.

Job Wrap-Up, continued

General housekeeping items include, but are not limited to:

- Picking up used pull strings and pull ropes immediately after use.
- Removing all non-plenum rated items used from plenum spaces (e.g., cable ties, pull string).
- Disposing of removed sheath and wire scrap.
- Storing cable reels and boxes when the pulling function is complete.
- Vacuuming residue from cutouts in framed walls.
- Disposing of all personal items (e.g., food, utensils, coffee cups) and used cleaning supplies.
- Storing tools, equipment, and unused materials properly at the end of the workday.

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Installing Cable Setup (Horizontal)

Overview

Through project planning tasks, the ITS installer has already identified the type of cable, supporting structures, locations, and pulling tools and methods required for the job. Once onsite, additional preparation tasks help to organize the work and provide an efficient and safe installation.

Before the job of pulling cable begins, everything should be in its proper place. All materials and equipment must be in place so that the cables can be handled properly. This includes any specialized equipment capable of holding large reels, if required.

Smaller equipment (e.g., cable trees) may be brought in to handle numerous rolls containing low pair-count cable. If all preparations are made correctly, time will be saved once the cable pulling begins.

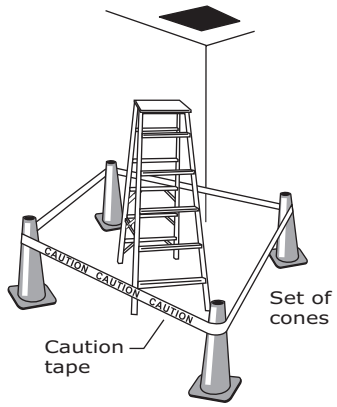
Cable installation setup tasks include:

- Securing the area.
- Posting floor plan drawings in the area.
- Setting up the appropriate cabling installation system components.
- Selecting and identifying the cable labeling system to be used.
- Identifying pull points, TPs, and pull angles.
- Identifying and establishing group pulls.
- Setting up and placing the pull strings.
- Setting up and securing the cable reels or boxes.
- Identifying TE locations.

Steps—Pulling Cable Setup

Step	Pulling Cable Setup
1	Secure the area (see Figure 5.24). • Set up cones, signs, barricades, and caution tape in the areas of work to alert everyone of danger in the area. • Place caution tape across the entrance to the area to restrict access to anyone other than ITS installers or other authorized personnel. • Notify appropriate personnel that the work is beginning.

Figure 5.24
Area secured with safety cones and caution tape



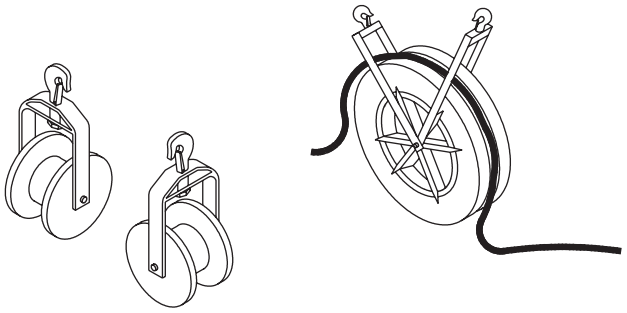
2	Post floor plans in a conspicuous location prior to the start of cable pulling. The plans provide a record of the pathways and media being installed. As work is completed, the ITS installer should note the type of cable installed, its proposed usage, and if a specific cable color is required. After the cabling installation is complete, the building owner has the reference documents to refer to for future work. It is a lasting record of cable information that documents the placing of cables.
3	Cabling installation systems are a series of components that provide the ITS installer a controlled and consistent method for securing, supporting, and moving reels or boxes of cable, accurate color-coded labeling, maintaining bend radius and tensile pressure limits, eliminating spiraling, twisting and kinks in the cable, verifying cable lengths on each pull, and allowing for sorting and staging cables after they have been pulled into the pathway. These cabling installation system components should allow all ITS installers to perform each specific task of the installation using the same methods. Thus, the methods used will not vary from crew to crew, consistency and controls will be maintained, and best practices will be enforced. NOTE: Cabling installation system components include improved cable trees or reel support units, labeling systems, pulling harnesses or swivels, pathway rollers and pulleys, and cable sorting/staging units.

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Steps—Pulling Cable Setup, continued

Step	Pulling Cable Setup
4	Set up pull string or pull rope. If no pull string or pull rope exists and is required in the conduit system, one must be installed.
5	Identify pull points for each horizontal cable run. • Determine the distance of the complete cable run. Ensure that the distance does not exceed 90 m (295 ft). Take care to identify the changes in direction, vertically or horizontally. These changes in direction may cause the run to exceed the 90 m (295 ft) limit. • Cables should always be installed parallel or perpendicular to major building structures. Do not run diagonally across a room. • Best practices for pulling cable dictates pulling from the telecommunications space to the work area. • Take notice of the number and locations of bends, and identify where to feed the cable around sharp bends or turns. Pulley hangers may be used at some changes in direction or elevation to reduce the need for additional personnel (see Figure 5.25). Always use correct size pulleys to maintain minimum bend radius.

Figure 5.25
Bullwheel and pulley hangers

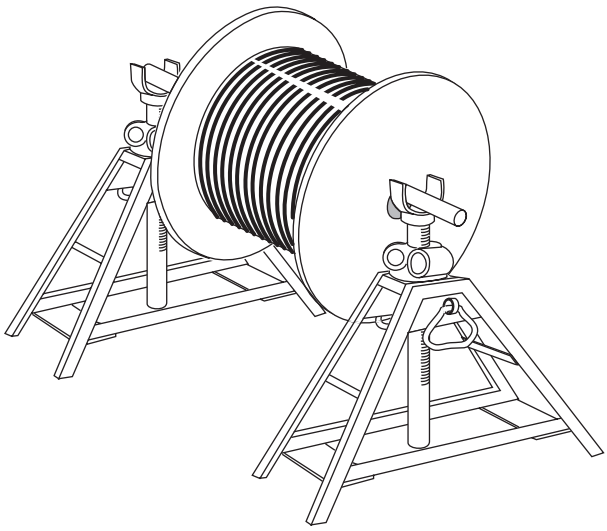


- Allow no more than two 90-degree bends per 30 m (98 ft) pull if in conduit.
- Divide the total cable run distance into segments where each segment is less than the maximum of 30 m (98 ft), including end measurements, if in conduit.
- Identify a pull point, where necessary, for accessing and handling the cable.

Steps—Pulling Cable Setup, continued

Step	Pulling Cable Setup
5 cont.	• Where possible, minimize the number of pull points because each pull point requires an additional person, pulley, or a separate pull. NOTE: When coworkers are not available to be at all the pull points, the cable may have to be pulled to the farthest manned pull point and then placed in a figure-eight on the floor. To continue the pull, workers are relocated to the next vacant pull points until the cable pull is complete.
6	For most large cable reels, use the appropriate cabling installation system. In some cases, it may be necessary to set up a pair of jack stands, reel dolly, or set of cable rollers (see Figure 5.26). A reel dolly is basically a jack stand with wheels that allows easy relocation of the assembly. A set of cable rollers is two shallow metal troughs, each containing two small rollers. The reel can be rolled on top of the small rollers. • Find out if the cable reel being installed is too large and/or heavy, requiring the use of a jack stand or reel dolly. NOTE: Many contractors use jack stands for holding the reels of cable off the floor. Sometimes this equipment is made from homemade supports, and a pipe is used to appropriately suspend the reels.

Figure 5.26
Large reel and adjustable jack stands



- Select a location that is large enough for the number of spools needed.
- Set up the jack stand inside the TR if there is space for it, or set it up in the area just outside the TR.

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Steps—Pulling Cable Setup, continued

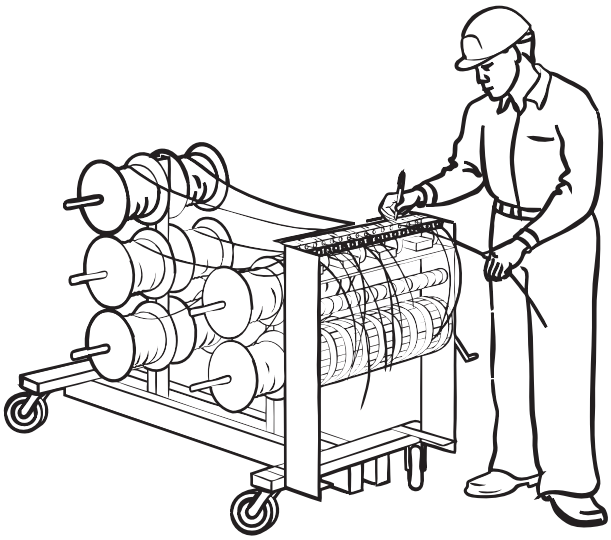
Step	Pulling Cable Setup
6 cont.	• When a TE is used, the floor area must be set up so that it will not impede other trades.
7	Place a pipe or crossbar (known as a mandrel) through the center hole in the reel. Get help from coworkers to lift the spool onto the jack stand. Jack stands used for placing larger cables usually have a mechanical ratcheting or hydraulic lift mechanism to assist in lifting the reels into place for pulling. Ensure that the mandrel can support the weight of the cable reels. NOTE: In some pulling operations, reel brakes may be needed to control the payout of the cable.
8	Prepare the cable bundle. Balanced twisted-pair cable is shipped in several different containers: • Payout box • Reel-in-a-box • Reel NOTE: Cable reels can be ordered with various put-up lengths. Boxes are usually 305 m (1001 ft).
9	For reels and boxes, use the appropriate cabling installation system component. • Cable support units are used when there are multiple small cables being pulled at the same time. • Select a location near the cable feed point that is large enough for the cable support unit (Figure 5.27). • Set up the cable support unit inside the TR if there is space or in an area outside the TR (e.g., hallway). • Mount the spools or boxes on the cable support unit. • Find the end of each cable, and thread it through a guide hole on the head of the support unit. These holes serve as a fixed location to hold all the cables secure for separating, labeling, grouping into each pull, and feeding the cables into the pathway. It also helps to ensure that no cable kinks are caused by the cable pulling and placement into the pathway.

Steps—Pulling Cable Setup, continued

Step	Pulling Cable Setup

9 cont.

Figure 5.27
Cable installation system



10 Attach drag line.

- While not always possible, it is a good practice to use a pulling harness that does not allow the lead string to tie directly to the cable bundle. Attaching the lead string directly to the cables causes excessive cable spiraling as the cables move through the pathway and causes subsequent pulls to be forced through the spiraled cables previously installed. Also, the string places undue tensile pressure on a few of the exterior cables in a bundle.
- A pulling harness and swivel attached to the string may prevent the drag line from twisting around the cable and may ensure evenly distributed tensile pressure on all cables in the bundle.
- When conditions exist that do not allow for use of a pulling harness, use the following process:
  - Select one of the cables in the group as a guide cable.
  - Take the next two cables and tape them to the guide cable approximately 77 mm (3 in) behind the guide cable. Continue attaching cable to the bundle in groups of two until all cables are attached to the bundle. Staggering cables may ease pulling in some areas.
  - Attach the cables to the pull string.

NOTE: Consider the use of a swivel to reduce cable twist.

- Position personnel to feed the cable into the pull to prevent any kinks or entanglements.

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Steps—Pulling Cable Setup, continued

Step	Pulling Cable Setup
11	Label the cables. Use the identifying/numbering convention assigned for the project. • Label cables prior to pulling cable into place. It is easier to identify and label the cables before they are pulled through the pathway. Use the labeling component appropriate for the cabling installation system being used. • The cable label shall be a unique identifier that is clearly visible on each end of the cable after the pull is complete. It is recommended that the identifier not be written onto the cable itself. This approach is time consuming and causes many errors. As this is a temporary label, the use of a fast and accurate label produced by a cabling installation system component ensures that the label is legible and accurate. Numbers can be quickly and legibly hand written on to labeling tape segments and those tape segments applied to each cable as they are held in the holes of the cable support unit. The label should identify the cables so that the ITS installers will be able to identify the cables for termination. Greater efficiency is gained by using a simple color code system of labeling tape employed by many cabling installation system labeling components. This allows for quick sorting and termination.
12	Feed the cable into the pathway. Always use a cabling installation system component that controls the bend radius and friction as the cable enters the pathway. This is often where a cable is damaged, later causing impaired transmission performance. A 77 mm (3 in) diameter smooth static pipe or 51 mm (2 in) roller will help to maintain proper bend radius limits for all balanced twisted-pair cable. Position personnel to feed the cable bundle as it is being pulled off the reels. Personnel must ensure that cable moves smoothly and does not become entangled as it is fed into the pull.
13	Pull in appropriate cable service slack. • Horizontal cables shall have enough slack to reach the farthest corner of the TR via the pathways and add the distance from floor to ceiling. This allows storing enough service slack for future reconfigurations. • Backbone cables shall have enough slack to reach the farthest corner of the backboard via the pathways in case new equipment is added later. • Balanced twisted-pair horizontal cables shall have 0.3 m (1 ft) of slack left in the work area after termination. Cable shall not be stored in loops.
14	Perform job wrap-up tasks. • Secure and label all cables. • Remove all debris, barriers, tools, and scraps from the area. • Mark the prints to indicate which cables were installed.

Pulling Horizontal Cable in Conduit

Overview

Conduit pathways for horizontal cable are usually designed to be parallel or perpendicular to the external walls of the building. Pulling cable through these pathways requires the installation and use of a pull string or rope. When pulling multiple cables, the use of a lubricant may be needed. Lubricating the cable as it enters the conduit helps ensure a smooth pull.

Conduits must maintain a minimum bend radius to avoid damage to cables during installation. A conduit with an internal diameter of 51 mm (2 in) or less must maintain a bend radius of at least six times the internal conduit diameter. Conduits greater than 51 mm (2 in) should maintain a bend radius of at least 10 times the internal conduit diameter.

No single conduit segment shall be more than 30 m (98 ft) in length, and no more than two 90-degree bends are allowed in one segment. Exceeding these limits increases the coefficient of friction and can possibly stretch the cable and damage it.

Pull String Installation

A pull string is a thin cord used for pulling cable through the conduit. The pull string must extend through the entire length of the conduit before cable can be pulled.

Pull string has a specific tensile strength rating that appears on the box. Tensile strength ratings range typically from 334 N (75 lbf) to 890 N (200 lbf). Some pull string is designed to break if excessive tension is placed on the cable.

Placing the pull string in conduit can be done manually by using fish tape or by pressurized air methods using a foam rat attached to a pull string.

Fish tape is used for pulling the string through the conduit and is not used for pulling the actual cable. The tensile strength of the fish tape precludes using it to pull the cable. The fish tape passes through the conduit to reach the pull string attached to the cable at the far end. Some fish tapes have swivel-type clips on the end for attaching to objects that need to be pulled back through the conduit.

When the fish tape method is not practical (e.g., placing pull string in excessive conduit lengths), use pressurized air methods. These methods include a vacuum cleaner or a compressed air bottle and a lightweight propellant object (e.g., foam ball). These methods produce the intended result of retrieving the pull string at the far end.

The following steps explain the process of installing pull string with fish tape and via pressurized air methods.

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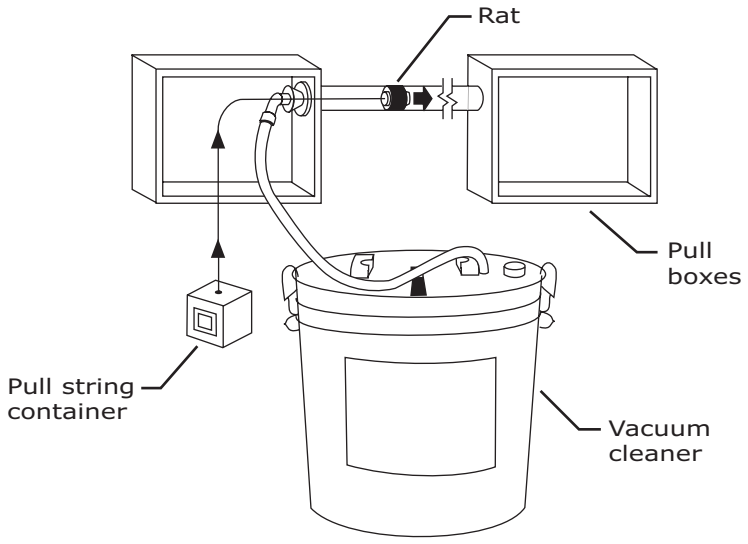
Steps—Pull String Installation with Fish Tape

Step	Placing Pull String in Conduit with Fish Tape
1	Determine the length of fish tape required. After estimating the length of the run, add a few meters (feet) to each end to be sure enough fish tape is available.
2	Feed fish tape through conduit. • Put on all necessary personal safety equipment. • Feed the fish tape into the end of the conduit. • Do not force the fish tape if the conduit contains existing cables. • If there is a metallic tab on the end of the fish tape, cover it with electrical tape to prevent snagging other cable already in the conduit. • Never feed a fish tape into a conduit without knowing where it may go. It could accidentally be fed into a live electrical junction box. • Push the fish tape through the conduit until it comes out the far end of the conduit.
3	Attach pull string to fish tape. • Go to the far end of the conduit where the end of the fish tape is now located. NOTE: The end of the fish tape will have a hook, a ring, or some type of attachment device. • Securely attach the end of the fish tape to the pull string to be pulled through the conduit to prevent it from coming off during the pulling operation. • If the clip at the end of the tape has been removed, secure the attachment by wrapping a piece of electrical tape around the pull string and the fish tape.
4	Pull the fish tape out of the conduit. • Go back to the other end of the conduit. • Slowly rewind the fish tape reel to retrieve the pull string from the far end of the conduit, storing the fish tape in the holder as it is taken up. • Detach the fish tape from the pull string. • If there will be a delay prior to cable pulling, tie off the pull string at both ends. This will prevent accidentally pulling the string back into the conduit and the need to refish the conduit. • Detach the fish tape from the pull string.

Steps—Pull String Installation with Air-Propelled Methods

Step	Blow Pull String through Conduit
1	Select a lightweight propellant object (e.g., crumpled up plastic bag, piece of foam rubber designed for the purpose).
2	Tie a pull string to the object.
3	Place the propellant object in the conduit.
4	Place the grommet on the conduit, and attach the air hose.
5	Using pressurized air, blow the object attached to the string through the conduit until it reaches the other end. **WARNINGS:** Never look into the end of a conduit when a pull line is being blown through it. Conduits often contain water. Always consider what could be damaged at the far end of the conduit if water were forced out of the conduit (e.g., electronic private branch exchange [PBX], freshly painted walls).
6	Go to the opposite end of the conduit, and tie off the pull string, separating it from the propellant object (see Figure 5.28).

Figure 5.28
Vacuum blowing a ball or a bag

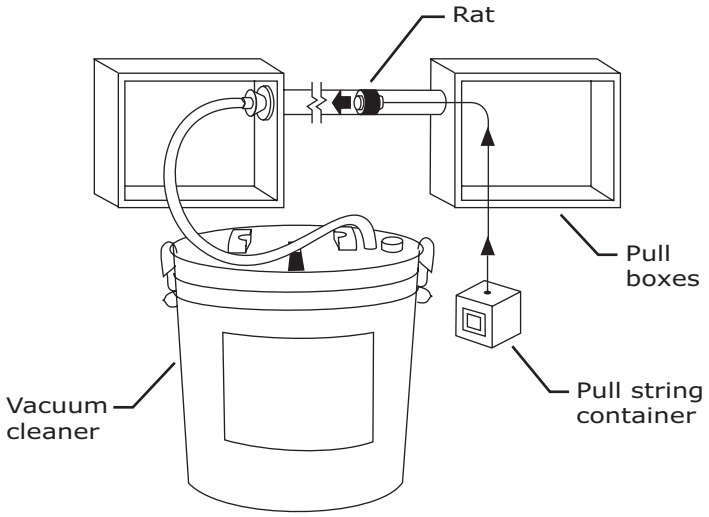


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Steps—Pull String Installation with Air-Propelled Methods, continued

Step	Blow Pull String through Conduit
7	Attach a vacuum hose to the conduit to pull a propellant object forward from one pull point to the next (see Figure 5.29).

Figure 5.29
Vacuuming a ball



8	Retrieve the object with the pull string attached.
9	Secure the string at the receiving end of the conduit.
10	If it is necessary to pull heavy cable, attach the pull string to a heavier string or rope strong enough to pull the weight of the cable in the conduit. **WARNING**: Always use a wet vacuum in case there is water in the conduit.

Conduit Pull

After the pull string is placed in the conduit, the ITS installer is ready to pull the cable. Maintaining the proper pulling tension is critical to the success of the pull. The manufacturer's tensile strength rating for the cable should be verified and must not be exceeded.

For example, the maximum pull force for one 4-pair, 24 AWG [0.51 mm (0.020 in)] cable is 110 N (25 lbf). The ITS installer may consider using an 11 kg (25 lb) breakaway swivel or an 11 kg (25 lb) breakaway line attached between the pull rope and the balanced twisted-pair cable to ensure that no more than 110 N (25 lbf) of tension is exerted on the pulled cable.

Steps—Conduit Pull

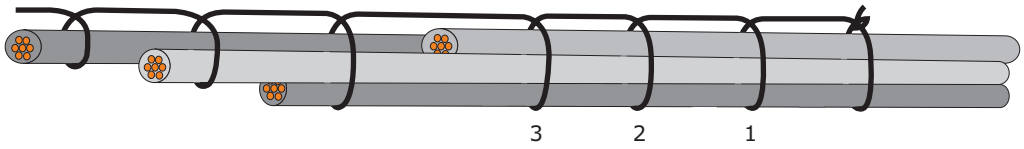
Step	Pulling Horizontal Cable in Conduit
1	Choose a method of establishing cable run distances. Methods include: • Using the lead string. NOTE: Once the string is installed into the conduit, thread the string through the meter on the cabling installation system cable support unit, tie a small knot, and pull the distance. The meter reading will be very accurate. • Pacing or walking off the distance. NOTE: The average walking span is approximately 1 m (3.28 ft). Determine your own span. • Using a measuring wheel. • Using a tape measure. • Counting ceiling tiles. • Counting conduit sections if visible. NOTE: A common general practice is to count ceiling tiles of known length (e.g., 0.6 m [2 ft] by 0.6 m [2 ft] lay-in or 0.6 m [2 ft] by 0.6 m [2 ft] decorator tile).
2	Estimate the length of the cable run. • Find the area on the floor that is just below the location in the ceiling where the conduit run is located. • Walk the distance of the cable run, noting the locations of conduit bends and pull boxes. • Estimate the distance walked and allow for all changes in elevation (e.g., include the vertical distance from conduits to floors or ceilings). • Ensure each cable dispenser has enough cable to reach the full length of the run (including service slack). • Place an identification label on each cable end. • Label each cable dispenser and cable a few meters (feet) back from the cable's end. Do not put the label too close to the end, or the tape used for attaching the pull line to the cable will cover the label.

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Steps—Conduit Pull, continued

Step	Pulling Horizontal Cable in Conduit
2 cont.	• Feed out a few meters (feet) of cable to prepare for entering the conduit. • Arrange the cables to form a smooth transition from a single cable to a larger bundle. Tape cables as necessary to hold them in place while the pull string is attached to the cable bundle. • Attach the pull string using a minimum of three half hitches and a knot to secure the end of the rope. Each half hitch will bite into the cables and prevent them from slipping. Place electrical tape over the knot, half hitches, and cable ends to prevent them from slipping or becoming caught during the pull (see Figure 5.30).

Figure 5.30
Attaching pull rope to the cables



• Attach a trailer string to the cables to provide a string for future pulls.
• As the cable is being pulled through the conduit, keep the slack available at the entrance so the cable can flow freely into the conduit.
• Guard against developing excessive bends or kinks as cable is led to the conduit.
• Some conduits may require the use of pulling lubricant to prevent excessive pulling tension on the cables.

NOTE: It has been demonstrated that some commercial cable pulling lubricants can degrade insertion loss performance at high frequencies. Although the effect from the lubricant typically will be reversed when the lubricant dries, BICSI recommends the use of lubricants specially formulated for high-performance data cables.

3 Pull cable.

• Maintain the proper bend radius of the cable type being pulled.
• Monitor pull force closely during installation to be sure that the manufacturer's specifications are never exceeded.

NOTE: Maximum pull force for one 4-pair, 24 AWG [0.51 mm (0.020 in)] cable should not exceed 110 N (25 lbf). Bends and lubricants may also affect transmission performance.

Steps—Conduit Pull, continued

Step	Pulling Horizontal Cable in Conduit
3 cont.	• Avoid excessive tension and deforming of the cable when going around corners or bends. • Leave enough slack in the TR via pathways to reach the farthest corner, and add the distance from floor to ceiling. This allows service slack to be stored within the TR for future reconfiguration. • Allow 0.3 m (1 ft) of slack after termination for copper conductor cables at the work area telecommunications outlet/connector. • Tie off both ends of the pull string.
4	Identify cables. • Once the amount of required service slack has been determined, mark the cable prior to cutting it off the cable spool or box. • The cable label shall be a unique identifier that is clearly visible on each end of the cable after the pull is complete. It is recommended that the identifier not be written onto the cable itself. This approach is time-consuming and causes many errors. This is a temporary label, so the use of a fast and accurate label produced by a cabling installation system component ensures that the label is legible and accurate.
5	Perform job wrap-up tasks.

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Pulling Horizontal Cable in Ceiling Spaces

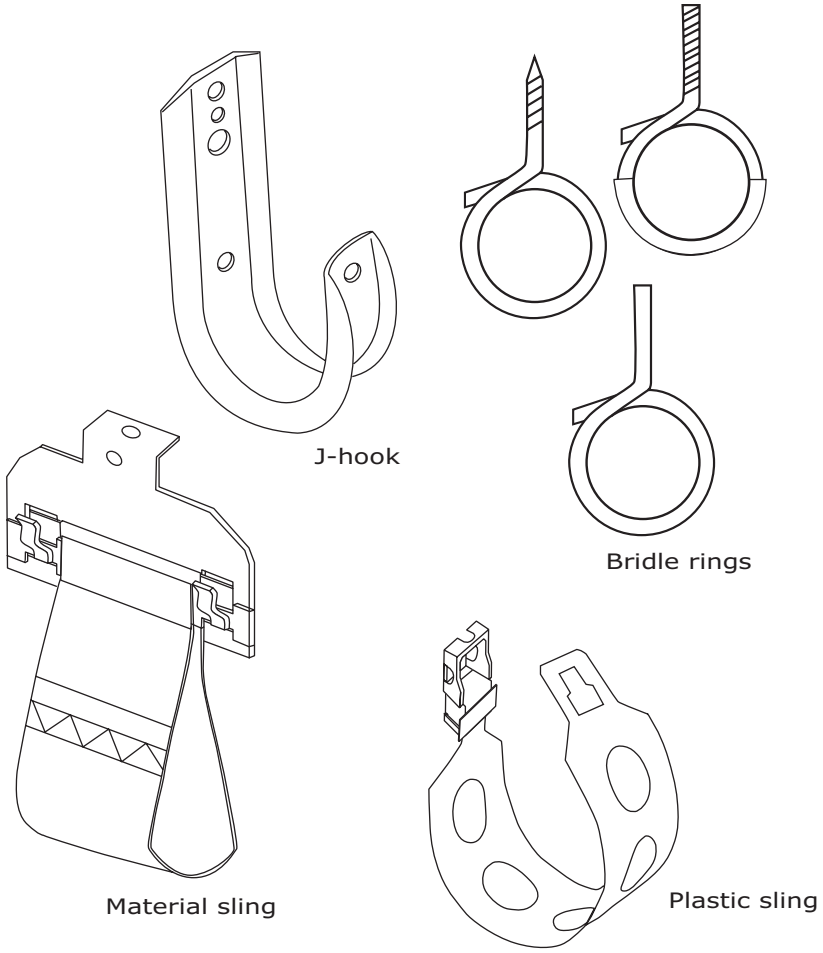
Overview

Cables installed within open ceiling spaces must be routed and supported in such a manner as to reduce or eliminate mechanical stress. The cables should be suspended above false ceiling tiles and away from potential sources of electrical emissions (e.g., fluorescent light fixtures) using hooks or supports mounted every 1.2 m (4 ft) to 1.5 m (4.9 ft) and at each change of direction.

No single support device should exceed the manufacturer's recommended load rating, and the pulling tension used for placing a cable should not exceed the manufacturer's recommendations.

Small supports (e.g., bridle rings, small J-hooks) should only be used to carry a few cables or may need to be fitted with a saddle to keep the support from distorting the cable (see Figure 5.31). Cables must not be stretched tightly around corners or wrapped tightly with tie wraps.

Figure 5.31
Slings, J-hooks, and bridle rings



Overview, continued

Structural steel members (red iron) may not be used to directly support cable. The pathways may have sharp edges or corners that may nick or damage the sheath of a cable. Structural steel may be used for the attachment of proper cable supports.

Determine if the ceiling space is used as an environmental air plenum, and ensure that all products (e.g., cables, tie wraps, support systems) meet applicable codes for the application. Any physical damage to a high-performance 4-pair cable can significantly degrade performance.

Similar to conduit pulls, a pull string with adequate tensile strength or pull tape may be used to pull cable into place in open ceiling runs by first threading it through the supports.

A telescoping pole is helpful in threading the string through the supports. Use of the telescoping pole limits the number of ceiling tiles that must be moved to provide access to the ceiling area if tiles are installed prior to pulling cable. The pole also reduces the number of times a ladder has to be moved.

Other devices are available for installing pull strings in open ceiling installations, including 6.3 mm (0.25 in) fish tape, remote controlled vehicles, and spring-loaded dart guns.

NOTE: Do not attach tools to pull strings and throw them through the ceiling. This presents a safety hazard and may cause damage to the ceiling system, tiles, or other utilities contained in the ceiling space.

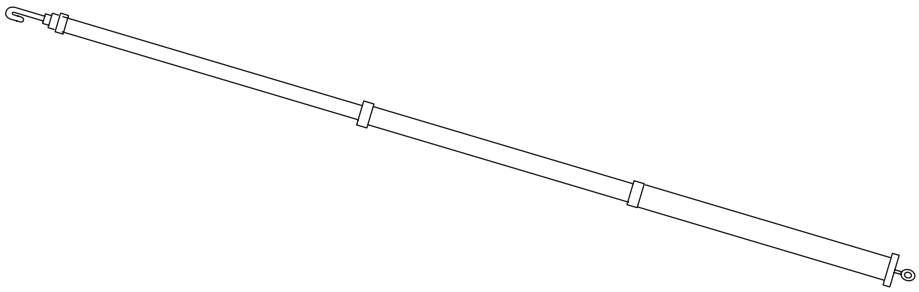
Each 90-degree bend identifies a pull point, which requires an ITS installer at that spot to assist in pulling the cable. Using a pulley can help minimize labor.

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Steps—Installing Pull String

Step	Installing Pull String in Open Ceiling
1	Verify tensile strength of string. • Pull string has a tensile strength rating that appears on the container. • Tensile strength ratings range typically from 330 N (75 lbf) to 880 N (200 lbf).
2	Route string through the ceiling area. • Select an appropriate extender tool that will reach the required distance. Telescoping poles (see Figure 5.32) reach from 2 m (6.6 ft) to 8 m (26 ft).

Figure 5.32
Telescoping pole



	• Attach the pull string to the hook on the end of the extender tool, and pull back.

Steps—Open Ceiling Pull

Step	Pulling Horizontal Cable in Open Ceiling
1	Verify the manufacturer's specifications for cable tensile strength limitations. • Read the manufacturer's guidelines for instructions on cable strength limitations. • Excessive tension on the cable may stretch the conductors inside the cable, degrading the cable's transmission performance. • Pay close attention to the requirements to not exceed minimum bend radius limits, which for 4-pair cable is equal to four times the diameter of the cable. • For extensive quantities of cable in a ceiling environment, use cable trays or ladder racks. • Avoid selecting paths that require exceeding the minimum cable bend radius.
2	Attach string to pulling harness and lace cables into harness grips. • If conditions do not allow for the use of a pulling harness, tape the pull string to the lead end of the cable along with an additional pull string for future use. • Manually lift the cable into a position to follow the string into the open ceiling area.
3	Take precautions. • Upon entering the pathway, always pull cable over a cabling installation system pathway entry component that controls bend radius and eliminates friction. Do not pull successive cable bundles over the existing cable bundles already placed. Move the previous cables out of the pulling path of future pulls. • Pull cable, being careful not to snag or pull the string against sharp objects (e.g., ceiling obstructions—heating, ventilating, and air conditioning [HVAC] duct) or ceiling grid stringers. • Avoid creating friction that causes burns or tears in the jacket of the cable. • Eliminate spiraling and twisting wherever possible. • Do not pull the cable directly through the support devices.
4	Place cable in support devices. Once the pull is complete, lift the cables and place them in the cable supports. Once all cables have been installed into a support, close the support if required.
5	Perform job wrap-up tasks.

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Pulling Horizontal Cable in Raceways

Overview

The horizontal cable installation is the cabling from the TR or TE to the work area telecommunications outlet/connector. Pathways to the workstation location generally have some method of concealment for cable protection and visual aesthetics.

Examples of the concealment methods include:

- Modular furniture raceways.
- Utility columns.
- Surface raceways.
- Floor raceways.

Many installations use a combination of pathways to reach the work area. It may be necessary to pass through a conduit, into a ceiling space, and then on to a utility column to complete the run. In the planning stage, the ITS installer must identify all the methods to be used and develop the cabling installation plan accordingly.

Types of Horizontal Pulls

Some similarities exist in methods of pulling horizontal cable through the various types of pathways to the outlet. Placing cable in conduit and direct wall pulls (fishing) usually requires some type of pull string or fish tape. All practices for the utilization of these pulling methods should be observed.

When surface raceway, furniture raceways, floor monuments, or utility columns are used, the ITS installer should follow the manufacturer's installation requirements. These pathways generally have an access method or removable cover for cable placement. Pulling cable directly through these pathways should be avoided whenever possible.

Conduit

Many projects provide horizontal cabling access with a conduit and junction box or installation of the cables. The conduits will run up or down the wall and stub into an access area in the ceiling or floor. In some instances, the conduit may be an extended length that is home run to the TR, TE, or remote access point (AP).

Installation considerations:

- Ensure that the conduit has sufficient diameter for the quantity of cables to be pulled.
- Note the proper conduit fill ratio, and identify the conduit entrance point to start the pull.
- Adhere to the proper cable bend radii and pulling tension on all pulls, especially at the conduit entrance and outlet box exit.
- Leave service slack where the cable enters the conduit so it does not degrade the cable.
- Include the portion of a bundle that will remain in the conduit that should not be bound with tape. This will prevent removal of individual cables.

Types of Horizontal Pulls, continued

Fishing Walls

In some instances, there is no conduit access to the work area location. The ITS installer will be required to provide access into the wall from the top plate and through the wall material. When a wall is fished, the framed wall or wall material must be opened for the outlet, and the top of the wall, or top plate, must be drilled for cable access.

Installation considerations:

- Verify the work area telecommunications outlet/connector height. Generally, it will be at the same height and orientation as the electrical outlet. These outlets are often installed at approximately 381 mm (15 in) to 457 mm (18 in) above finished floor (AFF). Once the openings have been established, the cable can be fished through the wall.
- Prior to cutting the wall or top plate, the ITS installer must determine that the wall has a clear vertical pathway from the top plate to the projected outlet location.
- If a wall is constructed with a horizontal barrier between vertical studs that blocks access to the lower area of the wall, it may be necessary to use a flexible or extended drill bit to make a pathway. If that is not possible, it may be necessary to place a surface-mounted raceway.
- At the top plate entry location, install a protective ring to prevent cable damage during the pull.
- Wall access location must use some type of mechanical attachment unit (e.g., mud ring, receptacle box, wallboard fastener) to allow the outlet a secure mounting point in the wall material.

Modular Furniture

Work area cabling in modular furniture systems will often have multiple vertical, horizontal, or both vertical and horizontal pathways (raceways) for cable installation. These raceways are separated by a barrier and generally used for both electrical and telecommunications cabling. Proper power separation between low-voltage and high-voltage cabling must be maintained.

NOTE: See Chapter 3: Cabling, Pathways, and Spaces for proper power separation guidelines.

Installation considerations are to:

- Remove covering panels of the raceway to access the pathway for cable installation if possible.
- Identify the correct pathway to be used for the ITS cable.
- Maintain proper separation from electrical services.
- Plan for the transition from the wall, floor, or utility column to modular partitions.

NOTE: Most furniture access from the horizontal pathway will require some method of mechanical cable protection for exposed cables. This is generally true for the transition from wall or floor APs.

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Types of Horizontal Pulls, continued

Utility Columns

A vertical pole is often used to provide a pathway from the ceiling or horizontal pathway area when the outlet location is not adjacent to a wall. The utility column installation should be treated the same as a conduit installation. The difference with the utility column is that it usually has a removable side cover that provides access.

Installation considerations:

- Maintain the proper cable bend radii and pathway fill ratio.
- If the utility column is used to provide electrical power, maintain the proper separation between the ITS cabling and the electrical cabling.
- Exercise care when opening and closing these units for installation access to avoid damage to the cable (pinching) or the utility column cover.

Surface Raceways

Vertical or horizontal surface raceways may be required to gain access to the work area location. The raceways must be securely attached to the wall and installed parallel to the horizontal or vertical building lines.

Installation considerations include maintaining the proper fill ratio and bend radii as well as providing anchoring in addition to any two-sided adhesive tape provided by the manufacturer. The raceway will provide a removable cover for cable placement. Use this cover whenever possible. When this cover is replaced, exercise care so the cables are not pinched.

Installing Backbone in Vertical Pathway—From Top Down

Overview

Backbone cable in the vertical riser shaft may be high pair-count cable, which is extremely heavy, or high strand-count optical fiber cable. The cable may be placed vertically directly in an open riser shaft—through cores, sleeves, or slots—or within a large conduit.

Through the initial project planning process, the ITS installer has already completed several tasks, including:

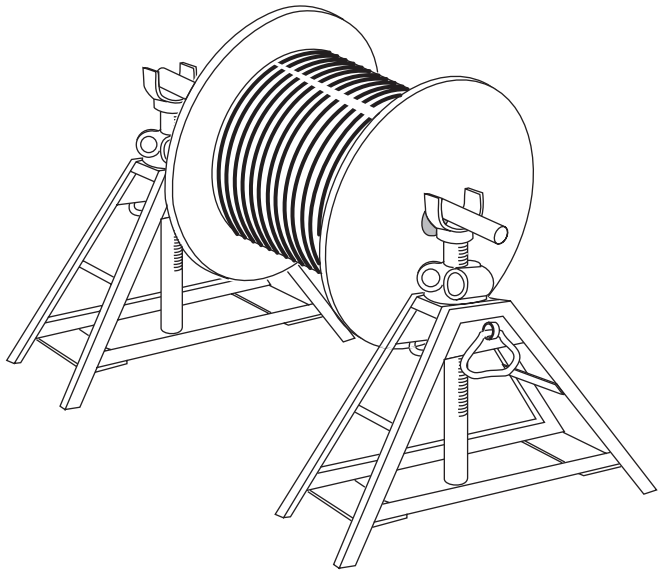
- Verifying correct types and lengths of cable available on the work site.
- Determining access for moving and positioning cable reels (e.g., loading docks, freight elevators).
- Selecting the tools required for pulling the cable.
- Identifying and providing the proper safety and ITS equipment.
- Identifying the requirements and methods for labeling and documenting the cable pulls.

Setting Up for the Pull

Setting up the work site and preparing for the pull involve additional tasks and considerations as follows:

- Once a reel is brought to the top floor, it must be set up for the placing operation. The reel should be situated in a location that provides enough slack for the top floor termination once the placing operations are complete.
- A reel dolly or a set of jack stands is necessary to feed the cable (see Figure 5.33). A reel brake may be required to help control the descent of the cable as it is pulled off the reel.

Figure 5.33
Large reel and adjustable jack stands



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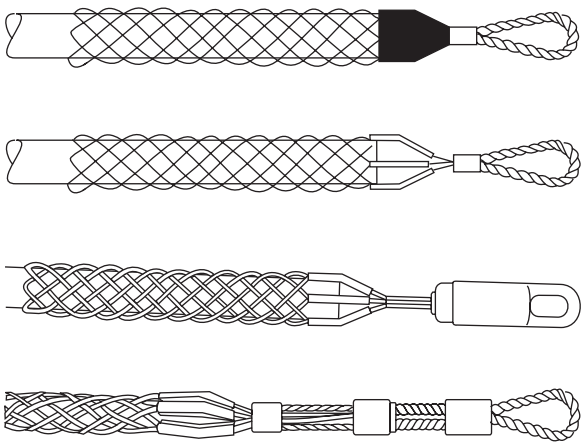
Setting Up for the Pull, continued

- Pulleys may be needed to handle the cable from the reel location to the point where it will be dropped down to lower floors. These pulleys can be attached to the overhead structure in the building and provide a pathway for the cable as it is being placed.
- In the TR where the cable will enter the vertical pathway, a bullwheel is generally required to ensure that the jacket is not damaged as it enters the pathway.

  Place the bullwheel so that it will allow the cable to drop vertically into the pathway. Bullwheels must be attached to the building structure, thereby preventing any lateral movement. Lateral movement will cause the cable to become misaligned with the vertical pathway and could damage the outer jacket.
- Install a guide rope throughout the cable route. This rope is used to guide the cable through the various spaces rather than pull the cable.
- If a pulling eye was not factory installed, install a substitute device. An alternate method of pulling is the use of a pulling grip, which is a flexible wire mesh device that clamps down on the cable as tension is applied (see Figure 5.34).

These devices are available in various sizes based on cable diameter. Ensure that it is properly sized for the cable. Place it over the cable jacket, and then tape the end to the jacket. This will prevent it from coming off should the pull be halted and the tension relaxed on the grip.

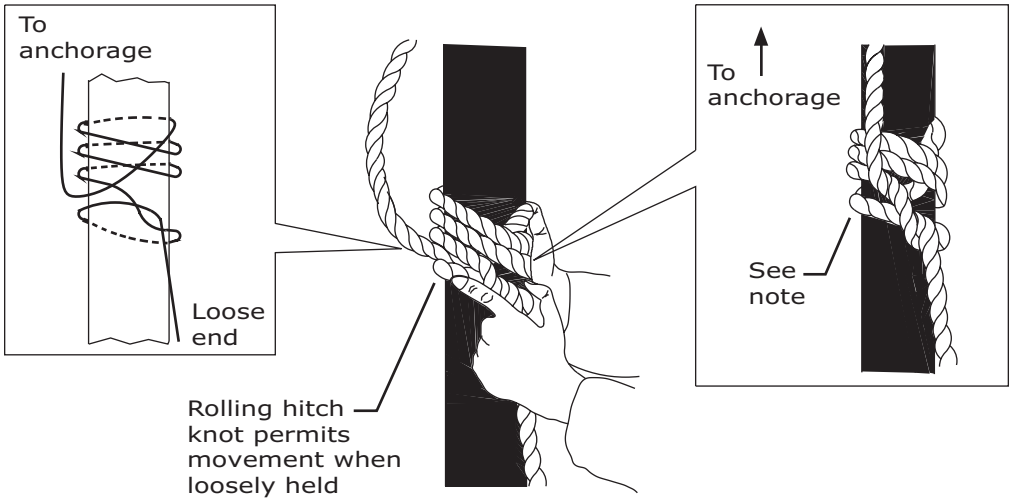
Figure 5.34
Wire mesh grips



Setting Up for the Pull, continued

- If a wire mesh grip is not available and the pathway is large enough, attach the pull rope over the jacket in a series of half hitches. Place vinyl tape over the guide rope, securing it to the cable (see Figure 5.35).

Figure 5.35
Rolling hitch knot



NOTE: Release of the rolling hitch knot provides immediate snubbing action on cable to stop movement.

- The coefficient of friction may be one of the obstacles to installation of cables, especially in conduit pathways. The use of cable lubricants can significantly reduce friction and speed cable installation. Select the lubricant to be used based on the type of pull, type of conduit, cable jacket, and size of the cable. Apply the lubricant as the cable is placed, keeping in mind the pulling tension of the cable. The lubricant must be allowed to dry before cable testing is completed.
- Mark the backboards for cable lashing. Identifying locations on the backboards for both temporary and permanent lashing prior to the start of pulling allows immediate use during and after cable pulling. This effort will provide for final cable backboard placement and anticipated slack requirements.

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Setting Up for the Pull, continued

ITS installers should be located on each floor through which the cable will pass as well as the floor where it will terminate. The ITS installers must be equipped with the proper tools to perform critical tasks during the placing operation.

Some of the tools include:

- PPE (e.g., safety glasses, hard hats, gloves).
- Communication equipment (e.g., portable, handheld radios).
- Temporary restraining devices for the cable. Cable type and size will determine the necessary restraining devices. One common method of temporarily restraining cable is the use of a large hemp or manila rope equipped with an eyelet. The eyelet is attached to some secure structure in the TR. A half hitch is made in the rope, and the ITS installer pulls on the rope.

  The amount of tension placed on the rope will control how quickly the cable slips through the half hitch. This method allows the cable to be halted and restarted during cabling installation without losing control of the cable as it descends (with or without a reel brake).

Installing the Cable

Once everyone and everything is in place, install the cable. Communicate with coworkers, and advise them that the pull is starting. Begin to lower the cable, and monitor its progress throughout the pull. Continue the placing operation until the cable is completely placed.

When the cable reaches the bottom floor, the ITS installer must temporarily restrain the cable. Beginning on the bottom floor, the ITS installer should pay out the additional slack needed in each TR. Once the slack is brought into the TR, secure the cable in its final location.

Securing the cable on each floor ensures that the weight of the cable will not become excessive at any one point. Many different devices can be used to secure the cable. One of the most common devices is the split grip, which is a wire mesh grip that is open on one side. The wire mesh grip is placed around the jacket of the cable. A pin is then weaved through the open sides of the wire mesh grip, securing them around the cable jacket.

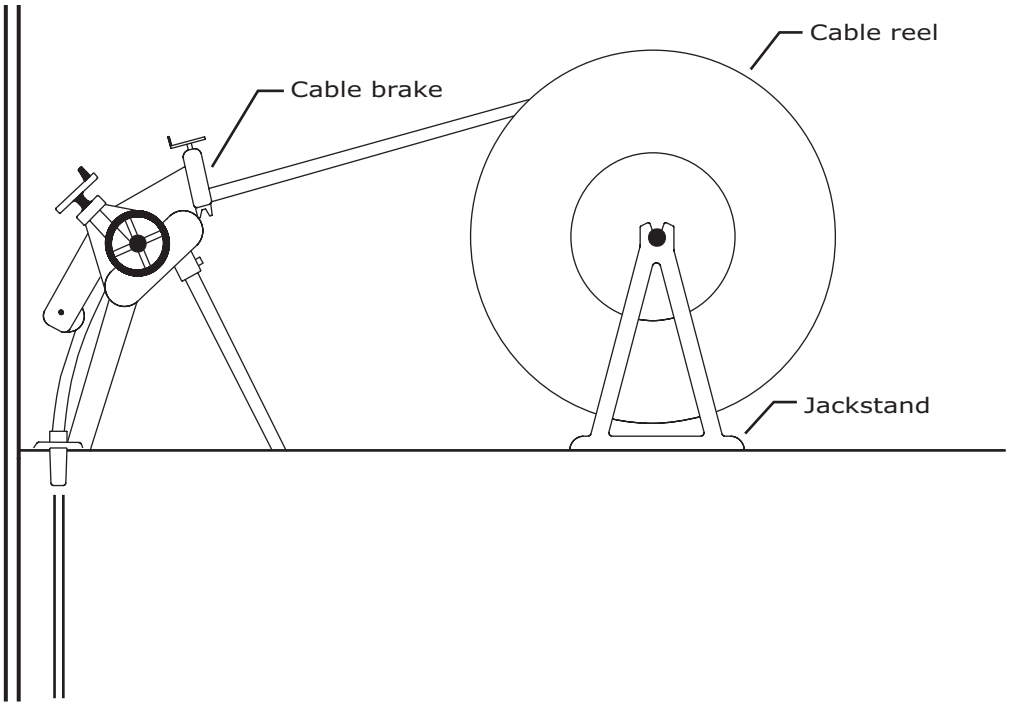
A section of steel rod, a minimum of 13 mm (0.51 in) thick, is inserted through the loop in the end of the wire mesh grip. The cable and grip are then allowed to slide through the opening in the vertical pathway until the steel rod lies on the top of the pathway. Another method of securing the wire mesh grip is to attach it to the building or a plywood backboard with an anchoring device. The cable should then be identified and labeled, and the documents should be updated to reflect the work operation.

After completing the work operation, the cable reel and any remaining cable can be returned to storage or prepared for salvage. If the cable was shipped on a wooden reel, the reel can be dismantled and disposed of. If the cable was shipped on a metal reel, it should be returned to the manufacturer for credit.

Steps—Vertical (Top Down)

Step	Installing Backbone in Vertical Pathway—From Top Down
1	Verify proper cable length and path. • Examine the vertical backbone pathway for the installation, and check for a clear pathway. If possible, avoid a cable path with obstacles or transitions. Check vertical pathways visually and, if necessary, with a flashlight. • Determine the actual length of the cable run based on information from the blueprint or by installing a pull tape equipped with sequential footage markings. If sufficiently sized, this pull tape can be used as the guide rope.
2	Move cable reels to the upper floor of the vertical feed point.
3	Set up the cable pulling area and put reels on a jackstand or reel dolly. Secure the area.
4	Attach a cable brake to the cable if needed (see Figure 5.36).

Figure 5.36
A cable brake attached to the cable reel

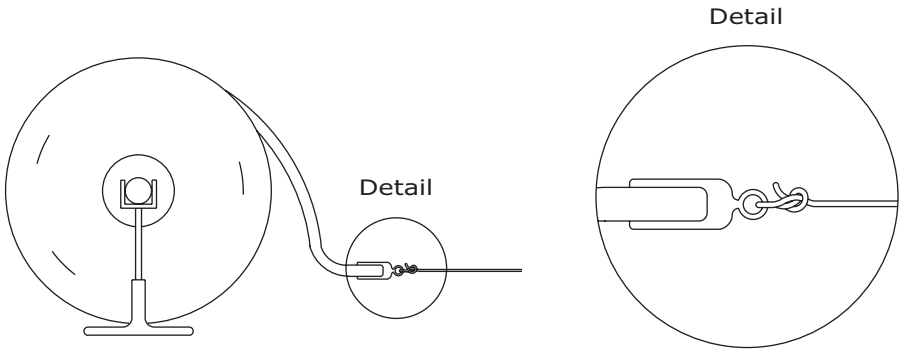


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Steps—Vertical (Top Down), continued

Step	Installing Backbone in Vertical Pathway—From Top Down
5	Install and attach a guide rope to the cable lead (see Figure 5.37). This guide rope will help guide the cable as it descends.

Figure 5.37
Pull rope attached to the cable leadtail

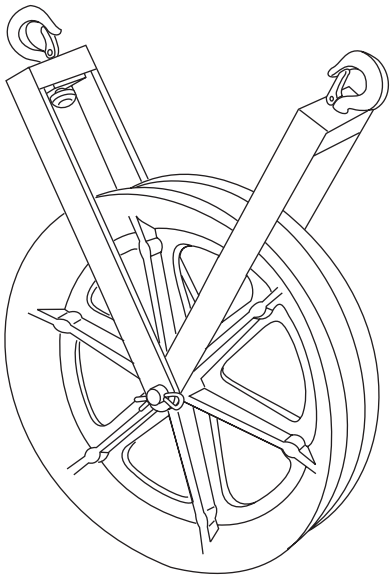


6	Attach pulleys if required. • Decide if the weight (based on the size and length of cable) requires the use of pulleys and a brake to help control the gravitational pull. • Feed the cable off the reel and onto the pulleys mounted above the route to the pathway to support the cable to the point of entry into the vertical pathway. • Mount the pulley on any appropriate superstructure available at the location or on overhead steel. If none is available in the place where needed, set up a swing-set type of pulley mechanism.

Steps—Vertical (Top Down), continued

Step	Installing Backbone in Vertical Pathway—From Top Down
6 cont.	• Use a bullwheel to direct the cable into the vertical pathway, keeping the cable from scraping the edge of the floor and chafing the jacket, which damages the integrity of the cable (see Figure 5.38). NOTE: This operation may require that the bullwheel be attached to the building in three places. The three attachments will support the bullwheel and prevent it from pulling away from the pathway entrance and from moving laterally.

Figure 5.38
Bullwheel



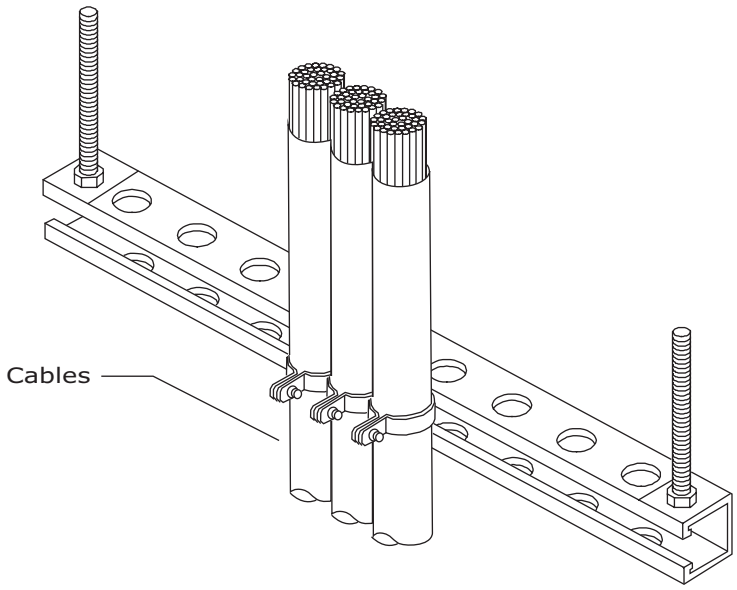
7	Communicate with coworkers for routing. • Establish locations for coworkers to clearly view the progress of the cable descending. • Have constant communication between floors to notify the person controlling the cable brake of the progress being made. • Listen carefully for reports from coworkers who may spot a problem in the cable path that no one else can see.

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Steps—Vertical (Top Down), continued

Step	Installing Backbone in Vertical Pathway—From Top Down
8	Drop until finished. • Watch and observe the functions of any pulley in use. • Maintain control of all pull strings or guide ropes in use. • Stay in position as a communicator with coworkers until the drop or pull is finished. Be prepared to temporarily take up the cable if a problem develops in the placing operation and prior to permanently securing the cable on each floor. • Secure all cables at each floor level (see Figure 5.39). Cables that are extremely heavy may fall if they are not properly supported. Free-hanging cables create a serious hazard.

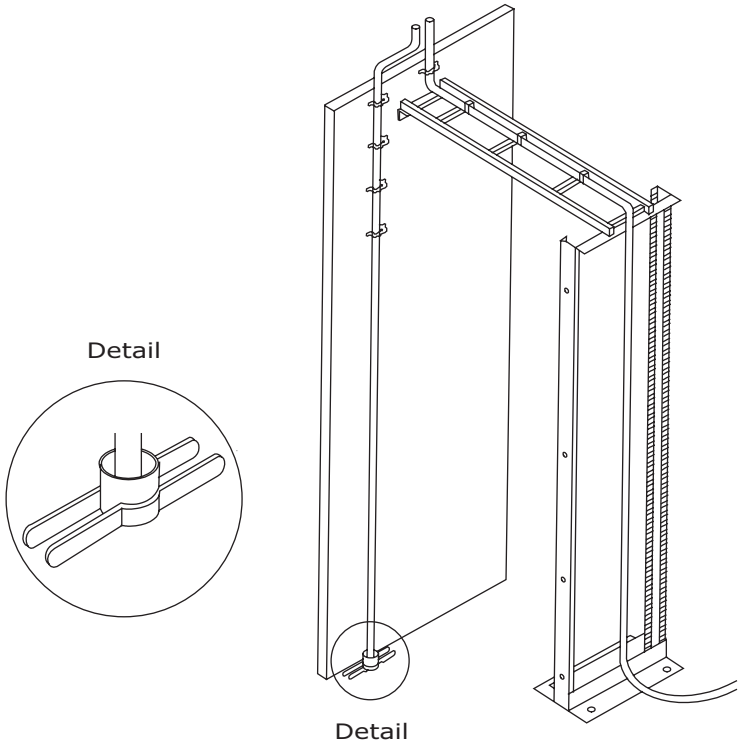
Figure 5.39
Vertical backbone cable support



Steps—Vertical (Top Down), continued

Step	Installing Backbone in Vertical Pathway—From Top Down
9	Route and secure cables in the vertical pathway.
10	When the vertical pathway enters a TR: • Make a sweep of the cable toward the termination point. Do not exceed the proper bend radius of the cable. Multipair cables require a bend radius of 10 times their diameter. • Secure the cable with cable ties, straps, split, wire mesh grips, or clamps, and place the cable in the provided cable trays (see Figure 5.40). Distribution rings are intended for small bundles (e.g., horizontal cables). The weight of backbone cabling typically is too great for D-rings. Additionally, D-rings and hook and loop/tie wraps allow frequent MACs while backbone cabling is permanent.

Figure 5.40
Cable on tray from vertical pathway

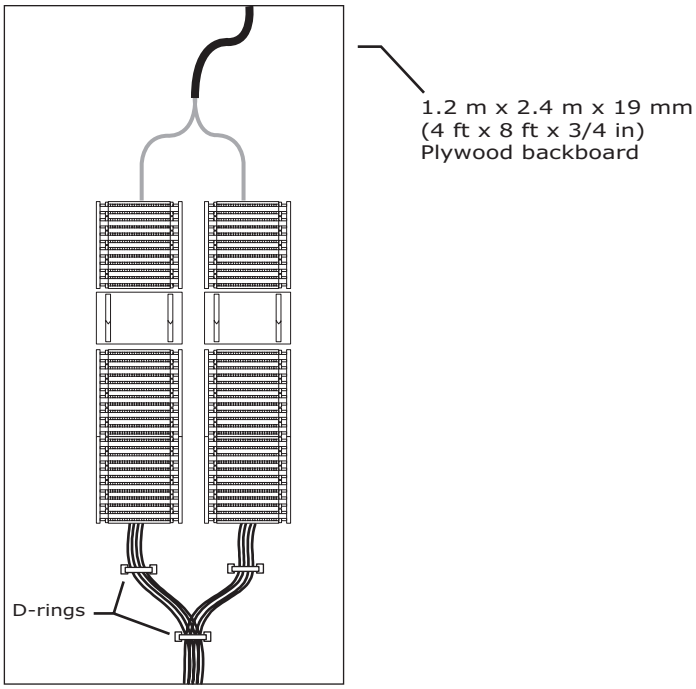


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Steps—Vertical (Top Down), continued

Step	Installing Backbone in Vertical Pathway—From Top Down
10 cont.	• Mount the cable to the wall using cable clamps or special-purpose cable ties designed to support the weight and type of cables to be installed (see Figure 5.41).

Figure 5.41
Backboard layout with D-rings



ft = Foot
in = Inch
m = Meter
mm = Millimeter

11	Identify cable. • Place unique identification numbers (from the installation drawings) at each end of the cable showing the point of origin and destination. • Place a label on the cable where it enters or leaves a TR on each floor.
12	Document cable information on the posted floor plans. • Show clearly what kind of cable was installed. • Show clearly which conduit was used. • Describe the purpose of the installed cables.
13	Perform job wrap-up tasks.

Installing Backbone in Vertical Pathway—From Bottom Up

Overview

Conditions sometimes exist that prevent pulling backbone cable from the top down. The first choice is to pull the cable from the top down. Sometimes, however, it is not possible to get the large spools of cable up to the top floor of a building. In those situations, specific equipment must be brought in to handle the task of installing the cable up through the riser to the necessary heights. Because of gravity, the heavy weight of the cable makes a bottom-up installation more difficult.

Through the initial project planning process, the ITS installer should have already completed several tasks, including:

- Verifying correct types and lengths of cable are available on the work site.
- Determining access for moving and positioning cable reels (e.g., loading docks, freight elevators).
- Selecting the tools required for pulling the cable.
- Identifying and providing the proper safety and communications equipment.
- Identifying the requirements and methods for labeling and documenting the cable pulls.

Setting Up for the Pull

Setting up the work site and preparing for the pull involves additional tasks and considerations. Before pulling the cable, determine the required cable length and how the weight will be distributed. The number of floors and TRs that must be accessed are factors in the decision process.

Once the reel is brought to the bottom floor, it must be set up for the placing operation. A reel dolly or set of jack stands is necessary to allow for paying out the cable. The reel must be situated in a location that will provide enough slack for the bottom floor once placing operations are completed.

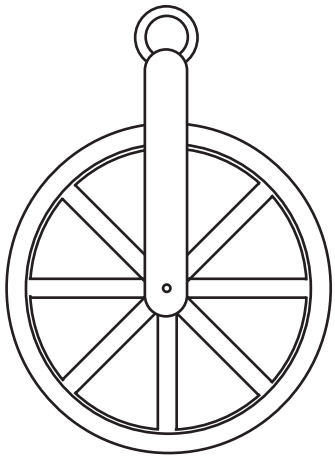
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Setting Up for the Pull, continued

Pulling sheaves may be necessary to handle the cable from the reel location to the point where it will be pulled to upper floors. These pulling sheaves can be laid on the floor along the route to the vertical pathway and provide a pathway for the cable as it is being placed.

In the TR, where the cable will enter the vertical pathway, a bullwheel may be required to ensure that the jacket is not damaged as it enters the pathway (see Figure 5.42). The bullwheel should be located so that the cable ascends vertically into the pathway. A bullwheel must be attached to the building structure to prevent any lateral movement. Lateral movement will cause the cable to become misaligned with the vertical pathway and will damage the outer jacket.

Figure 5.42
Bullwheel



This operation may require that the bullwheel be attached to the building in three places. The three attachments will support the bullwheel and prevent it from pulling away from the pathway entrance and from moving laterally.

The pull rope choice for this operation is critical. A rope with limited stretch characteristics should be used for this operation because it does not stretch when placed under tension. The rope does not deteriorate quickly when subjected to the friction (and heat caused by the friction). It has a tendency to twist as tension is applied, which requires the use of a swivel between the cable and the pull rope. The swivel will prevent the cable from twisting during the placing operation, thus damaging the jacket, the screen/shield, and the conductors.

If a pulling eye was not factory installed, install a substitute device. An alternate method of pulling is the use of a pulling grip, which is a flexible wire mesh device that clamps down on the cable as tension is applied. These devices are available in various sizes based on cable diameter. Ensure that the device is properly sized for the cable. Place it over the cable jacket, and then tape it to the jacket. This will prevent it from coming off if the pull is halted and the tension is relaxed on the grip.

Setting Up for the Pull, continued

If a wire mesh grip is not available and the pathway is large enough, attach the pull rope over the jacket in a series of half hitches. Place vinyl tape over the guide rope, securing it to the cable.

NOTE: Pulling eye or wire mesh grips are the preferred methods of pulling cables. The placement of rope directly around the cable, even using multiple half hitches, can provide too much pressure at a single point on the cable. This pressure can distort the conductors, changing the mutual capacitance of the cable.

Attach the swivel to the pull rope, and then attach the cable to the swivel. Ensure that the swivel is rated for the weight of the pull.

To lift a cable of significant weight, a winch is required. A winch is an electrical motor equipped with a capstan, which is secured to the building structure on the top floor. The pull rope is wound around the capstan. When the ITS installer places tension on the rope, the rope tightens around the capstan. Friction created by the tightening causes the rope to advance toward the ITS installer. The ITS installer can control the rate at which the rope advances, thus controlling the advance of the cable along its route.

WARNING: It is critical that the winch is securely attached to the building structure. If the winch is not properly attached to the building structure and loosens, it becomes a projectile and may cause damage or injury.

The coefficient of friction can be an obstacle when installing cable, especially in conduit pathways. The use of cable lubricants can significantly reduce friction and speed up cable installation. Select a lubricant based on the type of pull, type of conduit, cable jacket, and cable size. The lubricant should be applied as the cable is placed. When placing the cable from the bottom up, use a gel-type lubricant.

When pulling cable through sleeves, ITS installers should be posted on each floor through which the cable will pass as well as the top floor where the cable will terminate. These individuals must be equipped with the proper tools to perform critical tasks during the placing operation.

Some of the tools include:

- PPE (e.g., safety glasses, hard hats, gloves).
- Communication equipment (e.g., portable handheld radios).
- Temporary restraining devices for the cable. Cable type and size will determine the necessary restraining devices. One common method of temporarily restraining cable is the use of rope with limited stretch characteristics and an eyelet. The eyelet is attached to a secure structure in the TR. A half hitch is made in the rope, and the ITS installer pulls on the rope. The amount of tension placed on the rope controls how quickly the cable slips through the half hitch. This method allows the cable to be halted and restarted during placing operations without losing control of the cable if it falls (with or without a reel brake).

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Installing the Cable

Once everything is in place, the cable can be installed. Communicate with members of the team and advise them that the pull is ready to begin. Begin pulling the cable up through the vertical pathway. Monitor its progress throughout the pull. Continue the placing operation until the cable is completely placed.

Ensure that enough slack is pulled to the top floor before it is permanently secured so that it can be lowered back down to the individual floors where it may be required later.

Once the cable reaches the top floor, the ITS installer must temporarily restrain the cable. Beginning on the bottom floor, pay out the additional slack that is needed in each TR. Once the slack is brought into the TR, secure the cable in its final location.

Securing the cable on each floor ensures that the weight of the cable will not become excessive at any one point. Many different devices can be used for securing the cable. The most common one used today is the split grip, which is a wire mesh grip that is open on one side.

The wire mesh grip is placed around the jacket of the cable. A pin is then woven through the open sides of the wire mesh grip, securing them around the cable jacket.

A section of steel rod, a minimum of 13 mm (0.51 in) thick, is inserted through the loop at the end of the wire mesh grip. The cable is then allowed to slide through the opening in the vertical pathway until the steel rod lies on top of the pathway.

Another method of securing the wire mesh grip is to attach it to the building or a plywood backboard with an anchoring device.

The cable should then be identified and labeled, and the documents should be updated to reflect the work operation.

After completing the work, the cable reel and any remaining cable can be returned to storage or prepared for salvage. If the cable was shipped on a wooden reel, the reel can be dismantled and disposed of. If the cable was shipped on a metal reel, it should be returned to the manufacturer for credit.

Steps—Vertical (Bottom Up)

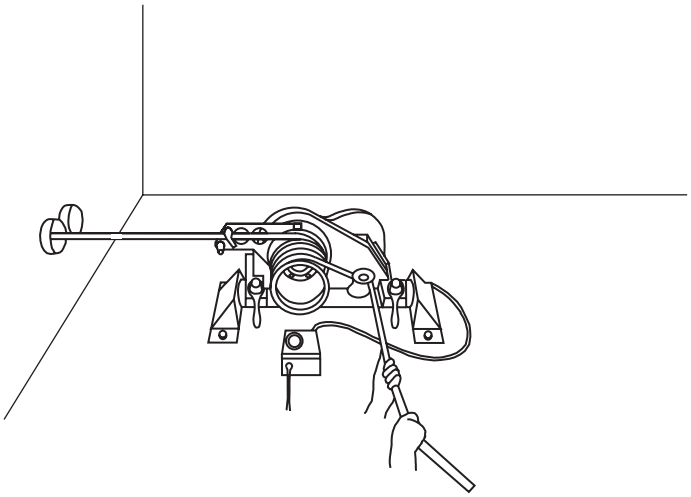
Step	Pulling Backbone in Vertical Pathway—From Bottom Up
1	Verify proper run and cable length. • Examine the conduit and vertical pathway for the planned installation, and check for a clear pathway. If possible, avoid a cable path with obstacles or transitions. • Use the blueprints to estimate the actual length of the cable run, or verify by installing a pull tape equipped with sequential footage markings. This pull tape, if sufficiently sized, can be used as the guide rope.
2	Move cable reels into place, and secure the pulling area. Place the reel on a reel dolly or jack stands. If necessary, place cable sheaves along the floor to the entrance of the vertical pathway.
3	Determine the appropriate rope size and strength. • A critical factor in the success of the job depends on the strength of the rope used in the pull. • Check the manufacturer's specifications about the length and weight of the cable that will be installed to ensure that the rope meets the strength requirements.
4	Install the pull rope. • Check to see that the pull rope, which must hoist the cable to the upper floors, is lowered down to the proper building level so that it can be attached to the cable. – Bring the pull rope to the upper floor. – Secure one end at the top. – Lower the rope to the bottom floor or vertical feed point.
5	Attach the cable to the rope. • Check the pulling end of the cable to see if it is equipped with a factory-installed pulling eye. Attach the pull rope to a swivel. Attach the swivel to the cable. • Use a wire mesh grip if a pulling eye is not provided on the cable.
6	Use a bullwheel if required. • Use a bullwheel to maintain the proper bend radius as the cable comes off the reel and is fed into the opening. • The arc formed by pulling the cable under the bullwheel protects the integrity of the conductors. • Unlike pulleys, bullwheels do not alter the pulling force required.

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Steps—Vertical (Bottom Up), continued

Step	Pulling Backbone in Vertical Pathway—From Bottom Up
7	Attach winch and pulleys; if required, verify they are anchored and secured (see Figure 5.43).

Figure 5.43
Winch in position and properly secured to a concrete slab



- Confirm that the winch is at the required location.
- Verify that the winch is solidly anchored and firmly secured. Adjust winch pulley wheels to proper tension to begin tugging.
- Verify that vibrations created by the winch's short tugging motions will not move the equipment.
- Verify that each pulley is positioned in a secure location and that it is firmly anchored.
- Pulling equipment must be anchored to the structure of the building (e.g., concrete anchors, steel cables, bolts).

8 Lubricate cable/pipe.

- Obtain an approved lubricant that is not abrasive or damaging to the cable.
- Apply a liberal amount of the lubricant to the open end of the conduit.
- Apply the lubricant to the end of the cable where it is attached to the pull rope. Some commercially available dispensers automatically distribute lubricant over the cable as it enters the conduit.

Steps—Vertical (Bottom Up), continued

Step	Pulling Backbone in Vertical Pathway—From Bottom Up
9	Communicate with coworkers. • As the cable pull begins, communicate with coworkers to pass on information about how things are going. • Ask all coworkers to call out the job status—check if everything is okay or if there is a problem. • Encourage everyone to take responsibility for the job and to report even the slightest appearance of a problem. It is better and safer to prevent the problem than to correct or repair one.
10	Start the winch slowly, and communicate your actions to the coworkers at the other end. • Ensure that a coworker is at each end of the pull and at all midway positions. Otherwise, coworkers will have to move between floors. The pulling operation may have to be temporarily halted for them to relocate. • Notify coworkers of the conditions at the end where cable is being fed into the riser shaft. • Start the winch slowly so that the tugs do not come too fast and everyone can observe what is going on.
11	Maintain the operation until the cable is in place. Keep coworkers in position and watching for problems until the pull is complete.
12	Route and secure the cable as necessary. • Secure the cable in the riser shaft. • Bring the cable into the TR. • Bring the cable toward the termination point. • Continue securing the cable with tie wraps or other appropriate devices to the backboard, tray, or rack. • Prepare the service slack, leaving slack in the cable for termination. Mount the cable to the wall, using clamps or ladder rack and cable ties. NOTE: The service slack is used to help relieve tension on the cable and provide slack for future moves and changes. • The service slack should be long enough to reach the opposite side of the TR following the pathway, plus floor to ceiling, in case of equipment relocation or enhancement. Keep in mind that these cables usually require a minimum-bending radius of 10 times the cable OD for multipair cables.

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Steps—Vertical (Bottom Up), continued

Step	Pulling Backbone in Vertical Pathway—From Bottom Up
13	Identify the cable. • Place unique identification numbers (from the installation drawings) at each end of the cable showing the point of origin and destination. • Place a label on the cable where it enters or leaves the TR on each floor.
14	Document cable information on the posted floor plans. • Show clearly what kinds of cables were installed. • Show clearly which conduit was used. • Describe the purpose of the cables installed.
15	Perform job wrap-up tasks.

Installing Backbone—Horizontal

Overview

Horizontal multipair backbone cable is used for interconnecting TRs. Horizontal multipair backbone cable may or may not be installed in the conduit between TRs.

Cable support mechanisms are required to provide all protection necessary for keeping the cable free of excessive tension. Excessive tension will often cause damage to the pairs inside the cable.

Beam clamps, cable trays, lay-in raceway, or a trapeze system may support horizontal backbone cable runs. Because of the heavy weight of the bulk cables, it is imperative that the load-handling capabilities of the pathway support system are adequate to handle the installation.

High pair-count backbone cables must be placed individually to manage their weight. Placing high pair-count backbone cables presents the same problems as pulling from the bottom up. Additional changes in direction will increase the pulling tension required. The coefficient of friction increases because the entire weight of the cable is horizontal and creates friction with everything it contacts. Open-type supports (e.g., cable trays, ladder racks) preclude the use of lubricants. As a result, pulleys may have to be employed to overcome the problem of friction.

Through the initial project planning process, the ITS installer has already completed several tasks, including:

- Verifying correct types and lengths of cable are available on the work site.
- Determining access for moving and positioning cable reels (e.g., loading docks, freight elevators).
- Selecting the tools required for pulling the cable.
- Identifying and providing the proper safety and ITS equipment.
- Identifying the requirements and methods for labeling and documenting the cable pulls.

Setting Up for the Pull

Setting up the work site and preparing for the pull involves additional tasks and considerations.

- Horizontal backbone installations sometimes require the use of pulling equipment (e.g., pulley, winch). A winch may be motor driven with a capstan. It is securely attached to the building structure, and the pull rope is wound around the capstan. When the ITS installer places tension on the rope, it tightens around the capstan. Friction created by the tightening causes the rope to advance toward the ITS installer. The ITS installer can control the rate at which the rope advances, thus controlling the advance of the cable along its route. In other installations, an ITS installer can manually perform the tugging.

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Setting Up for the Pull, continued

- The pull rope choice for this operation is critical. Rope with limited stretch characteristics should be used because it does not stretch when placed under tension, nor does it deteriorate quickly when subjected to friction and heat. However, the rope has a tendency to twist as tension is applied. To prevent this, use a swivel between the cable and the pull rope. The swivel prevents the cable from twisting during the placing operation and prevents damage to the jacket, screen/shield, and conductors.
- If a pulling eye was not factory installed, install a substitute device. A wire mesh grip that is properly sized can be installed on the cable. This prevents it from coming off if the pull is halted and the tension is relaxed on the grip.
- When a wire mesh grip is not available and the pathway is large enough, attach the pull rope over the jacket in a series of half hitches. Place vinyl tape over the guide rope, securing it to the cable.
- Attach the swivel to the pull rope; attach the cable to the swivel. ITS installers should be equipped with the proper tools to perform critical tasks during the placing operation. Some of the tools include:
  - PPE (e.g., safety glasses, hard hats, gloves).
  - Communications equipment (e.g., portable handheld radios).

Installing the Cable

Once everything is ready, install the cable. After informing the members of the cabling team that the pull is starting, begin pulling the cable into the horizontal pathway. Monitor the cable's progress throughout the pull, and continue the placing operation until complete. Ensure that enough slack is pulled to the last TR.

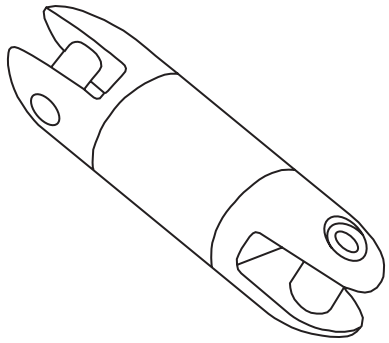
Cable should be identified and labeled, and the documents should be updated to reflect the work operation. Documentation is an essential part of the job and includes labeling the cable and updating the building plans to specifically indicate the cable installed by the cabling team.

When the work is complete, return the cable reel and any remaining cable to storage or prepare for salvage. If the cable was shipped on a wooden reel, the reel can be dismantled and disposed of. If the cable was shipped on a metal reel, return to the manufacturer for credit.

Steps—Horizontal Backbone

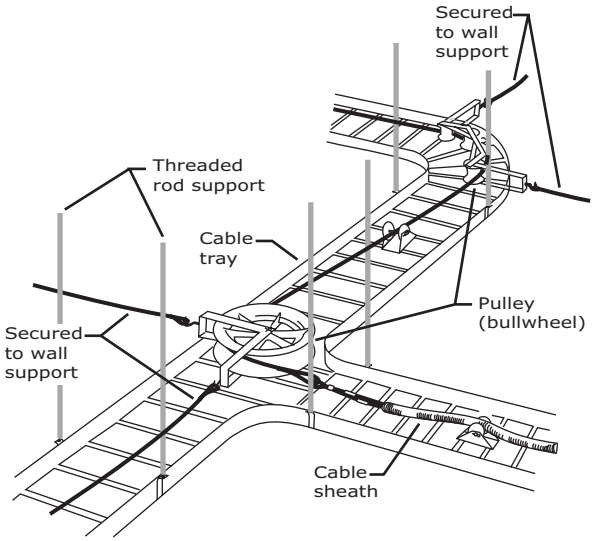
Step	Pulling Backbone—Horizontal
1	Install and attach pulling mechanism to the cable. • If possible, use only manual strength to pull the cable. • When more power is required, use a winch. • Attach the pull rope to the winch. • Use a swivel to prevent the cable from twisting as it is pulled forward (see Figure 5.44).

Figure 5.44
Swivel to prevent cable twisting



2	Attach pulleys (bullwheel), if required. • Decide whether pulleys are required to advance the cable during the pull or to stabilize it (see Figure 5.45). • Pulleys also help guide cables around obstacles.

Figure 5.45
A properly secured bullwheel pulley



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Steps—Horizontal Backbone

Step	Pulling Backbone—Horizontal
3	Communicate with coworkers. • As the cable pull begins, communicate with coworkers to pass on information about how the work is progressing. • Ask all coworkers to call out the job status; check if everything is all right or if there is a problem. • Encourage everyone to take responsibility for the job and to report even the slightest appearance of a problem. It is better and safer to prevent a problem than to correct or repair one.
4	Pull the cable until it is in place. • Carefully monitor the cable's progress to the last location. • Maintain control of any pulley that may be in use. • Maintain control of all pull ropes that may be in use. • Stay in position as a communicator with coworkers until the pull is finished.
5	Route and secure the cable in TRs if necessary. • Route the cable into the TR. • Route the cable to the termination point. • Secure the cable with tie wraps or other appropriate devices to the backboard, tray, or rack. • Prepare the service slack, leaving slack in the cable for termination. Mount it to the wall using clamps or ladder rack and cable ties. NOTE: The service slack is used for helping relieve tension on the cable and providing slack for future moves and changes. • The service slack should be long enough to reach the opposite side of the TR following the pathway, plus floor to ceiling, in case of equipment relocation or enhancement. Keep in mind that these cables usually require a minimum-bending radius of 10 times the OD for multipair copper cables.
6	Identify cables. Place unique identification numbers (from the installation drawings) at each end of the cable showing the point of origin and destination. Place a label on the cable where it enters or leaves each TR.
7	Document cable information on the posted floor plans. • Show clearly what kinds of cables were installed. • Show clearly which pathway was used. • Describe the purpose of the installed cables.
8	Perform job wrap-up tasks.

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Splicing Cable

Overview

Intrabuilding splices are generally constructed in ERs, TRs, and EFs.

NOTE: Intrabuilding multipair balanced twisted-pair cable splicing is only allowed in the backbone cabling and never in horizontal cable.

The ITS distribution designer should specify cable splice locations and other splicing details on the work order prints. The location of splices can be an aid when troubleshooting for opens, shorts, and insertion loss because of the joining of copper pairs. These work order prints must be strictly followed because the splicing work could affect future cabling system plans.

Where questions arise concerning cable pair counts or specific splicing methods, seek direction from the immediate supervisor. For the purpose of this section, the cable splicing techniques described are for in-building applications using single sheath cable.

Backbone cables are bundled in 25-pair color-coded binder groups with color-coded pairs in each binder.

NOTE: See Table 5.6 for cable sizes up to 600 pairs.

Intrabuilding backbone cables commonly range in size from 25 to 2400 twisted-pairs. The first binder group of the cable is normally located near the center of the cable, and successive groups are layered toward the cable sheath (see Table 5.11).

Table 5.11
Color codes for super binder groups

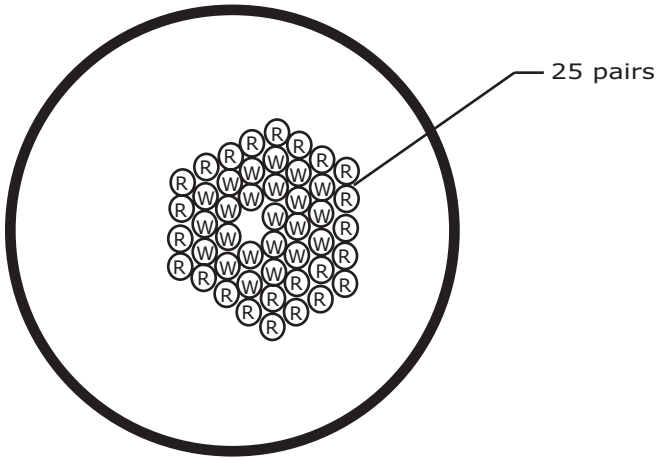
Pair Number	Super Binder Group
1–600	If smaller than 600 white or no super binder
601–1200	Red

Overview, continued

Cables larger than 1200 pairs are no longer grouped in 25-pair binders (as shown in Figure 5.46) but now have groups of 100 pairs. Within each 100 pairs are four multiunits of 25 pairs, with a blue/orange/green/brown 25-pair binder in each 100-pair group.

These cables, assembled in 100-pair groups, must be counted differently in what is often referred to as a mirror-image configuration. Some manufacturers refer to this construction as clocking because the construction starts in the middle and spirals outward in a clockwise direction to the outside of the sheath. The understanding of mirror image is more involved and requires knowledge of feeder and field orientation and is outside the scope of this manual.

Figure 5.46
Super group color code



Tip Colors
White (W) 1-600
Red (R) 601-1200

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Single and Dual Conductor Splice Connectors

Generally, outside plant (OSP) cable is spliced using:

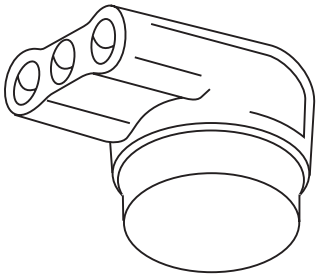
- Single connectors—Available in butt, half-tap, or straight-through models.
- Multisplicing modules—Available in straight-through models or half-tap.

Both methods use IDCs to ensure reliable connections of the conductors (see Figure 5.47).

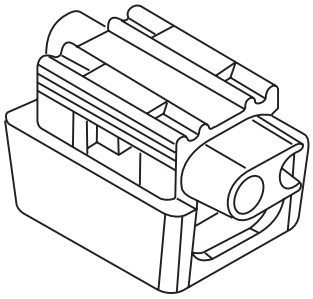
Figure 5.47
Splice connectors



Full pair straight-through splice connector



Butt splice connector



Half-tap splice connector

Single and Dual Conductor Splice Connectors, continued

Single connectors:

- Are not to be used in category-compliant installations (e.g., category 3/class C or higher).
- Are available in designs capable of terminating two or three conductors.
- Can be filled or nonfilled.
- Accept different gauge wires.
- Require no special tools.
- Require minimum setup time.
- Are not recommended for splices more than 50 pairs.

NOTE: Where electrical codes or building codes apply, only the listed cable can be used within a building structure except for an entrance cable that is terminated or transitioned within 15 m (49 ft) from its point of entrance. The only exception would be to extend unlisted or outside cable in uninterrupted rigid metal conduit (RMC) or intermediate metal conduit (IMC) from the point of entrance into the building to the point of termination within the building. This would allow 5 m (49 ft) of exposed cable where the cable emerges from the RMC or IMC as long as the conduit extends directly from outside the building. Some international codes limit entrance cable to 3 m [10 ft]. Consult the local AHJ.

Planning is critical to the splicing operation. Several items must be considered (e.g., cable placement, support structure for the splice, selection of the type of closure). Generally, the ITS designer who prepares the drawings, and many times ensures that the parts are ordered, does the planning. The splicing operation can be done with one of the two commonly used types of equipment, MS^2 or Type 710. Both use IDCs for conductor termination.

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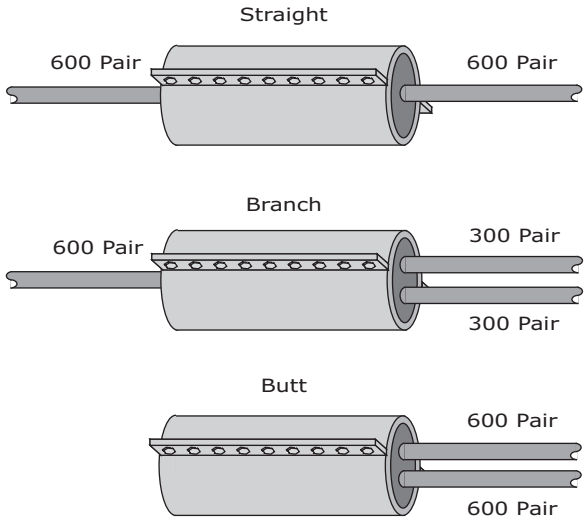
Single and Dual Conductor Splice Connectors, continued

The ITS installer must position the cable, rig the support structure, and ensure that the proper materials are used such as the right splicing modules and closure (e.g., too many cable conductors spliced in a closure without adequate splice banks may stress the wires). Reentry and repetitive access (churning) to conductors without proper planning can lead to deterioration of the cables at the weakest point—the splice. Three major types of splice closures are typically used in both copper and optical fiber splicing (see Figure 5.48):

- Straight—Connecting cables straight through in a line-by-line (generally the same pair count) manner
- Branch—Three or more cables entering a splice case from any direction in which cable pairs or optic counts move from one sheath to another
- Butt—Two or more cables that enter a splice case from the same direction

NOTE: Although all three closures are the same (round drum container), the endplates, ordered separately, make the difference.

Figure 5.48
Example of splice closures



Other considerations when ordering closures are the:

- Diameter of the closure, based on splice volume.
- Length.
- Final location of the splice: underground or buried.
- Fire retardant or non-fire retardant.
- Endplates: single, multiple, or blank.
- Diameter of each cable.

It is a good rule of thumb to ask the cable splicer to make these decisions before ordering splice closures. The cable splicer must ultimately make the splice fit into the ordered closure.

Single and Dual Conductor Splice Connectors, continued

Once the cables are set up, they must be prepared for the opening of the sheath (outer cable covering). After the screen/shield is open and bonding shield removed, install a bullet bond clamp kit on each cable and connect it with the bonding bar ribbon.

NOTE: For more information on bonding, refer to Chapter 4: Bonding, Grounding (Earthing), and Electrical Protection.

Decide what method of splicing will be used and the number of banks within the splice (e.g., how the 25-pair modules are laid in and stacked). The setup has everything to do with the final close-up. These decisions will facilitate selecting the sheath closure and opening that would fit the length recommended in the closure manufacturer's instructions.

Once the sheaths are open, the cable shields bonded together, the closure endplates installed, and the binder groups marked, the chosen splicing method can be used to join the cable pairs.

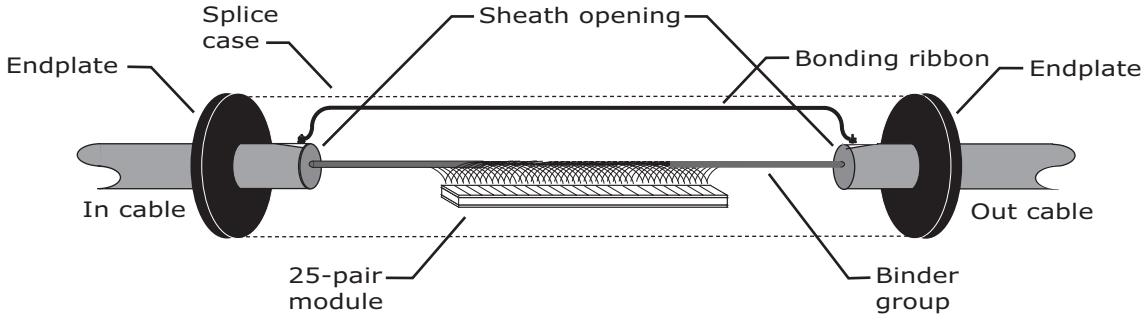
NOTE: After the endplates are installed, permanently mount in place the back half of the splice closure. This keeps the splice opening from varying during the splicing operation, making the close-up easier.

Two common modular (groups of pairs) splicing techniques are:

- Inline.
- Foldback.

With the inline splicing method, wire is placed in a straight-across arrangement and allows little wire slack. The inline method is not designed to be rearranged and should receive minimum handling (see Figure 5.49).

Figure 5.49
Inline splice

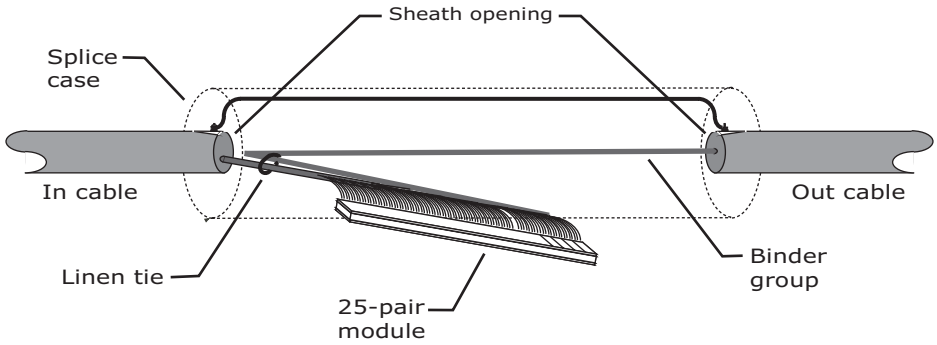


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Single and Dual Conductor Splice Connectors, continued

The foldback splicing method allows the conductors to be folded into the splice. The foldback method allows maintenance, rearrangement, and transfer of the conductors. It typically requires more cable to be stored within the splice and could increase the size of the needed splice closure. Most splices are foldback (see Figure 5.50).

Figure 5.50
Foldback splice



Most balanced twisted-pair cable splicing is performed with modular connectors. To enhance the conductor organization, multiple 25-pair connector modules are used on larger splices.

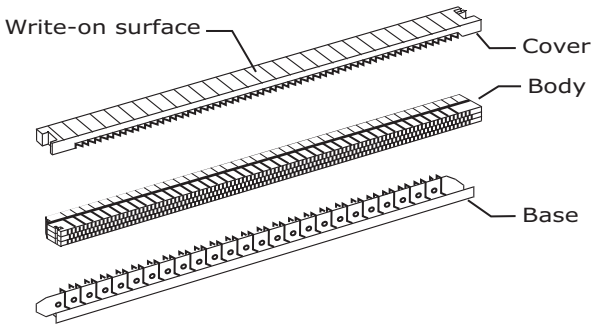
Modular connectors are available in several varieties—straight, bridge, and half-tap (see Figure 5.51).

Straight module joins the end of a binder group from two separate cables using one 25-pair module. It is the most common module used in permanent splices.

Bridge module connectorizes the end of a single cable with a pluggable bridging module that can be repeatedly separated and joined to other connectors. The bridging module allows system reconfiguration and maximum infrastructure flexibility.

Half-tap module allows a second cable to be spliced into the middle of an existing cable without service interruption. The half-tap module connectorizes a cable midspan without cutting the cable's conductors. A second cable can be permanently hardwired onto the half-tap module. A second cable that has been connectorized with a bridging module can be plugged into the half-tap module.

Figure 5.51
Splicing using 25-pair connectors



Single and Dual Conductor Splice Connectors, continued

These modules are for interbuilding OSP or intrabuilding (inside plant) use and, depending on the manufacturer, accommodate 22 AWG [0.64 mm (0.025 in)] to 28 AWG [0.32 mm (0.013 in)] wires.

In addition, these connectors are available in 5 pairs, 10 pairs, or 25 pairs. The 5-pair uses a handheld crimp tool sold by the module manufacturer and is used in low pair-count situations.

Testing cables and splices can be done as they are being constructed or after they are completed in accordance with the supervisor's instructions.

Each module should be labeled with the cable number and pair counts as the splice is constructed.

NOTE: Only use fire-retardant modular connectors and splice closures for intrabuilding splices.

After the conductors are spliced, they must be prepared using a polyethylene wrap before the splice closure is installed. The splice wrapping should be snug, yet not overtightened, so that modules and cable pairs do not become lodged in the splice closure seams. Once the splice is wrapped, a splice closure must be installed over all intrabuilding splices.

An intrabuilding splice closure is a strong, lightweight, fire-retardant covering that protects splices. The closure shields the splice against humidity and moisture and may even resist temporary immersion in water. When the closure is installed, it must be properly supported, grounded, and tested for air leaks according to the manufacturer's recommendations.

Labels must be affixed to all cables entering the splice, indicating cable numbers and pair counts. Care must be taken to clearly designate the incoming and outgoing cables of the splice (see Figures 5.52 and 5.53).

Figure 5.52
Wrapped splice

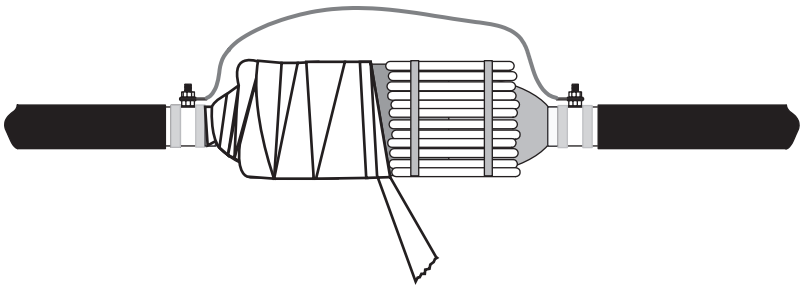
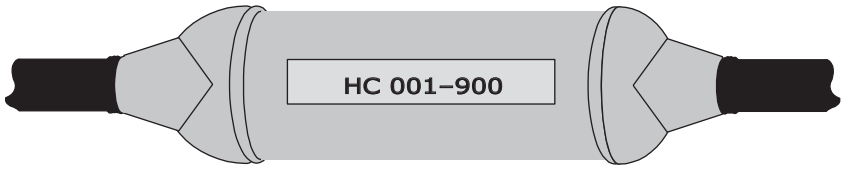


Figure 5.53
Completed splice case



HC = House cable

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Safety

Follow the splicing rig and closure manufacturer's guidelines when performing splicing operations. In addition, the items listed below should be enforced:

- Follow all safety guidelines.
- Wear safety glasses.
- Check the cable screen/shield for presence of unsafe voltages (e.g., foreign voltage).
- Ensure that there is adequate lighting.
- Wear safety gloves when opening the cable sheath.
- Keep cable screens/shields bonded at all times.

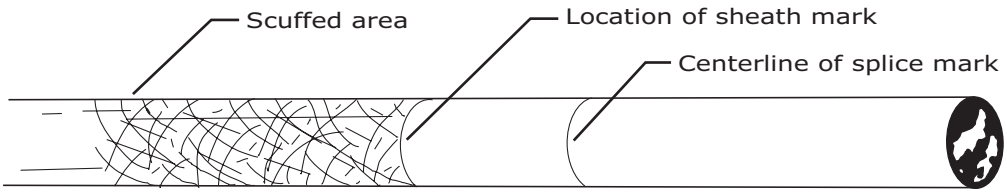
Steps—Splicing Copper Cable

Step	Splicing Copper Cable
1	The person performing the splice should ensure that the right materials and tools are available for the job. Verify that the appropriate modular connectors have been selected for splicing, making sure the tools accommodate the modular connectors to be used. For an intrabuilding splice, ensure that the modules are fire-retardant and the gauge of the wire within the cable corresponds to the range of sizes accepted by the connector module. Ensure that the appropriate fire-retardant closure has been selected, including endcaps. To calculate the splice and closure size, consider the following factors: • Cable pair count • Wire gauge • Connector type • Number of banks of connectors • Splicing method
2	Determine the scope of setting up the splice (also known as sizing up the job). Consider the space needs of the splice closure, the working space, and the cable pathway leading to the splice. Do not bend the cable so that it twists or kinks. As a rule, the bending radius of the cable should not exceed the cable manufacturer's guidelines. Always follow the cable manufacturer's guidelines when bending cables.
3	Check the work area to ensure safe working conditions. Verify that there is adequate space within the work area and that dangerous power conditions do not exist. The cable screen/shield should be checked for foreign voltages because neither the other end of the cable nor the pathway in which it is installed can be seen. Foreign voltages can be transmitted by accidental contact with a power cable or electromagnetic induction.

Steps—Splicing Copper Cable, continued

Step	Splicing Copper Cable
4	Safely set up the splicing area using ladders or scaffolding where necessary. Use warning cones and tape if working in an area that is accessible to the public. To ensure splice accuracy, set up portable lighting to clearly see the color-coded cable pairs and binder groups. Have tarpaulins available to protect both the splice in harsh environments and the splice area from debris while performing the work operation. It will be useful to have a garbage bag and a scrap wire bag close by while constructing the splice.
5	Install a support structure (e.g., trapeze, ladder rack, cable tray, cable rack) for the splice, if necessary. Move the cables to the support structure to position them for splicing. Do not twist or kink the cable. Maintain the proper bending radius of the cable, and allow room for the appropriate splice closure. NOTES: Most splices are built and assembled horizontally; however, because of design constraints (e.g., room size, cable alignment), splice and closures may be mounted vertically. It is best to set up and splice the cables in the location where they will always remain. Relocation of an existing splice closure could possibly damage cables and endplates. If this is necessary, a retest using air pressure within the splice and bubble solution around all seams and cable entrance points on endplates is highly desirable.
6	Place a mark on the cables at the center location of the splice. Mark the cables at the proposed location of the splice sheath opening according to the manufacturer's instructions for the selected closure. Scuff the sheath of the cables, using a carding brush or similar tool, for a manufacturer recommended distance away from the marking of the sheath opening toward the area where the endcaps will be placed (see Figure 5.54).

Figure 5.54
Scuffed sheath with markings on the sheath

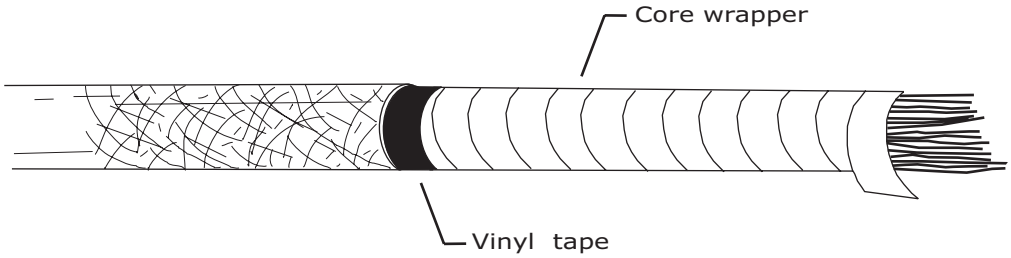


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Steps—Splicing Copper Cable, continued

Step	Splicing Copper Cable
7	At this time, install the closure endcaps. Follow the manufacturer's instructions for installation.
8	Ring (circular cut) one of the cables with a cable knife where the splice opening will begin. NOTE: The cable screen/shield under the sheath may be felt as the cable is ringed. **WARNING**: Do not put more pressure on the knife than necessary to extend the knife blade to the metallic screen/shield. At a 90-degree angle from this circular cut, use the cable knife and cut into the sheath again, running the knife to the end of the cable. Remove the outer sheath of the cable and discard it. Nick the metallic screen/shield at the sheath ring to remove the screen/shield. By putting enough pressure on the screen/shield, it will sever as the screen/shield is removed. Care must be taken because the screen/shield may be very sharp. NOTES: Be careful that the core wrap and binder tapes do not unravel from the cable end so that the cable pairs of different binder groups do not become mixed. Secure the core wrapper at the end of the cable with vinyl tape. Place three wraps of vinyl tape (adhesive side out) around the core wrapper and adjacent to the cable sheath. Slide half of the tape's width under the screen/shield. Ensure that exposed edges of the screen/shield are trimmed off or bent up and away from the cable core (see Figure 5.55).

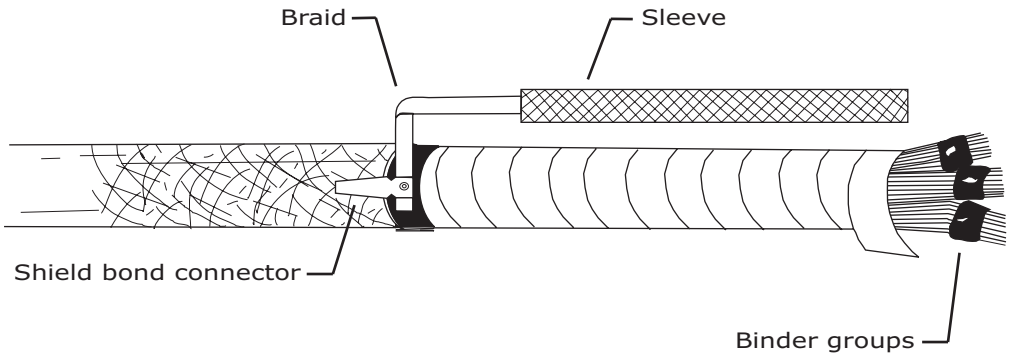
Figure 5.55
Sheath opening with core wrapper in place and vinyl tape protection from screen/shield



Steps—Splicing Copper Cable, continued

Step	Splicing Copper Cable
9	The hardware for connecting the cable screens/shields can usually be found within the packaging of the closure. If it is not included with the package, obtain the proper materials to bond the cable sheaths. In most cases, a bonding braid (equivalent to a minimum 6 AWG [4.1 mm (0.16 in)]) and an insulating sleeve are provided along with the screen/shield bond connector. Slide a length of insulating sleeve over the bonding braid, which will connect the screens/shields of the cables to be spliced. According to the manufacturer's instructions, install a screen/shield bond connector on the back side of each cable. This may require cutting a small piece of the sheath and screening/shielding it with tabbing shears. Attach the bonding braid to the connector stud of each cable. The braid should exit the side of the connector (see Figure 5.56). An alignment hole can be punched through the braid with a blunt object (e.g., pencil, approximately 13 mm [0.51 in]) from the end of the braid. Use vinyl tape to cover over the screen/shield connectors and extending 20 mm (0.8 in) out from the sheath opening (onto the inner sheath or core wrap).

Figure 5.56
Sheath opening with screen/shield bond connector, braid, and insulating sleeve



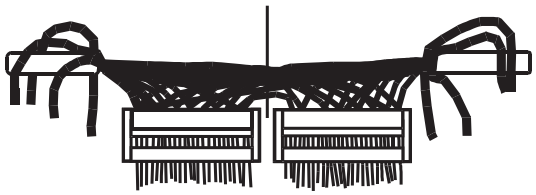
10	Remove the core wrap to the taped edge of the cable butt. Secure the ends of each binder group with vinyl tape to prevent loss of conductor pair identification.
11	Identify each 25-pair binder group within the cables by using the appropriate color-coded plastic cable ties or the original binder wraps tied around each binder. NOTE: Scrap wire pairs from junk cable should never be wrapped around the binders. This is an obsolete practice that has been shown to become an inductive choke detrimental to data transmission. Place the plastic cable tie or binder wraps approximately 26 mm (1 in) from the butt of the cable. When placing the plastic cable ties, ensure that they are loose enough to turn freely.

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Steps—Splicing Copper Cable, continued

Step	Splicing Copper Cable
12	Align the cable binder groups from both cables. Grasping the core of the cable and turning it within the cable sheath can align the binder groups.
13	Align the cables and secure them so that the splice opening does not spread or collapse during the splice operation. Ensure that the cables are aligned to the splice location and that the splice opening meets the instructions of the splicing rig and the splice closure. Secure the cables in place by tying them to the cable rack.
14	Determine whether the splice will be constructed using the inline or foldback method. With the inline splicing method, wire is placed in a straight-across arrangement. The inline method is not designed to be rearranged and should receive minimum handling. The foldback splicing method allows the conductors to be folded into the splice, which provides for maintenance, rearrangement, or transfer of the conductors. These steps describe the inline, two-bank, splicing method.
15	Attach the support tube and related components of the splicing rig to the cable sheaths. Follow the manufacturer's recommendations for setting up the splicing rig. This usually involves strapping a support tube to the cables, attaching a traverse bar with a clamp, and adjusting the splicing head to the position of the cable with the head clamp.
16	Select the back, bottom, 25-pair group from the feeding cable. The position of the splicing head is very important to the operation so that the wires will fit snugly into the splicing head and connector module (see Figure 5.57).

Figure 5.57
Example of positioning the splicing head to the cable groups

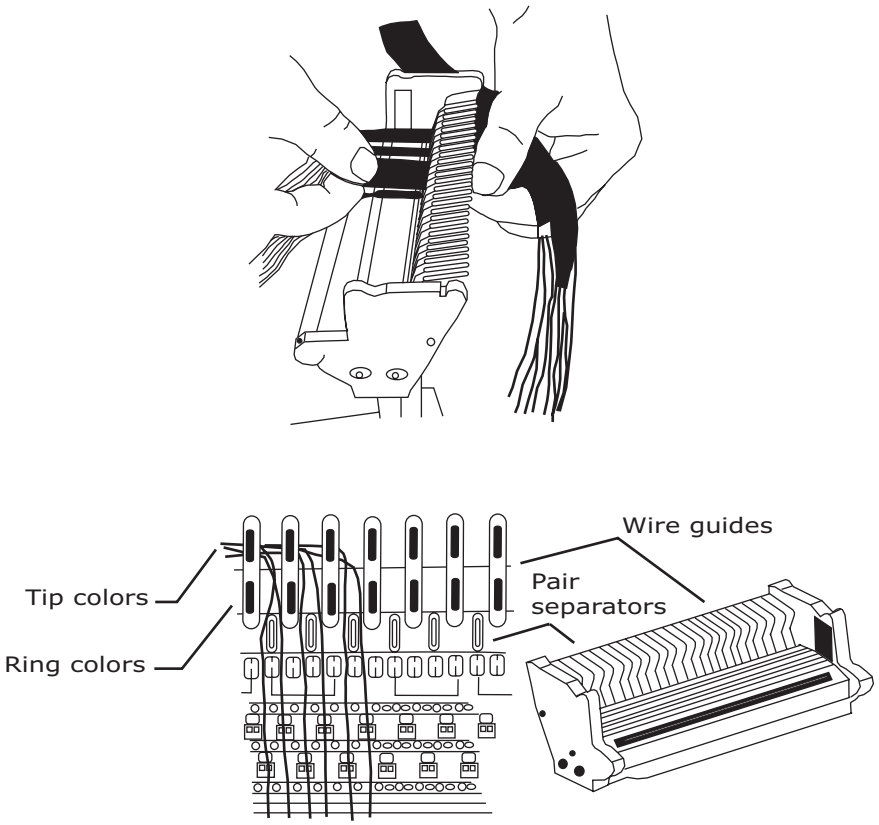


Front view

Steps—Splicing Copper Cable, continued

Step	Splicing Copper Cable
17	Place a connector module base into the splicing head. Lay the pairs of the feeding cable into the connector module base following the color code (see Figure 5.58).

Figure 5.58
Example of placing cable pairs into splice head

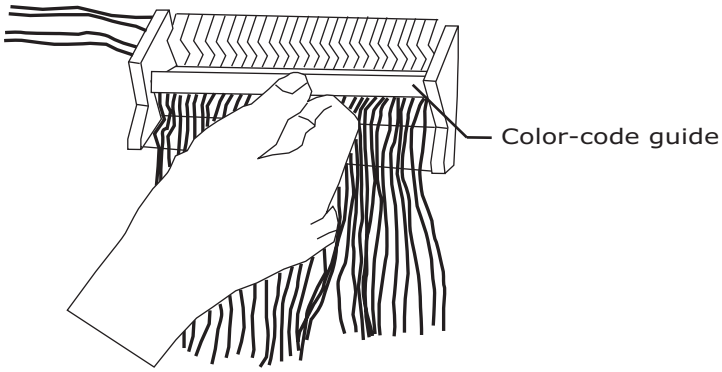


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Steps—Splicing Copper Cable, continued

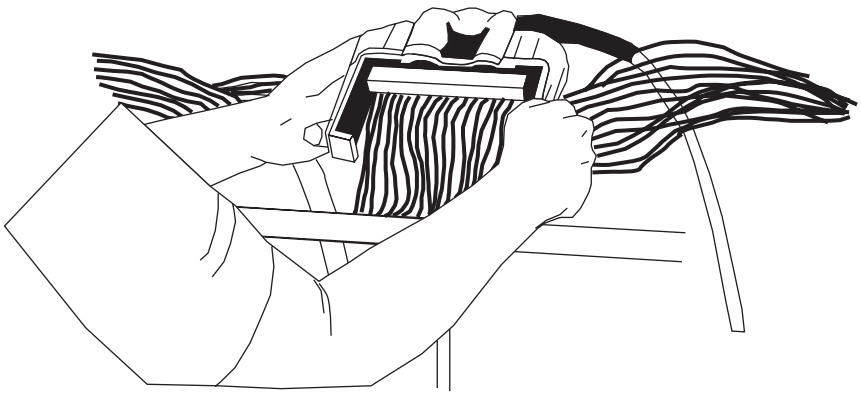
Step	Splicing Copper Cable
18	After the 25 pairs have been placed into the connector module base, visually check to ensure that each wire (e.g., ring and tip) is positioned properly (see Figure 5.59).

Figure 5.59
Module check for correct color code



19	Place the connector body over the connector base that holds the arranged cable pairs. Follow the same process for the group of wires from the away cable side of the splice. Place the connector cover over the connector body. Position the crimp head onto the splice head and crimp the connector module (see Figure 5.60). The binder group pairs may be electrically tested from the splice point if the equipment is available and the cable ends away from the splice have been cleared of potential trouble (e.g., shorts, crosses).

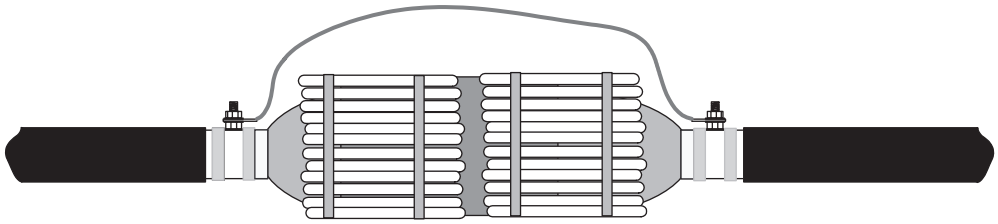
Figure 5.60
Example of placing crimper on splicing head



Steps—Splicing Copper Cable, continued

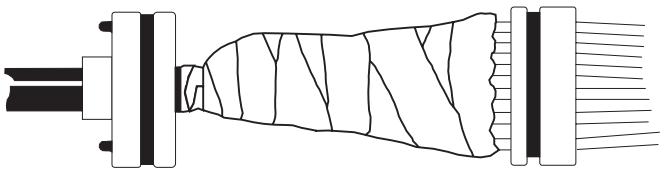
Step	Splicing Copper Cable
20	Continue splicing the cable groups according to the ITS designer's work order prints. The binder groups can be tied with color-coded tie wraps, binder wraps, or cotton sleeving with a clove hitch. Mark each module cover with the cable number and pair numbers using an indelible marking pen.
21	Tie down the splice bundle in the center, working any slack toward both cable butts (see Figure 5.61).

Figure 5.61
Spliced cable after being tied down



22	Cover the splice with a polyethylene wrap. The polyethylene wrap material may be on a 100 mm (3.94 in) wide roll. Wrap the splice so that the connector modules and cable pairs do not become pinched in the closure (see Figure 5.62).

Figure 5.62
A splice wrapped with polyethylene and endcaps



23	Install the closure according to the manufacturer's instructions. Part of the closure may have been installed earlier in the splicing operation. A grounding lug is usually provided in one of the endplates and must be connected to the cable sheath bonding braid. The grounding lug on the exterior of the closure must be bonded to the location indicated by the work order prints or by the ITS designer. Ensure that the cable and splice closure are properly supported, and test the closure for air leakage according to the manufacturer's instructions.

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Steps—Splicing Copper Cable, continued

Step	Splicing Copper Cable
24	Label the cables entering and leaving the splice case with the cable number and pair count.
25	Remove the ladders, scaffolding, and other equipment, and clean the work area.
26	Cable testing from the cable ends can now take place if the cable has not previously been tested from the splice point.

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Cable Termination Practices

Overview

This section describes the methods, tools, and practices for terminating balanced twisted-pair and coaxial cables. It lists pretermination steps and addresses several different applications relative to the termination of a cable, including:

- Termination blocks.
- Patch panels.
- Telecommunications outlet/connectors.
- Direct connections.
- Balanced twisted-pair cables.
- Coaxial cables.

Pretermination Functions

Overview

Planning and preparation for cable termination improves the quality of the job, decreases the amount of time required for termination, and adds to the speed of testing through having to do less reworking.

Pretermination tasks include:

- Using a cabling installation system cable-sorting component, which organizes the cable according to its destination in the TR. This provides for fast organization and dressing without wasting time resorting cables. Also, using the color-coded labeling system offered by many labeling components, which terminates onto the final destination, is highly accurate and fast.
- Organizing the cable by destination. Cable to be terminated should be placed in close proximity to the point of termination. The cable must be properly identified on both ends to ensure that it is terminated in the correct position. Avoid conflict by planning the routing of cables with other services and other cables, avoiding crossovers, etc.
- Forming and dressing the cable. Prior to termination, properly align the cables and position the cables in a neat and orderly manner. Changes to the lay of cables post-termination and testing can change the performance characteristics and, hence, the test results achieved. The length of cable needed to reach the termination location must be determined, taking into account enough cable slack to reterminate, if necessary. Caution should be exercised not to exceed the manufacturer's recommended pulling tension when installing the cables and deforming the pairs in the cable as the cables are dressed down and racked into the panels.
- Using proper cable management. Neat and orderly cable bundles should be formed; however, try to avoid a fully symmetrical pattern. It is important to be aesthetically acceptable, but be careful to avoid creating excessive outside noise interference (alien crosstalk). Proper cable management provides support and mechanical protection of the pairs. Care should always be taken to maintain the minimum bend radius of all cables within a bundle, particularly the cables on the inside arc of the bend.
- Using proper cable management hardware. All connecting hardware must be properly and securely mounted to its intended surface (e.g., racks, walls, modular furniture). Floor-mounted terminations must use the appropriate hardware for the floor enclosure.
- Allowing cables to lie naturally within a cable tray.

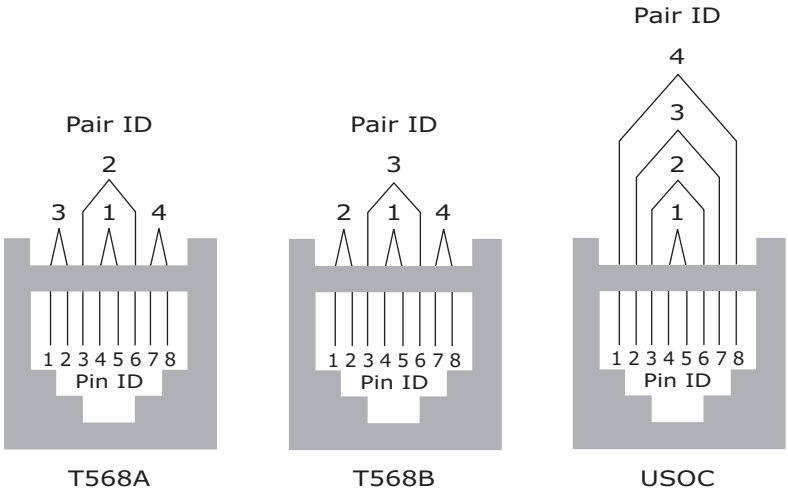
The following section describes the steps required to complete these pretermination functions.

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Steps—Pretermination

Step	Pretermination Functions
1	Organize cable by destination. • Know the pin/pair assignments for balanced twisted-pair cabling. If incompatible configurations are used for termination (e.g., mixing T568A and T568B), the overall success of the cabling project could be jeopardized. For balanced twisted-pair cabling, the connecting hardware, equipment cords, and patch cords used in horizontal and backbone cabling channels must be rated in the same transmission performance classification as the corresponding horizontal and backbone cables or in a higher performance classification than that of the cable. This will provide some assurance to the customer that the installed cables will not perform to lower performance levels as a result of being attached to lower performing connecting hardware, equipment cords, and patch cords. The performance of the channel is only rated at the lowest performance component. If a category 6/class E cable is terminated into category 6/class E outlets but only category 5e/class D cords are used, then the channel will only be valid to support category 5e/class D applications. With balanced twisted-pair IDC terminations, there are two standards-based pin/pair assignments: T568A and T568B. Only the T568A and T568B pin/pair assignments are compliant with the requirements for high-speed data transmission. An alternate pin/pair assignment is known as the USOC. Each of the pin/pair assignments is shown in Figure 5.63.

Figure 5.63
Wiring schemes

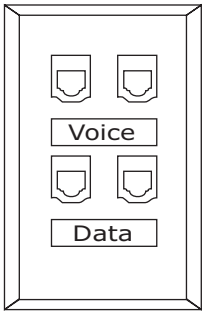


ID = Identification
USOC = Universal service order code

Steps—Pretermination, continued

Step	Pretermination Functions
1 cont.	• For work area terminations, check that all cables are available and properly labeled at the wall, furniture, ceiling (wireless access point [WAP]), or floor monument outlet locations. In ERs, ensure that connecting hardware is installed according to the ITS designer's layout. • Verify that the right products are on hand for the application. Modular furniture often requires a different type of outlet than framed wall offices. Floor monuments may require a special outlet to fit within the monument. Ensure the proper product type and manufacturer is specified. See Figure 5.64 for an example of a work area outlet.

Figure 5.64
Work area outlet



2	Form and dress cable at the rear of the outlet or panel. • Prepare the cable for termination by first bringing all cables into a layout that prevents them from crossing over each other and cascading in a sweeping curve to the destination. • For patch cord management, it is recommended that a minimum of one rack unit (RU) of 45 mm (1.77 in) of horizontal cable management is used for every two RUs of patch panels. This may change when a rack that provides its own cord and cable management function is used.

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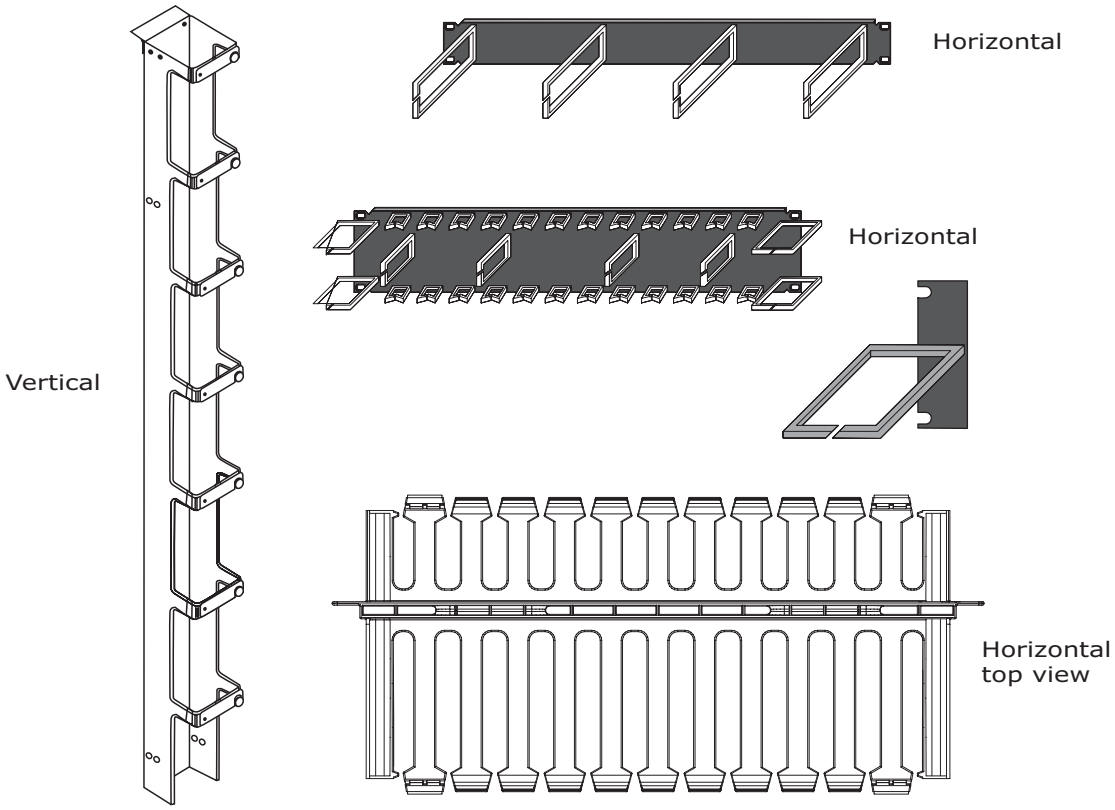
Steps—Pretermination, continued

Step	Pretermination Functions
2 cont.	• Cables may enter the ERs or TRs from multiple directions, which will frequently result in cables of many different lengths. After determining the amount of cable slack necessary, relabel the cables and cut the cables to uniform lengths. • Use hook and loop straps to secure the cables. The hook and loop straps should be evenly spaced throughout the dressed length. Hook and loop straps should be used to prevent a change in the physical geometry of the cable that typically results from use of nylon tie wraps.
3	Determine the length and slack required. • Provide an adequate amount of cable to reach the destination point for termination. • When running cables from a centralized point and the exact location of termination is unknown, leave enough cable to reach the farthest point in the ER or TR following the pathways plus enough cable to reach from floor to ceiling. It is important to remember that through the use of additional cable slack, the exact location of the backboard and rack termination hardware location can be adjusted to allow for additional equipment and hardware. If there is not enough cable slack, either the location of the termination hardware must be adjusted to fit the horizontal cabling or a new horizontal cable must be installed. Relocation of the termination hardware may alter the organized symmetry of the TR to such a point that future MAC activity becomes difficult. • When the exact location of the connecting hardware is unknown, it is recommended that backbone cables running vertically are laid in with enough slack to reach the floor or ceiling plus the distance across the backboard. When dealing with backbone cable, remember that the ITS installer generally is dealing with a very heavy, high pair-count cable that requires a large amount of termination connections. If a major redesign of a TR is undertaken and an adequate amount of slack in the backbone cable is not available, it may not be possible to maintain the proper design specifications and symmetry.

Steps—Pretermination, continued

Step	Pretermination Functions
4	Use the proper cable management hardware. • There are several different types and styles of cable management hardware. All cable management products are designed to properly support the in-place cables and relieve tension as well as to provide support for future cable that may be installed as a result of MACs. Figure 5.65 shows examples of cable management hardware.

Figure 5.65
Cable management products



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Steps—Pretermination, continued

Step	Pretermination Functions
4 cont.	• In balanced twisted-pair cable, maintain the minimum bend radius to protect the integrity of the cable being installed. Table 5.12 provides guidelines for the minimum bend radius of various cable types under different conditions (e.g., load and no load).

Table 5.12
Guidelines for minimum bend radius of various cable/cord types

Cable/Cord Types	Minimum Inside Bend Radius Under No Load (No Stress)	Minimum Bend Radius Under Load (Stress)
Patch Cords/Equipment Cords		
4-Pair, balanced twisted-pair cord	One time the patch cord cable's diameter	One time the patch cord cable's diameter
Horizontal Cables		
4-Pair, balanced twisted-pair	Four times the cable's outside diameter	Four times the cable's outside diameter
Backbone Cables		
Multipair backbone (more than four pairs) cables	Follow manufacturer specifications	Follow manufacturer specifications

NOTE: If a cable manufacturer's bend radius requirements are more stringent than those stated above, the ITS installer must adhere to the more stringent requirement.

- In balanced twisted-pair cables, the cable twist design is critical to the proper operation and standards compliance characteristics of the cable. To maintain the factory-designed specifications, untwisted pairs at the points of termination should not be retwisted. When proper termination techniques are followed, minimal untwisting should be required.

Copper Insulation Displacement Contact (IDC) Termination

Overview

Proper cable termination practices are vital for the complete and accurate transfer of both analog and digital information signals. IDC termination is the recommended method of balanced twisted-pair terminations. This method removes or displaces the conductor's insulation as it is seated in the connection.

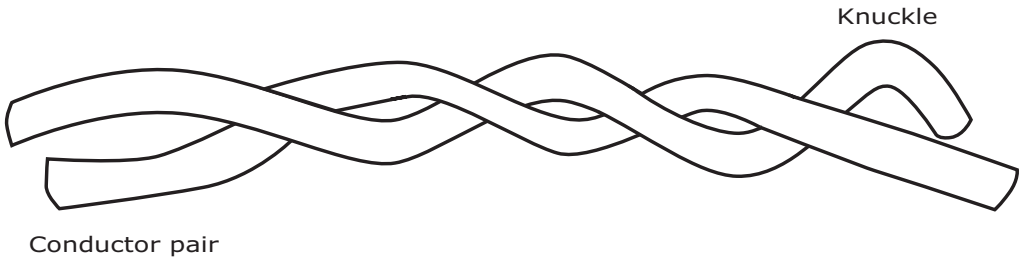
Four basic types of IDC termination blocks are used to terminate horizontal and backbone balanced twisted-pair cabling: 66, 110, BIX®, and LSA. These comprise the majority of the market. However, other connecting hardware devices are available, and standards development could increase the availability of new terminating products.

Several manufacturers provide rack-mountable and wall-mountable IDC termination hardware that can house multiple connecting blocks.

To ensure a good connection, care must be taken to closely follow the IDC connecting hardware manufacturer's specifications. Special attention should be given to complying with the following procedures:

- Determine the proper method and length of sheath (jacket) removal.
- Recognize the importance of each individual pair twist, and maintain the same pair twist for each individual pair when terminating to the connecting hardware. Pair twists may vary from pair to pair within a given cable. The objective is minimizing pair disturbance.
- Apply pair untwist specified by the manufacturer.
- Avoid severe changes of twist rate. Do not knuckle the conductor pair where one of the conductors does not follow the manufacturer's twist rate by making a sharp turn crossing its mated conductor at a 90-degree angle (see Figure 5.66).

Figure 5.66
Example of a knuckle



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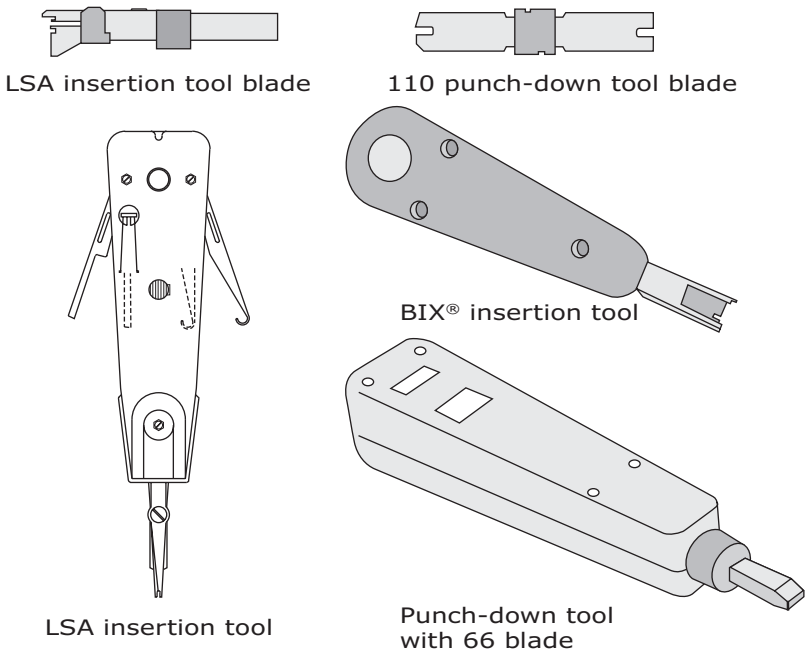
Overview, continued

Specific tools designed for making IDC connections are required. During the IDC termination, the cable is pressed between two edges of a metal clip, displacing the insulation to make contact with the copper conductor. The copper conductor is held tightly within the metal clip, ensuring a solid gas tight connection.

When terminating category 5e and higher cables, the cable pair twists must be maintained to within 13 mm (0.51 in) from the termination point. When terminating category 3 cables, the cable pair twists must be maintained to within 77 mm (3 in) from the termination point. For best performance when terminating cable on connecting hardware, maintain the cable pair twists as close as possible to the termination point.

Several manufacturers market termination tools (see Figure 5.67) that have interchangeable blades for use on different styles of IDC termination blocks. Caution should be taken to ensure that the brand of tool being used is compatible with the blade. Blades may look similar, but there are slight differences in design. Improper matching of the termination tool handle and termination blade can lead to serious personal injury as well as poor IDC terminations.

Figure 5.67
Examples of termination tools



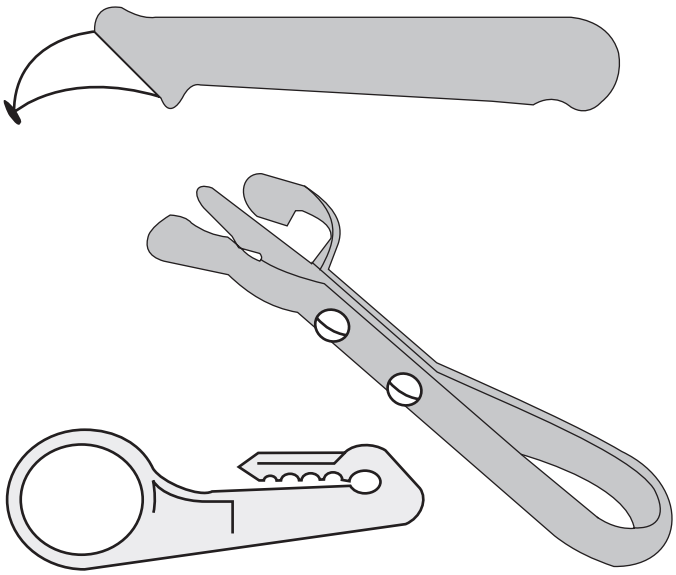
The following procedures generally address the proper methods and tools required to terminate each type of IDC termination block.

Adhere to the manufacturer's or customer's specifications and guidelines regarding all terminations. Document all termination information properly. This helps to identify the origin, destination, and routing of all cables.

Steps—Insulation Displacement Contact (IDC) Termination

Step	Copper IDC Termination
1	Determine the method and length of sheath removal. Sheath removal can be performed in three ways (see Figure 5.68): • Cable preparation tool—Carefully place the cable preparation tool around the cable sheath at the place where you intend to remove the sheath from the cable's wire pairs. Rotate the cable preparation tool around the cable in a 360-degree rotation. Remove the severed sheath from the cable. • Electrician snips—Using the electrician snips, carefully score the sheathing to a depth that exposes the ripcord. Using the ripcord, pull down the sheathing until the proper length of sheath is ready to be removed. Then remove the severed sheath with the electrician snips. When a ripcord is not present, be very careful when scoring the sheath. • Ringing tool—The ringing tool contains a razor blade set to a depth that allows the sheath to be slit deep enough to score the sheath, but not nick the inner pairs. To properly use this tool, insert the cable into the tool per the termination hardware manufacturer's recommendations. Inspect the conductor insulations after ringing a new cable to ensure that the cutter is not damaging the conductors. • Slitter tool—Carefully insert the slitter tool between the cable sheath and the pairs. Slide the tool carefully down the sheathing until the proper amount of sheathing has been prepared for removal. Remove the severed sheath using the electrician snips.

Figure 5.68
Sheath removal tools



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Steps—Insulation Displacement Contact (IDC) Termination, continued

Step	Copper IDC Termination
2	Using a proper sheath removal tool, remove the cable sheath in accordance with best practices, applicable standards, and the cabling system manufacturer's specifications as follows: • Remove only as much of the sheath as necessary to terminate the cable pairs, and ensure that the twist of the pairs is maintained. • Position the sheath as close as practical to the point of IDC terminations, allowing conductor pairs to flow into the IDC without stress. NOTE: A common fallacy in the industry is that only 13 mm (0.5 in) of sheath should be removed from the cable. Sheath removal is different from maintaining the pair twist. The sheath removal requirement can vary depending on the type and size of the cable and type of IDC connecting hardware.
3	Separate, identify, and tie off binder groups while considering that: • Binder groups are associated with 50-pair and larger pair count cables. • A unique color-code identifies each binder group. Cables are grouped in 25-pair increments with each 25-pair group (or subgroup) individually wrapped with a fabric or plastic tape to identify the groupings. See Table 5.13 for clarification.

Steps—Insulation Displacement Contact (IDC) Termination, continued

Step	Copper IDC Termination
3 cont.	

Table 5.13
Binder color-code chart

	Pair		Binder Group	
Number	Tip	Ring	Color	Pair Count
1	White	Blue	White/Blue	001–025
2	White	Orange	White/Orange	026–050
3	White	Green	White/Green	051–075
4	White	Brown	White/Brown	076–100
5	White	Slate	White/Slate	101–125
6	Red	Blue	Red/Blue	126–150
7	Red	Orange	Red/Orange	151–175
8	Red	Green	Red/Green	176–200
9	Red	Brown	Red/Brown	201–225
10	Red	Slate	Red/Slate	226–250
11	Black	Blue	Black/Blue	251–275
12	Black	Orange	Black/Orange	276–300
13	Black	Green	Black/Green	301–325
14	Black	Brown	Black/Brown	326–350
15	Black	Slate	Black/Slate	351–375
16	Yellow	Blue	Yellow/Blue	376–400
17	Yellow	Orange	Yellow/Orange	401–425
18	Yellow	Green	Yellow/Green	426–450
19	Yellow	Brown	Yellow/Brown	451–475
20	Yellow	Slate	Yellow/Slate	476–500
21	Violet	Blue	Violet/Blue	501–525
22	Violet	Orange	Violet/Orange	526–550
23	Violet	Green	Violet/Green	551–575
24	Violet	Brown	Violet/Brown	576–600
25	Violet	Slate	25th binder is not used	

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Steps—Insulation Displacement Contact (IDC) Termination, continued

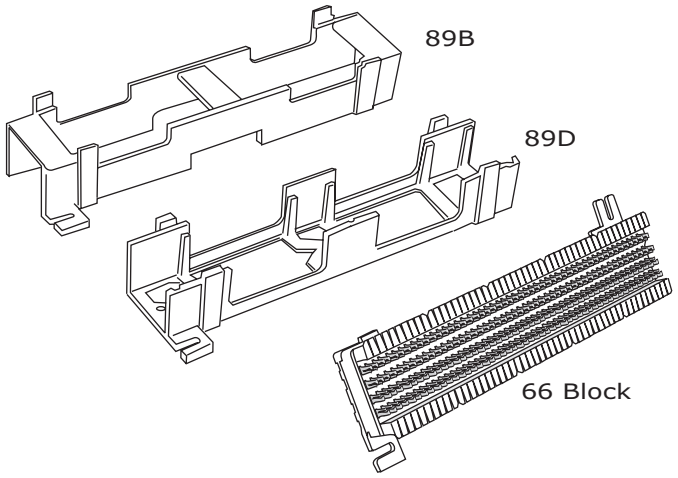
Step	Copper IDC Termination
3 cont.	• Depending upon the manufacturer, 25-pair binder groups are combined into identifiable master groups. • Identify each 25-pair binder group within the cables by using the appropriate color-coded plastic cable ties or the original binder wraps tied around each binder. NOTE: Scrap wire pairs from discarded cable should never be wrapped around binders. This is an obsolete practice that may cause an inductive choke and may be detrimental to transmission.
4	Fan out and form cable pairs from each binder group. • Cable pairs should be uniformly placed to be aesthetically pleasing. In addition, pairs should not cross or interfere with any other pairs. • Cable pairs should be parallel with no tension at the point of connection and equal tension on all connections.

66-Style Hardware

The 66-style IDC termination block has been a popular choice for connecting voice applications (e.g., PBX, key telephone systems [KTSs], some LANs). Several manufacturers of 66-style termination block designs have updated their connecting hardware to support high-speed data applications and to be compliant with category 5e/class D specifications. Caution should be used to ensure that the appropriate 66-style IDC termination block is installed in new installations.

The 66-style termination block may be mounted on backboards with an 89-style bracket (see Figures 5.69 and 5.70). Two different 89-style brackets are available for use. They are the 89B and 89D styles.

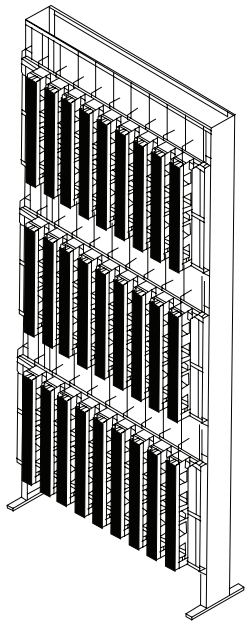
Figure 5.69
66 Block and 89 brackets



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66-Style Hardware, continued

Figure 5.70
66 Block distribution frame



Typically, these connecting blocks are mounted on backboards in vertical rows of four blocks each to accommodate up to 100-pair terminations. Several manufacturers provide preassembled single- or double-sided distribution frames to provide increments of up to 2700 pairs per side for large system installations.

Cable for a 66-style connecting block is routed through the 89 brackets to allow the pairs to be fanned out from the rear into the guides in the side of the block. Each five-pair increment is marked with a distinctive groove for ease of identification.

A 66M1-50 block provides the means of terminating two 25-pair or twelve 4-pair cables per block. These blocks have two columns of contacts that are mechanically connected to provide cross-connection capability. Voice applications use bridging clips to make a connection between the left and right sets of contacts on a 66M1-50 block. By lifting the bridging clips, which opens the circuit, it is easy to test the voice circuit in both directions when troubleshooting. The 66M1-25 blocks have four columns of connected contacts.

NOTE: Bridging clips are not category 5e/class D compliant. This description is provided for information purposes only.

A fine-tip permanent marker is generally used to designate cable-pair identifiers on the fanning strips of 66-style blocks. A potential problem with this marking method, however, is that the ink, while still wet, could accidentally be rubbed off by the ITS installer. More professional methods of labeling are the use of designation strips that are snapped onto the fanning strips or color-coded hinged covers that can be labeled on the inside and outside of the cover.

110-Style Hardware

The 110-style IDC termination hardware is used in both voice and data cabling applications. Backbone cabling is commonly terminated on wall- or rack-mounted 110 termination blocks in increments of 50, 100, or 300 pairs as well as on a 900-pair wall mount.

While many patch panels may be terminated in specific configurations (e.g., T568A or T568B) and mainly constructed with 110-style connectors, 110-style blocks are not designated T568A or T568B and always terminate in proper color-code order. In addition, many telecommunications outlet/connector terminations are manufactured with 110-style hardware.

Cables are routed through the middle pathway of the 110 wiring block from either the top or bottom and fanned into the wireway from alternate sides. The connecting block wireway is designed in such a way that one row is terminated on the wiring block by punching down from the bottom up. The next row is terminated from the top down. For the specific location of each termination, refer to the ITS designer's layout.

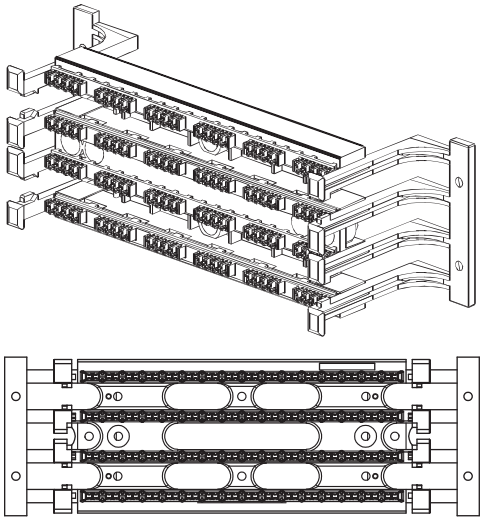
It should be noted that the 110-style wiring block itself contains no IDC. The IDC for this type of termination application is in the C-2 (2-pair), C-3 (3-pair), C-4 (4-pair), and C-5 (5-pair) terminating clip, or connector block, that is punched down on top of the 110-wiring block to permit cross-connection.

The terminating clip, or connecting block pair count, is determined by the application. For example, 4-pair horizontal cabling is terminated on a C-4 connecting block, and backbone cables in 25-pair increments are terminated on C-5 connecting blocks. The designation strips are then placed in the holder that covers the terminated cables.

Category 5e/class D or category 6/class E 110-style and category 6_A/class 210-style wiring blocks and connecting blocks are available from multiple hardware manufacturers in varying pair configurations. This 210-style hardware features enhanced categories of performance and form factors that differ from the original 110-style systems.

Figure 5.71 shows two different physical configuration changes that the manufacturers have made to achieve the category 6/class E and category 6_A/class E_A performance standards.

Figure 5.71
110-Style hardware

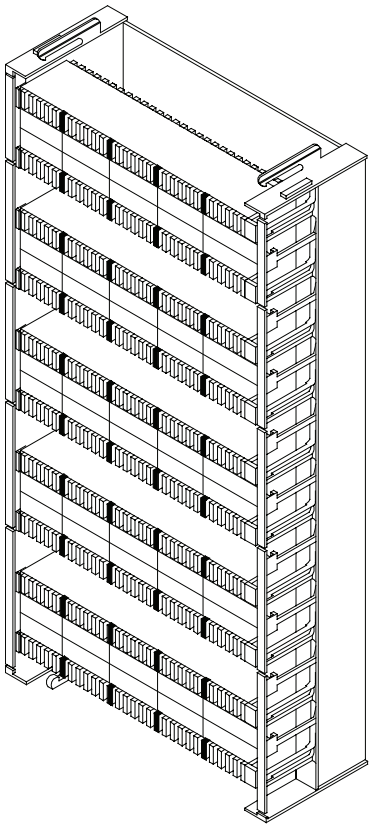


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BIX-Style Hardware

Unlike 110 hardware, which places clips on top of the wiring block, BIX equipment is a one-piece "pass-through" unit that is reversed in its mount after cable termination to expose the opposite side and provide a cross-connect field (see Figure 5.72).

Figure 5.72
BIX mount with connector



BIX termination block assemblies are available in 50-pair, 250-pair, 300-pair, and 900-pair increments for wall mounting and with floor-frame assemblies for large-size installations.

BIX-type termination hardware is available in both patch panel and telecommunications outlet/connector configurations.

BIX termination block connectors are designed with two slots for inserting small tie wraps to support terminating cables. These connectors can be identified in 2-pair, 4-pair, and 5-pair increments for various applications.

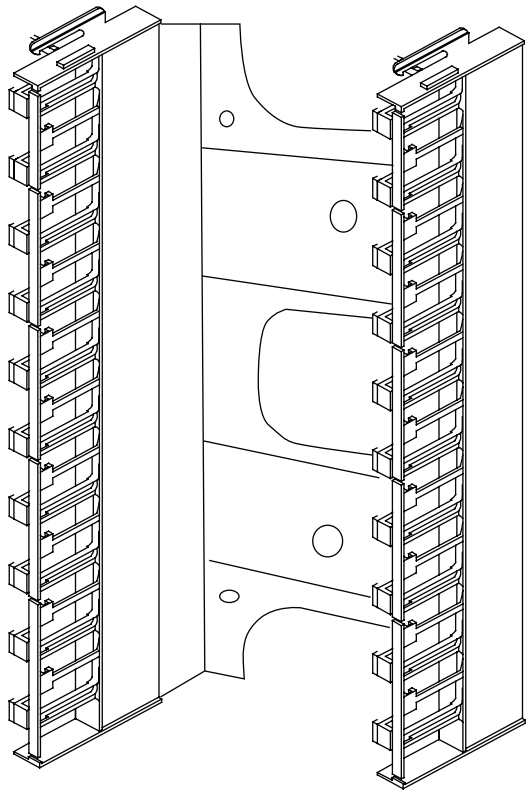
BIX-Style Hardware, continued

When terminating cables with larger than 25 pairs on BIX termination blocks, the binder (fabric or plastic) of each of the 25 pairs should be carried to the end of the connector. The designation strips are then placed in the holder that covers the termination cable.

Note that when routing cables for termination, the cables must enter the mount on the side opposite from the direction that the connector will be unseated. The extra cable routed from the mount to the connector will allow the connector to be removed from the mount by "hinging" it to one side of the mount. The cross-connects must exit the mount on the same side that the hinge is located.

Category 6/class E GigaBIX frames and blocks do not use the hinge concept. Previously, these frames and blocks required extensive sheath removal. The newer termination technique uses less sheath removal and is similar to cable and conductor routing into the rear of a patch panel. The new frames are deeper to allow for slack management (see Figure 5.73).

Figure 5.73
Category 6 GigaBIX frames and blocks



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LSA-Style Hardware

LSA stands for Lötfrei Schraubfrei Abisolierfrei (no solder, no use of screws, no insulation removal) in German. LSA-style termination hardware provides silver-plated IDCs at a 45-degree angle with the conductor being held in place by tension in the contacts.

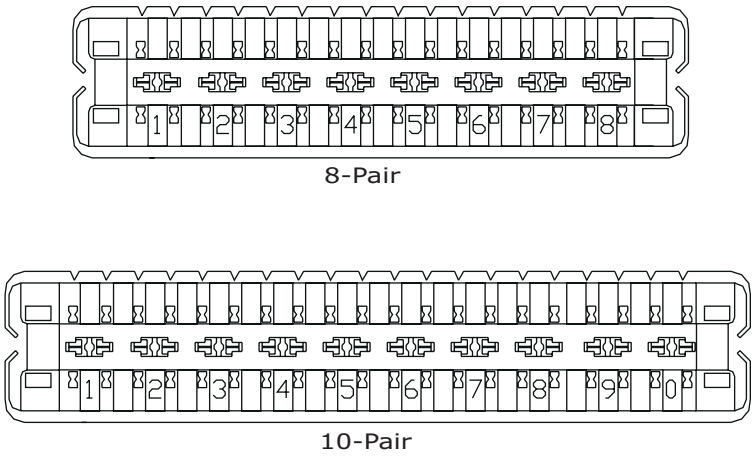
This hardware is available in patch panels, telecommunications outlet/connectors, and termination blocks. The hardware provides:

- Disconnect modules.
- Connect modules.
- Switching modules.
- Feed-through modules.

The advantage of LSA is that more than one conductor can be punched down into the same point without the risk of opening up the IDC.

Disconnect modules are normally closed, two-piece contacts that can be disconnected by inserting a disconnect plug into the wire pair. This allows temporary or permanent disconnect of the circuit. A test cord can be inserted into a pair to test circuits both ways when testing is necessary. These modules come in 8-pair or 10-pair increments (see Figure 5.74).

Figure 5.74
LSA high-band blocks



Connect modules use a one-piece contact that provides a continuous link between the cable and the cross-connect wiring.

Switching modules consist of a normally open, two-piece contact. Switching modules allow for high-density termination and patch cables.

Feed-through modules consist of a one-piece contact that passes the signal through the module, front to back, and provides a continuous link between the feeder and the jumper for high-density termination in small areas. These modules are available in 25-pair increments and resemble a BIX block.

For the specific locations of each termination, refer to the ITS designer's layout.

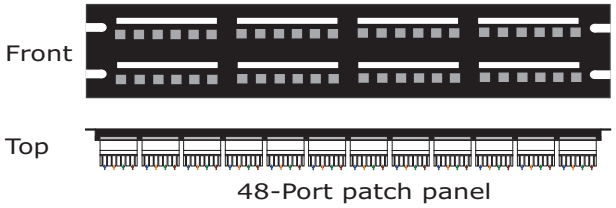
Other Termination Methods

The ITS installer may encounter other termination methods in existing installations (e.g., binder post, screw-type, wire wrapping). These methods are not IDC types of termination and are not recommended by BICSI or applicable standards for new installations.

Patch Panels

Patch panels are available from various manufacturers in many different styles and wiring configurations (see Figure 5.75).

Figure 5.75
Patch panels

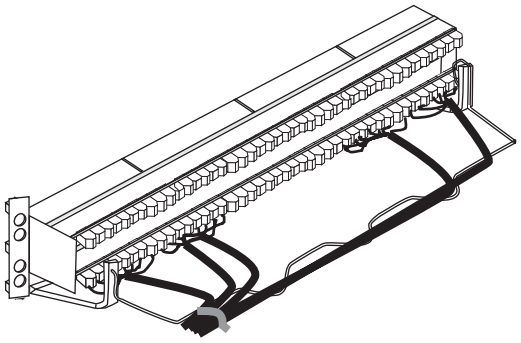


Patch panels that feature 110, BIX, and LSA connections are available. Commonly used configurations are 12, 24, and 48 ports.

To properly terminate a 4-pair horizontal cable onto a patch panel, keep sheath (jacket) removal to the minimum amount required. The cable should be routed from the rear toward the IDC location. If the cable is routed using a cable management bar and the cable will come directly from the rear to the termination point, the shortest will be the orange and green pairs. If it is being routed from the right or left, it will be either the blue or brown pairs.

Strain relief of the cables may be accomplished by the use of tie wraps or hook and loop straps installed on a cable management bar that is installed at the rear of the patch panel (see Figure 5.76).

Figure 5.76
Cable terminated on rear of patch panel with wire management bar



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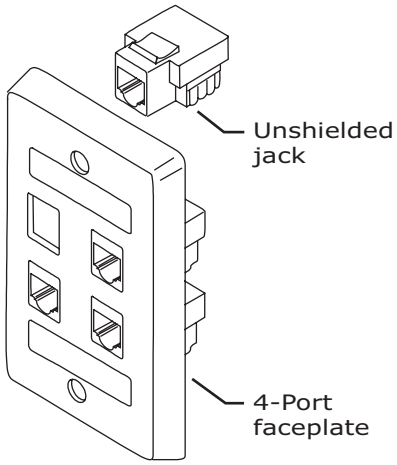
Patch Panels, continued

Prior to actual termination, verify that the work area telecommunications outlet/connector pin/pair assignment (T568A or T568B) matches the patch panel pin/pair assignment (T568A or T568B). Identify patch panel termination locations in the space allocated on the patch panel. The method of labeling patch panels will be provided by the ITS designer or owner.

Work Area Components

Many different styles of outlets are provided for work areas. Locations within a wall cavity can be terminated in single- or two-gang faceplates with jack inserts ranging from low-density single-port to high-density multiport devices (see Figure 5.77).

Figure 5.77
4-Port faceplate



Several manufacturers provide specially designed inserts for modular furniture in multiple jack configurations. These inserts are designed to fit in a specific model of furniture or housing. Maintain the required partition separation between power cabling and telecommunications cabling.

A common practice in office areas that have access floors is to place the cables into established pathways, tray or open top hanger, then run the last few meters (feet) of cable or each desk through a flexible conduit to prevent damage and resist exceeding the cable manufacturer's minimum bend radius. These flexible conduits are fixed at the floor grid point while the desk end is secured into a desk box, which houses the outlets. Most of the desk boxes are custom made for the intended purpose.

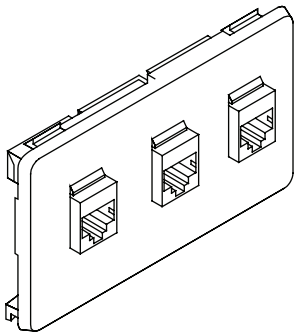
CPs may be required in some special design applications. A CP is a location for interconnection between the permanently installed horizontal cables from the HC (FD) to a fixed location where they are presented in outlets for connection of cables extending to the outlets.

Work Area Components, continued

A CP provides a design solution that allows for the rearrangement of furniture modules and the associated user outlets (see Figure 5.78). If a certified, preterminated furniture module cabling system is deployed, the manufacturer's installation procedures must be followed.

When field terminations are necessary at the CP, the installation procedures must follow the manufacturer's guidelines and the appropriate standards.

Figure 5.78
Modular furniture faceplate



Installations in an open floor area often require a flush-mounted box or an above-floor pedestal. Often these units share a pathway and the apparatus for both power and telecommunications. Ensure that the proper outlet for this installation is used. Maintain a partitioned separation between the power and telecommunications cables.

Termination of telecommunications outlets/connectors should be accomplished by removing the minimum required amount of the sheath according to the manufacturer's specifications.

The ITS installer must recognize the importance of each individual pair twist and maintain the same pair twist for each individual pair when terminating to the connecting hardware. Pair twist may vary from pair to pair within a given cable. The objective is minimizing pair disturbance.

Carefully store the remaining cable slack (maximum of 305 mm [12 in]) into the connecting hardware if it is not practical to push the cable slack out of the conduit. Do not kink the cable or exceed the bend radius of four times the cable's OD.

Use the same manufacturer's components at a given work site. This will minimize the possibility of component mismatch, especially when cabling for standards compliance and meeting the requirements for permanent link performance. Another aspect of component mismatch is the warranty issue for manufacturer-compliant installation practices.

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Direct Connection

In some cases, a customer's request for direct connection of horizontal cable requires that an ITS installer directly field terminates cables with modular plugs. This practice of field termination is not recommended. If the solution calls for plug-ended solid core cords, procure the cords from the cabling solution manufacturer. The manufacturer will apply the correct boot to the plug and ensure that the correct crimping plug is used for the cable.

Field-Constructed Patch Cords

Field-constructed patch cords are not recommended for category 5e/class D and higher systems, and they may not be allowed for systems above category 5e/class D. There may be circumstances in which field-constructed category 5e patch cords or equipment cords are requested (e.g., repair of an existing patch cord because a spare is not available, and the circuit must be restored). If this is the case, the repaired cord should be replaced with a factory-certified cord as soon as possible.

Screened/Shielded Twisted-Pair Cable

Screened/shielded twisted-pair cable is provided by several manufacturers. This form of cabling is especially beneficial for use in areas of high EMI generation and for protecting against mechanical damage. It is used for category 5e/class D and higher compliant installations and carries the same impedance and electrical transmission characteristics as UTP cable except it has a metallic screening or shielding around the individual twisted cable pairs, under the cable sheath surrounding all of the cable pairs, or both.

A screened/shielded twisted-pair cable must be terminated in a shielded modular jack in order to optimize the product's transmission performance characteristics. The shielded jack is enclosed by a metallic, EMI-resistant housing. The dressing block for cable pairs typically fits within the walls of the connector body so that, when terminated, the twisted-pairs and IDCs are completely enclosed by the metal, which forms an EMI shield.

The screened/shielded IDC terminations are typically made in the same manner as UTP cable IDC terminations with the added requirement of terminating the screen/shield and drain wire if present. Manufacturers of screened/shielded cables and connectors provide detailed instructions on the proper termination of their products. This procedure varies by manufacturer, and the specific methods provided for the selected product must be followed for acceptable shield effectiveness over the entire frequency range of interest.

The screen/shield may be terminated to the work area end by attaching the foil and drain wire, if present, securely to the shield of the modular jack, following the modular jack manufacturer's specifications. The other end may be terminated to a screened/shielded patch panel. The IDC terminations are typically made to the shielded patch panel in the same manner as unshielded twisted-pair cable with the added requirement of bonding the screen/shield and terminating the drain wire if present.

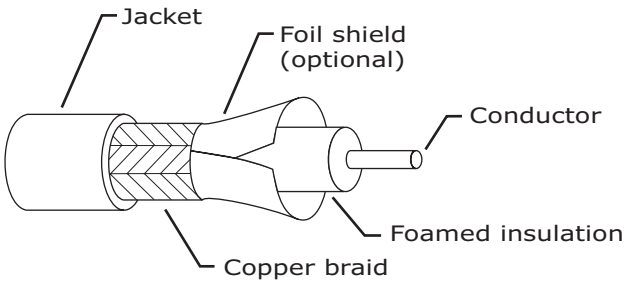
NOTE: Screened/shielded twisted-pair cable manufacturers provide detailed instructions on the proper termination of the braid screen or foil shield. This procedure varies by manufacturer, and the specific method provided for the selected product must be followed for acceptable shield effectiveness over the entire frequency range of interest.

Coaxial Cable Terminations

Overview

A coaxial cable consists of an inner conductor (solid or stranded wire) separated by a dielectric (core) from its outer conductor (braided screen or foil shield covered by a braided screen) and covered by a thermoplastic outer sheath (see Figure 5.79).

Figure 5.79
Typical coaxial cable construction

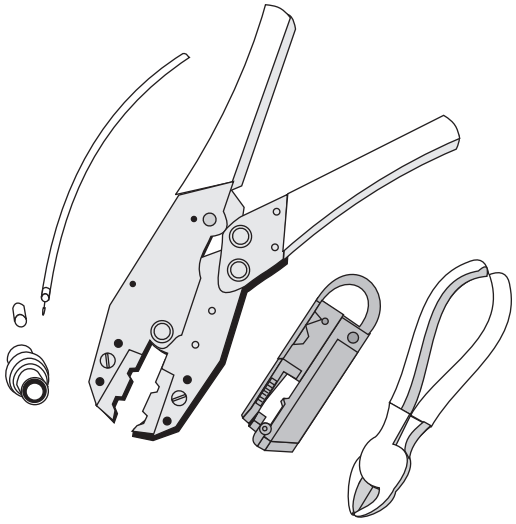


Crimp-Style Connector

The choice of crimp-style connector for coaxial cable depends on the cable shape and diameter. The cable may be round or flat, but ensure that the proper crimp connector and crimping tool for the specific cable is being used.

Coaxial cables used in video may be terminated using BNC connectors (see Figure 5.80). The tools required for proper stripping and terminating are a three-step, rotating stripper and a ratcheted crimping tool that is designed specifically for crimping of the BNC connector.

Figure 5.80
Coaxial cable termination tools for Bayonet Neill-Concelman connectors



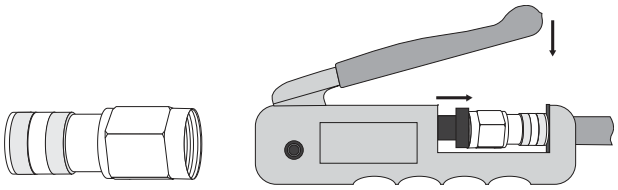
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F Connector

The most common video connector in the industry is the F connector. The F connector does not require the use of a center pin since the cable has a solid-center conductor strong enough to be inserted into another connector without bending.

The crimp style has been used for many years, but it is falling out of favor to the newer compression-style termination. The compression connectors are more expensive, but they provide better performance (see Figure 5.81). They are rated up to 2 gigahertz (GHz) and are compatible for satellite video distribution.

Figure 5.81
F connector compression

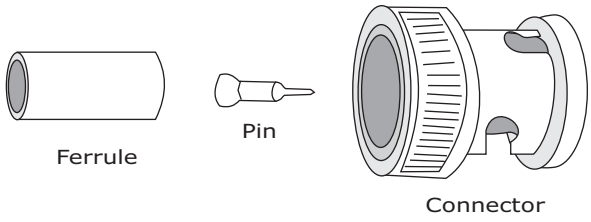


Coaxial cables can be terminated with either F or BNC connectors (see Figure 5.82) based on the application. The most commonly used connector in CATV applications is the F connector. There are two versions, each designed for use with performance specific cabling (coaxial). The crimp-on style was engineered for use with the older RG59, RG6, and RG11 cables that have a lower performance level (less than 1 GHz) compared with Series-6 or Series-11 cables that are engineered to perform at a much higher level (greater than 2.4 GHz). CATV, satellite, and high-definition television (HDTV) signals drive the need for more bandwidth.

BICSI recommends using the compression-style connecter to ensure proper performance. These connectors have the equivalent performance level of the series coaxial currently being installed. This is also true when installing the BNC connector for closed-circuit television (CCTV) cameras. The compression-style connector is recommended as best practice.

NOTE: Use of any screw-on style connector is strongly discouraged.

Figure 5.82
Captive-pin Bayonet Neill-Concelman connector



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Field Testing 100-Ohm Balanced Twisted-Pair Cable

Overview

Characterizing cabling provides useful data to identify the ability of the cabling system to support existing and future applications. The verification of the cabling system's transmission performance through field measurement results in a more professional hand-off from the ITS cabling installer to the customer.

This should improve the overall effectiveness of providing premises networking solutions as well as establishing a baseline for future troubleshooting, resulting in higher customer satisfaction.

This section covers the field testing of 100-ohm balanced twisted-pair cabling and coaxial cabling.

Testing the cabling infrastructure is most effectively performed using an organized, systematic method to verify that the ITS installation has been completed in accordance with all terms and conditions of the contract and industry standards.

This method is made up of three distinct phases:

- Phase 1—Specification and visual verification
- Phase 2—Testing with the various test equipment as required for each type of cable
- Phase 3—Documentation

Phase 1

The specification and visual verification should include an inspection of all pathways and spaces (where possible), TRs, TEs, and ERs.

Items to be inspected, both preinstallation and postinstallation, include:

- Infrastructure.
  - Cable placement.
  - Cable termination.
- Bonding and grounding (earthing).
- Equipment and patch cords.
- Proper labeling of all components.
- Safety.
- Compliance with all applicable codes, standards, and regulations.

Overview, continued

Phase 2

Once the specification and visual verification has been completed and all discrepancies corrected, it is now possible to move to Phase 2, testing with the various test equipment as required for each cabling type.

Field test equipment includes:

- Multimeter (volt-ohmmeter [VOM]).
- Inductive amplifier/tone generator.
- Wire map tester.
- Cable-end locator kit.
- Certification test set.
- TDR.
- Telephone test set (butt set).
- Test adapters, leads, and cables (appropriate for specific cabling type and test set).

It is important to remember that the field test equipment used must be appropriate for the type of cabling under test. All test results must be provided in the format identified in the SoW; where no result format exists, a format should be offered by the ITS installer.

Phase 3

Phase 3, documentation, is often the most neglected. One major part of the documentation process is for the ITS installer to download the test results from the test equipment to a computer or disk to review and process the test results. Documentation should be in the form requested by the customer or, if not specified, according to industry standards.

Test Equipment

Each field tester is designed to perform a specific function or a range of functions required for the testing and certification of a specific cable type. These testers vary greatly in capability and associated cost. Select the most cost-effective test equipment capable of performing the specific required tests.

Multimeter

Multimeters are one of the most basic field testers available. Both analog and a digital type are available. It can be used to measure alternating current/direct current (ac/dc) voltage, ac/dc current, and resistance. With the use of a shorting device on one end of a pair of conductors, continuity can be tested.

When testing cable, it is possible to calculate the length of the cable by determining the actual loop resistance using the material specification sheets. Because most coaxial cable used in LAN applications requires only continuity and length verification, the multimeter is one choice for this type of testing. The analog meter has the advantage of being capable of detecting a signal that is fluctuating, whereas a digital meter may never "lock in" on the fluctuating signal. TDR is the ideal choice for continuity and length verification.

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Test Equipment, continued

Inductive Amplifier/Tone Generator

Also known as a toner or cable tracer, this field test device provides the ability to identify a specific pair by generating a tone on one end of a conductor while using an inductive amplifier (wand) to identify it at the opposite end. Some induction amplifiers provide the ability to trace the pair throughout its entire length by the same method. This field test device is primarily used for cable identification and troubleshooting. Most units are now a combination of tone generator and continuity tester.

NOTE: A cable passing a tone does not guarantee that there is continuity from end to end. ITS installers must perform a continuity test to ensure end-to-end continuity. When working on an addition to an existing installation, the ITS installer must also verify that the tone generator will not impact the existing equipment or signals.

Wire Map Tester

Wire map testers, also known as pair scanners, are low-cost cable verifiers that usually test for opens, shorts, crossed pairs, and miswires in either a 4-pair or 25-pair cable. Some testers in this category/class will test for split pairs and length. These units are good for quick, basic tests, but they lack the sophisticated diagnostic capabilities of more expensive testers. Most testers in this category are designed exclusively for unshielded and screened/shielded, balanced twisted-pair cables.

Cable-End Locator Kit

Sometimes called an office locator kit, this is a set of numbered modular plugs that can be identified by the cable test equipment. The standard practice is to insert the plugs into work area outlets and then search with the tester at the patch panel or connecting block until the plug at the opposite cable end is found.

Certification Test Sets

Certification test sets are used to verify that an ITS cabling system meets the transmission performance requirements as specified in the applicable standard. Certification test sets are classified by the frequency over which they comply with a defined accuracy of performance.

Field testers must meet the respective accuracy specification for near-end crosstalk (NEXT) and insertion loss measurements up to 100 MHz for category 5e/class D cabling.

In addition, certification test tools must provide a length measurement of the cabling under test, a propagation delay measurement, and verification that the wire pairs are properly connected from end to end (wire map).

Level IIe accuracy requirements were established with the advent of category 5e/class D cabling systems. The frequency range for Level IIe remains as per the Level I testers at 1 through 100 MHz, but several new test parameters had to be measured. These additional parameters are power sum near-end crosstalk (PSNEXT), attenuation-to-crosstalk radio far-end (ACRF [formely known as equal level far-end crosstalk (ELFEXT)]), power sum attenuation-to-crosstalk radio far-end (PSACRF [formely known as power sum ELFEXT (PSELFEXT)]), and return loss. Level IIe testers must also compute the delay skew between the four wire pairs in a balanced twisted-pair link.

Test Equipment, continued

Level III testers are defined to test category 6/class E cabling systems up to 250 MHz. The accuracy requirements of Level III are significantly more stringent than those of Level II and IIe in order to produce sufficiently accurate measurement results up to 250 MHz.

Level IIIe testers are defined to test category 6_A/class E_A cabling systems up to 500 MHz. The accuracy requirements of Level IIIe are significantly more stringent than those of Level III, IIe, and II in order to produce sufficiently accurate measurement results up to 500 MHz.

Level IV testers are defined to test category 7/class F and category 7/class F_A infrastructure. The accuracy requirements of Level IV are significantly more stringent than those of Level IIIe, III, IIe, and II in order to produce sufficiently accurate measurement approaching 1 GHz.

When a certification test set is operated in autotest mode, it tests all of the parameters specified by the selected test standard and compares the measured values with test-limit values for category 5e/class D, category 6/class E, category 6_A/class E_A, category 7/class F, and category 7_A/class F_A. The test set displays pass or fail and the actual tested values for each parameter. These test sets are often capable of performing other measurements, including impedance, capacitance, resistance, attenuation-to-crosstalk ratio (ACR), and power sum ACR (PSACR) calculations. Many certification field test sets include some tests for coaxial cabling (e.g., continuity and TDR function for determining the length of coaxial cable when fitted with the correct balun or cabling interface).

The field tester shall be able to measure and report the following link parameters for the permanent link and channel test configurations as defined in applicable standards (e.g., ANSI/TIA-1152, ISO/IEC 11801):

- Wire map, including screen/shield connection if present
- Insertion loss
- Length
- NEXT loss, measured from local end
- NEXT loss, measured from far-end
- PSNEXT loss, measured from local end
- PSNEXT loss, measured from far-end
- Attenuation-to-crosstalk ratio far-end (ACRF [formerly known as ELFEXT])
- Power sum attenuation-to-crosstalk ratio far-end (PSACRF [formerly known as PSELFEXT])
- Return loss, measured from local end
- Return loss, measured from far-end
- Propagation delay
- Delay skew

Values across the frequencies for each of these parameters are defined in the respective cabling standards.

NOTE: Most of these Level IIe, Level III, Level IIIe, and Level IV testers have the ability, with an add-on module, to perform the power meter loss test of optical fiber cabling. Certification test sets can store test data and export it to a database or output it to a printer.

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Test Equipment, continued

Table 5.14 indicates the appropriate test unit to be used based on the application.

Table 5.14
Cable analyzer level descriptions

Field-Test Configurations	Frequency Range	Accuracy Level	Applicable Standards
10GBASE-T category 6_A/class E_A permanent link	1–500 MHz	IIIe or higher	ANSI/TIA-1152 and IEC 61935-1 (Noise floor tested to Level IV requirements)
10GBASE-T category 6_A/class E_A channel	1–500 MHz	IIIe or higher	ANSI/TIA-1152 and IEC 61935-1 (Noise floor tested to Level IV requirements)
Category 7/class F permanent link	1–600 MHz	IV	IEC 61935-1 (Level IV)
Category 7/class F channel	1–600 MHz	IV	IEC 61935-1 (Level IV)
Category 7_A/class F_A permanent link	1–1000 MHz	IV	IEC 61935-1 (Level IV)
Category 7_A/class F_A channel	1–1000 MHz	IV	IEC 61935-1 (Level IV)

ANSI = American National Standards Institute
IEC = International Electrotechnical Commission
MHz = Megahertz
TIA = Telecommunications Industry Association

NOTE: Users of this reference manual are advised to consult applications standards, equipment manufacturers, and system integrators to determine the suitability of these requirements for specific networking applications.

Test Equipment, continued

Time Domain Reflectometer (TDR)

The TDR technique has the ability to identify and locate cable defects, splices, connectors, and location at which impedance changes occur along the link-under-test. In addition, the TDR is used to measure the electrical length of a cable. Developed originally for use on coaxial networks, the TDR is an excellent troubleshooting tool for use with unshielded and screened/shielded balanced twisted-pair cabling.

Cable length measurement is accomplished by transmitting a high rise-time pulse into the cabling and then capturing and timing the reflections caused by impedance changes. Impedance changes caused by kinks or splices are displayed as well as a large mismatch at the end of the cabling. The reflections are displayed in graphical format on the screen or a printout.

Note that the TDR method finds the distance to the impedance change (or variance) by measuring the round-trip time of the electrical pulse from the end of the cable where the tester is connected to the point of the reflection (end of cable, kink, component mismatch). This time measurement is used by the test set to calculate the cable length using the NVP selected.

Telephone Test Set

A telephone test set (butt set) is used to test voice circuits and to perform the following functions:

- Simulate the user's telephone equipment
- Identify circuits
- Circuit diagnostics and troubleshooting

Test Adapters, Leads, and Cables

The ITS installer must have proper adapters available to connect test equipment to the cable under test.

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Testing 100-Ohm Balanced Twisted-Pair Horizontal Cable

Overview

This section covers the testing of 100-ohm balanced twisted-pair cabling used in horizontal cabling with:

- Wire map/continuity testing.
- Certification field tester.

Wire Map/Continuity Testing

This is the basic test to establish proper cabling installation. At a minimum, the test searches for:

- Open circuits—Indicates incomplete terminations, faulty connectors, or broken cables.

NOTE: At least one pair must be available for the field tester to recognize the remote.

- Short circuits—Indicates faulty connection or crushed cables.
- Wire pair miswiring (e.g., polarity reversal, transposed pairs, split pairs).
- Drain wire continuity when testing screened/shielded cable.

A multimeter can be used to measure dc loop resistance of any paired conductor; however, this is impractical because of the time involved in checking combinations.

Steps—Utilizing a Pair Scanner

Step	Utilizing a Pair Scanner (Wire Map/Continuity Testing)
1	Disconnect any active equipment from both ends of the cabling.
2	Attach pair scanner to one end of cabling. (This can include patch cords).
3	Attach the pair scanner's remote device to the opposite end.
4	If the pair scanner is unable to locate the distant end, determine why.
5	If needed, diagnose and repair any faults.
6	Scan cabling again.
7	Record the successful test results.

Certification Field Tester

Certification field testers are more complicated than pair scanners and require training and experience to ensure proper interpretation of results. Requirement limits are set into the test set, designated for all relevant cabling standards.

Setup

To ensure proper setup:

- Confirm that the test set is within calibration. If not, do not use the test set as this is a piece of certification test equipment. This also includes any use limits for the test cables and channel adapters supplied by the test set manufacturer. Typically, this limit is 5000 insertions.
- Confirm that the test set batteries are sufficiently charged for the work to be completed.
- Check the condition of the test set, the connecting cables, and adapters for damage.

NOTE: If the clip is broken on the 8P8C test plug, the unit cannot be used as the 8P8C latch is the reference dimension for mating the plug and outlet.

- Enter the operator details and any site identification into the test set to aid report preparation.
- Ensure that the latest limits and databases are loaded into the test set. This can be verified against the test set manufacturer's Web site.

NOTE: If the test set is being used in a project that spans a test set database update, confirm that the client wants the latest limits to be applied for the project.

The basic procedure is to select the cabling type:

- Unshielded
- Screened/shielded
- Coaxial

Some testers allow selection from a list of cable manufacturers and cable part numbers in the test unit. Refer to the test equipment manufacturer's data for selection procedure.

NOTE: The cable selection by part number is performed for the purpose of documenting test results and defining the NVP value that the test set will use to determine the cable length measurement. If the length measurement noted on the test result is out of specification, determine the appropriate NVP.

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Certification Field Tester, continued

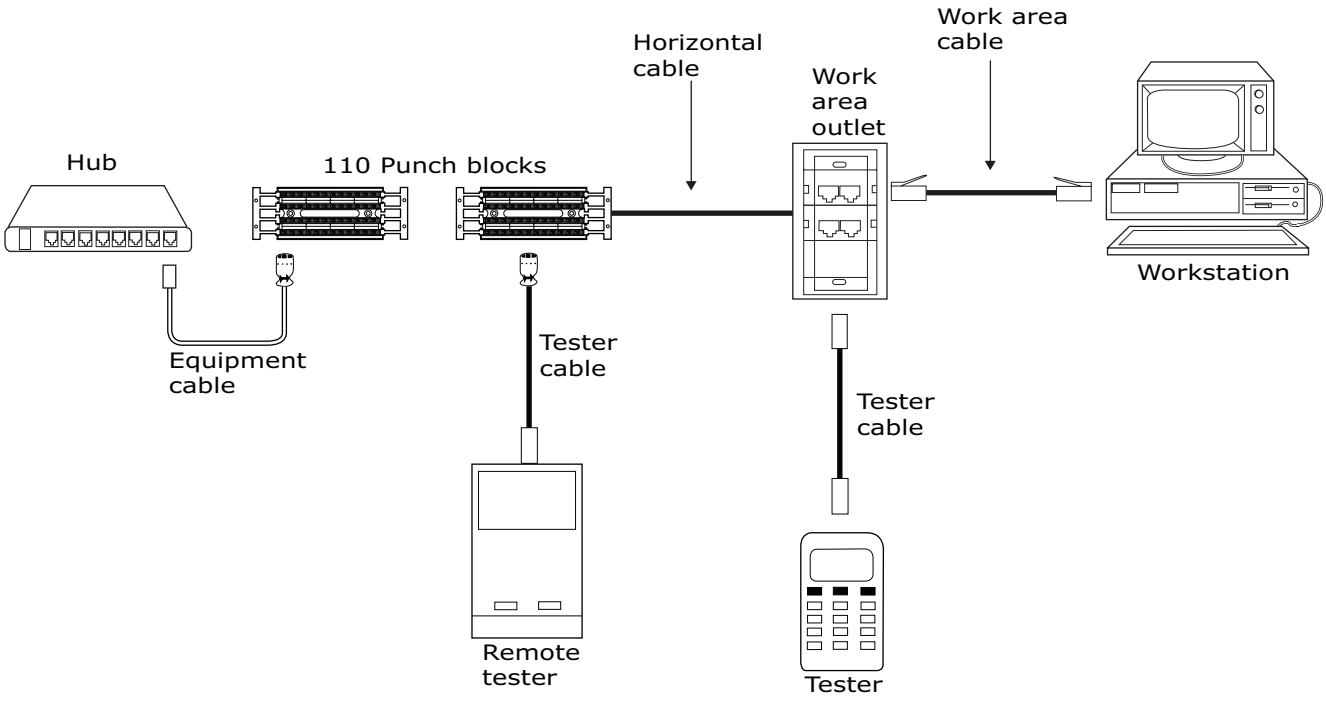
Select the cabling test standard category or classification:

- Category 3
- Category 5e
- Category 6
- Category 6_A
- Class C
- Class D
- Class E
- Class E_A
- Class F
- Class F_A

Select the test configuration:

- Permanent link (see Figure 5.83)
- Channel (see Figure 5.84)

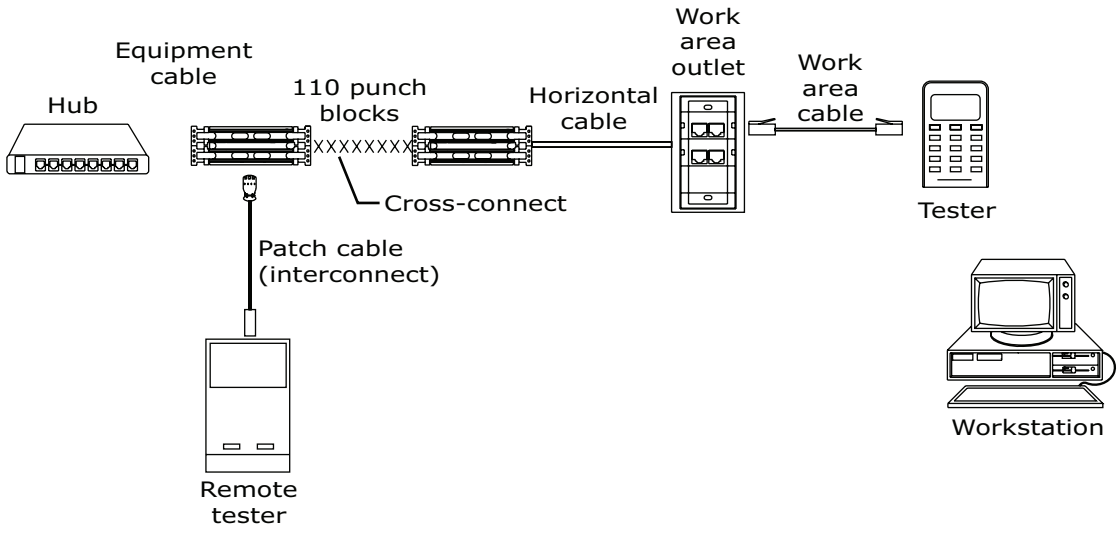
Figure 5.83
Permanent link test configuration



NOTE: The permanent link excludes both the cable portion of the field test instrument cord and the connection to the field test instrument.

Certification Field Tester, continued

Figure 5.84
Channel test configuration



NOTE: The channel includes the customer's equipment cords plugged into the field test instrument and excludes the connections to the field test instrument on each end.

Field Calibration

Calibration procedures differ among the various types of field test instruments. It is important to follow the manufacturer's procedures. This field calibration sets the reference for insertion loss measurements and is an important step to obtain accurate insertion loss results. Although the recommended time interval between field calibrations varies by manufacturer, a good rule of thumb is to perform the field calibration at least once a day or before beginning a new series of tests. A short tester equipment cord (supplied with field tester) or adapters are used to connect the main unit to the remote unit. The calibration sequence is activated from the main unit.

NOTE: Factory calibration may be required every 12 months for certification test sets.

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Certification Field Tester, continued

Verification Check

Any tester should undergo a regular performance evaluation or some form of check. The ITS installer should develop expertise to assess if a tester is providing reliable results.

One simple method is to construct a sample link to be used as a reference. Ensure that it is physically protected and is not subject to movement. Expect some variation with temperature, humidity, and time.

Testing

Most measurements are carried out using the autotest function, which automatically completes the required series of tests for the selected test standard.

Test Set Performance

Four possible results indicated by the tester are:

- PASS.
- *PASS.
- FAIL.
- *FAIL.

When the test result of a parameter is closer to the test limit than the measurement accuracy, the test result is marked with an asterisk (*).

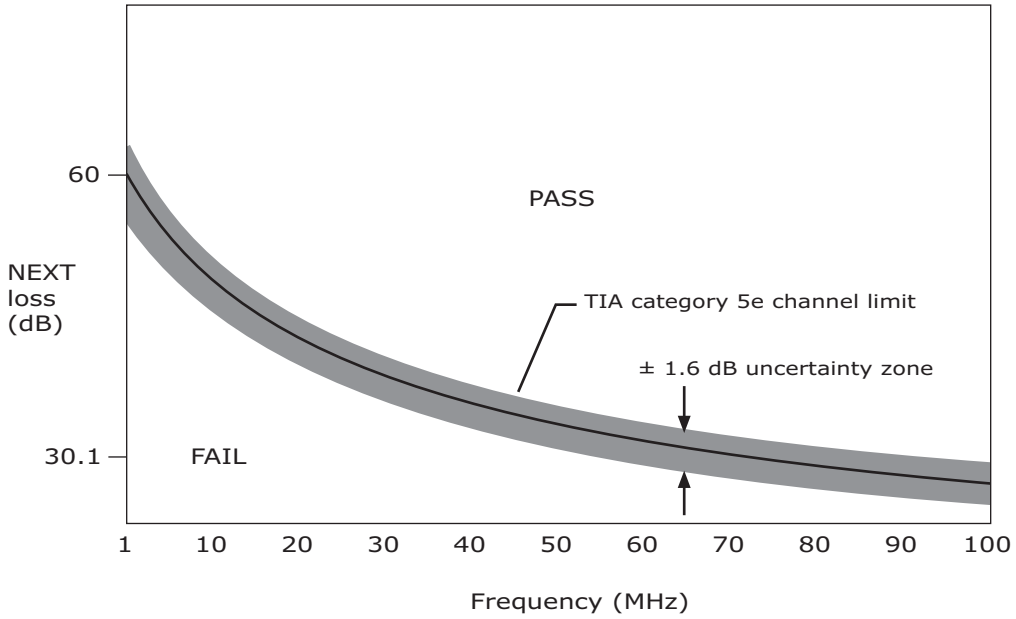
*PASS indicates that the result is better than the specified limit but is within the accuracy margin for the test equipment and should be questioned because of the accuracy of the instrument. Such a result assumes a probability that the tester was inaccurate, and the true result is *FAIL. However, a *PASS for any parameter could be treated as a PASS, and if all other parameters are acceptable, the result may be recognized as an overall PASS for the link under test. It is good practice to run some diagnostic tests on a *PASS outcome. Chances are that a marginal condition can be improved and turned into a solid PASS. It is a requirement in some cabling standards that the ITS installer and client agree how marginal or * passes and * failures are to be addressed.

Failures can be one of two types: FAIL or *FAIL. The * indicates that the failure is subject to some degree of uncertainty because the measured value is closer to the specified limit than the accuracy specification for the field test set at that frequency and test parameter value. Therefore, the result assumes a probability that the PASS/FAIL decision is incorrect. It is a good idea to investigate any FAIL or *FAIL parameters to understand the underlying cause. Note that any *FAIL of a single parameter will result in an overall FAIL for the link.

Test Set Performance, continued

The *FAIL and *PASS areas of uncertain measurements are often referred to as the uncertainty zone and are illustrated in Figure 5.85.

Figure 5.85
Uncertainty zone for certification field testers



dB = Decibel
MHz = Megahertz
NEXT = Near-end crosstalk
TIA = Telecommunications Industry Association

Durability

Durability is an important issue in keeping track of the life cycle of test interfaces. Any jack or plug has a limit on the number of reliable connect/disconnect cycles. Interfaces should be dated to give the user an indication of age so that reliable limits are not exceeded. Additional interfaces should be ordered and available for replacement at suitable intervals. If measurements are not repeatable or if the failure rate of links appears to increase, it may be time to replace the plug/jack interfaces.

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Test Set Performance, continued

Downloads

All certification field test sets are available with download software that will allow the operator to either download directly to a printer, portable storage media (e.g., USB flash drive), or hard drive of a computer. The connection is made through the communications port of the computer. As the software from each manufacturer varies, refer to the field test set manual for detailed instructions on the download process.

NOTE: Most field test sets give the ITS installer the option of either saving or not saving the individual test traces along with the basic pass/fail test data. If saving the traces, the storage capacity of the test set limits the number of tests that may be stored and will typically decrease to 10 to 20 percent of the normal capacity. For example, if the field test set normally stores 500 tests, it may only hold 50 tests. It is always considered best practice to save the test data with the highest level of results storage, which will also aid fault isolation and repair.

Backup

Backup protection is another important issue. Several manufacturers have equipped the test set with a multimedia card. Saving to the card rather than to the internal storage unit of the test set provides an immediate backup for all test results. When using units that are not equipped in such a way, a simple strategy could be to print test data every few hours. This might be suitable for some small jobs but too time consuming for most. A better strategy may be to download to a computer at regular intervals (e.g., every four hours) and make duplicates on removable media.

When applicable, ensure that an extra set of charged batteries and a battery charger is available on the site.

Delay Skew

Pairs within a 4-pair cable each use a different twist length to improve NEXT performance. This introduces a physical difference in length between pairs. Additionally, the velocity of propagation may vary between pairs if different insulating materials are used for one or more pairs. These cables are referred to as 1 + 3, 2 + 2, and 3 + 1 cables. A number of field test sets have settings to account for this difference. These differences should be within the operating limits of current cabling and applications standards.

Noise

Noise is an issue that concerns most customers and is difficult to assess. Some field test sets offer a noise diagnostic test. If noise is suspected or if a test result appears incorrect, then two successive tests of the same cabling link should be performed. (Some measuring equipment manuals cite the interference effect of portable radios; be sure to coordinate such usage.)

Test Set Performance, continued

Maintenance and Upgrades

Software and firmware upgrades are usually obtained directly by downloading new executable files into a computer and transferring these to the field test set.

Firmware computer programs are contained permanently in a hardware device as read-only memory (ROM). The only way to upgrade is to flash the ROM, deleting existing instructions and establishing a new set of operating instructions for the device. This is normally accomplished by access to the manufacturer's disk or on its Web site. Decide with the client which version of the tester limits is to be used at the start of each project. If updates occur from the tester manufacturer during a project, the ITS installer should discuss with the client when or if these updates should be applied to the testers.

IMPORTANT: Upgrade to the latest firmware, and maintain the current documentation (including readme files) of the test sets to ensure that operational procedures are up-to-date. In addition to these upgrades, it should be sent to the field test set to the manufacturer on an annual basis for factory calibration.

Batteries

All of these test units rely on rechargeable batteries. Some test sets charge while the pack is in the test set, and others offer a separate charging unit. Charging time, operating time, and battery life vary between units. Some test sets can be plugged into an ac power source and used while the battery is charging.

Battery status is an important issue to consider because the many hours of required testing might depend on a reliable battery charge. Continuous battery status in the main display window is a useful feature. Alternatively, warning messages with beeps to alert users about a low battery condition may be sufficient for most users. In any case, suitable battery management strategies outlined by each manufacturer should be followed.

Some rechargeable batteries require cycling to prevent battery memory. It is very important to let the batteries completely drain on a regular basis and then fully recharge. Failure to drain the batteries may create a memory that will not allow the battery to drain below the memory voltage and will shorten the battery's life expectancy.

There is a small disk battery in the field test set that maintains the volatile memory while batteries are being switched. This battery is changed at the factory when the unit is sent for its annual calibration.

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Testing Multipair Backbone Cable

Overview

Backbone cabling is used for connecting the MC (CD) located in the ER with either the IC (BD) or HC (FD) located in the TR. Backbone cabling also connects the TEs. Backbone cabling may be any of the cables utilized in the horizontal cabling system, or it may be the high pair-count cable used for voice distribution.

The balance of this section addresses the testing of multipair cable.

Continuity and Length Testing

Continuity and length testing may be accomplished using any of the available wire map scanners, which include a TDR function. There are several scanners that will test either a 4-pair group or a 25-pair binder group at one time.

Steps—Utilizing a Pair Scanner

Step	Utilizing a Pair Scanner (Continuity and Length Test)
1	Disconnect any existing cross-connect wire.
2	Attach the pair scanner to one end of the cabling.
3	Attach the pair scanner's remote device to the opposite end.
4	If the pair scanner is unable to locate the distant end, determine why.
5	If needed, diagnose and repair any faults.
6	Scan cabling again.
7	Record the successful test results.

50/75-Ohm Coaxial Cabling

Continuity Test

Adapters are available for Level IIe, Level III, Level IIIe, and Level IV test sets and TDRs that will allow for both continuity testing and length measurement of coaxial cable.

If the ITS installer does not have the required adapters, the use of the multimeter and a shorting plug may be required. This system requires removal of amplifiers and passive devices. The system may have to be tested one section at a time. Observe the following procedures if using the multimeter to test the cabling:

Steps—Coaxial Cable Testing

Step	Testing Coaxial Cabling
1	Set the multimeter for ac and read, and then set the multimeter for dc volts and read while checking the cabling for unwanted signals.
2	Remove any equipment that may have been generating unwanted signals.
3	Set the multimeter to the ohm position.
4	Calibrate (zero out) the meter.
5	With the multimeter, ensure that there is no continuity with the far end open.
6	Install a shorting plug on one end of the cabling.
7	Using the multimeter, read the dc loop resistance of the cable segment.
8	Calculate the dc loop resistance from the manufacturer's data for the cabling.
9	Compare the calculated value with the reading from the multimeter.
10	If needed, diagnose and repair any faults.
11	Maintain a record of the test results.

Length Determination

Using the dc loop resistance reading previously taken, calculate the length of the segment as follows:

- The resistance values of the core and the screen/shield are not the same. Using the cable manufacturer's data, add the nominal dc resistance of the core to the nominal dc resistance of the screen/shield (resistors in series).
- This specification is given in resistance per 1 kilometer (km [1000 m (3281 feet [ft])]) segment. Divide this number by 1000 or 3281 to obtain the loop resistance per meter or foot, respectively.
- Divide the reading received during the continuity test by the dc resistance per meter (foot) derived from the manufacturer's data.
- The result is the length of the cable in meters (feet).

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Troubleshooting Cable

Overview

This section describes the methods, tools and equipment, and knowledge required to troubleshoot ITS. It includes specific steps for locating, diagnosing, and repairing problems in copper cabling systems.

Most tasks in the troubleshooting process apply to all types of cabling systems. The ITS installer must identify, locate, and repair the problem and then test the repaired cabling system to ensure that it works correctly. The following sections describe the equipment and skills required to provide the foundation for efficient and effective troubleshooting.

Troubleshooting Methods

Effective troubleshooting requires experience, knowledge, patience, and skill. The effective troubleshooter:

- Has good communication skills.
- Is able to gain useful information by asking questions in a manner that does not alienate the person being questioned.
- Has learned how to observe objects and events to extract information about the possible causes of problems.

Additionally, a good troubleshooter knows how to:

- Locate information.
- Contact technical support.
- Use online resources.
- Use manuals and technical documents.
- Document findings for future reference.

A good troubleshooter understands the application for each of the available tools and keeps them in proper condition.

Troubleshooting is an investigative process. A troubleshooter looks for clues and follows leads. A troubleshooter must avoid making assumptions about the cause of problems; things are not always as they first appear, and false assumptions may cause hours of wasted time. Finally, a troubleshooter must know when to take a different approach or seek outside help. Sometimes, the most obvious things are difficult to identify because the ITS installer may be too close to the problem.

Although there is no set of rules to cover all situations, the ITS installer can use some general guidelines as a starting point.

Steps—Troubleshooting

Step	Troubleshooting
1	Gather relevant information. This includes locating cabling diagrams and documentation, asking questions of users, and observing the situation. Specifics may include: • Type of system (e.g., LAN, PBX). • Device experiencing problems (e.g., computer, telephone). • Type of cable (e.g., balanced twisted-pair, coaxial, optical fiber). • Location of TRs and ERs that house connections for the problem circuit. • Location of the telecommunications equipment. • Location of the user equipment. • Details of the circuit. • Cabling diagrams. • Certification test data. • Previous service records.
2	Contact the end user before beginning work, and ask the following questions: • What is the specific problem? This initiates the troubleshooting process and helps to narrow the possible problem. • When did the problem begin? • How often does this problem occur? • What else was happening in the area at that time? The problem could be related to the installation of other equipment or to another event that could help determine the cause of the problem. • What other actions can be taken that will help to narrow the cause (e.g., if the user's computer is working properly but cannot connect to the network, have the user check the connections)? If the connections are good, ask the user to check the faceplate. If the user has a Data 1 and Data 2 connection, have the user change the connection and try to access the network. If the trouble is a telephone set, have the user check the connections again. If the connections are good, determine if the talk battery is available. If so, have the user disconnect the set for 10 minutes. Sometimes, especially after an electrical storm, the PBX fault-detection program will correct the problem.

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Steps—Troubleshooting, continued

Step	Troubleshooting
3	Perform a visual inspection. Check out the overall site as well as the specific problem area. Look for evidence of equipment movement, construction, previous sloppy work, incorrect cable or components, and anything else that can aid in determining the cause of the problem.
4	Complete all actions that the troubleshooter would normally have the user do when talking over the telephone.
5	If the problem has not been resolved, ensure that all equipment is removed from the cable in question and perform the appropriate diagnostic tests.

If the problem has not been identified using the above procedures, break the problem into smaller parts and test those parts separately.

NOTES: Refer to Troubleshooting Tips for Isolation in this section for more information. It may be necessary to obtain assistance in locating a problem since modern networks are complex.

Asking for help is not a sign of failure or incompetence. An expert in a specific area, such as interpreting the scope pattern on a TDR, may be needed. In other cases, someone with a fresh viewpoint looking at the situation may identify the problem.

Troubleshooting Tools and Equipment

A variety of tools are available to help the troubleshooter find the source of cabling problems. This section briefly describes testing and other equipment used to complete troubleshooting tasks.

The troubleshooter should have appropriate test equipment available and know how to use it. Depending on the type of cabling system in question, this could include the following:

- Wire map tester
- Handheld cable tester
- Cable tracer
- Cable-end locator kit
- TDR
- Certification test set
- Multimeter
- Electromagnetic field strength meter
- Tone generator/wand
- Telephone test set (butt set)
- Appropriate test adapters, leads, and cables

Measurement Problems

In the event that a permanent link or channel fails to meet specifications, identify the cause of the failure. A failure is a measurement failure and could be caused by the cabling, components, test equipment, or poor installation practices.

Follow the procedures below to investigate a failure:

- Ensure that the test set is working properly by checking it against the reference link. If this link measures within the accuracy limit of its original measurement (maximum 1.5 decibels [dB] for NEXT and 1 dB for attenuation), the field test set appears to be functioning properly.
- Follow the troubleshooting guidelines in Table 5.15 for various problems.
- Identify the trouble, and take corrective action to repair the problem.
- Retest to ensure that the corrective action has worked effectively.

Other Troubleshooting Equipment

Other equipment that may be required to effectively perform troubleshooting tasks includes the following:

- Ladder
- Two-way radio
- Notebook
- Documentation
- Flashlight

Ladder

When troubleshooting cabling problems, a ladder may be necessary to access areas that are difficult to reach (e.g., space above a drop ceiling).

Two-Way Radio

Many troubleshooting tasks require two ITS installers—one positioned at each end of a cable link or data channel. A two-way radio can be helpful when ITS installers at opposite ends of a cable need to communicate with each other.

NOTE: Interference from such radios has been known to affect the operation and accuracy of some handheld cable testers.

The use of two-way radios may not be allowed in some facilities for safety or security reasons. Check with the job supervisor before using this equipment. Additionally, beware of the likelihood that two-way radios will not function properly in all environments.

Some certification test sets include a communications function.

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Other Troubleshooting Equipment, continued

Notebook

Data should be documented in a notebook if the test equipment does not store these results.

Documentation

The process of troubleshooting can be greatly eased when appropriate documentation is available. This should include:

- Cabling diagrams.
- Description and functioning of the equipment attached to the cabling system.
- Certification test data for the network.

Flashlight

A flashlight is needed to perform a visual inspection of dimly lit pathways and spaces.

Troubleshooting Knowledge

Troubleshooting involves a broad range of skills. In addition to knowing how to select and use the appropriate test equipment, the ITS installer must have a comprehensive understanding of:

- Communication skills.
- Industry codes, standards, regulations, and best practices.
- Safety requirements and procedures.

Communication Skills

Communication skills are an important element when troubleshooting a cabling system. A troubleshooter must be able to:

- Read technical manuals, instructions, catalogs, and other documents.
- Verbally communicate with customers, coworkers, contractors, and other support personnel.
- Understand blueprints and drawings that relate to cabling installation.

Ideally, an ITS installer will have computer skills to add, look up, update, and interpret cabling database information, view electronically stored documents, and obtain support information via online resources.

Industry Codes

Standards, Regulations, and Best Practices

The troubleshooter should be familiar with:

- Local codes.
- Local ITS industry standards, regulations, and best practices.
- Basic electrical and electronic principles.
- Basic troubleshooting techniques.
- Test equipment operation.
- ITS network basics.

Safety Requirements and Procedures

The troubleshooter should be familiar with the rules of safety that pertain to the job as well as any safety requirements of the facility in which the work is being performed. These rules include, but are not limited to, the following:

- Local fire codes
- Common safety practices
- Confined space safety
- Electrical safety
- Ladder safety
- Local employee safety and health standards
- Appropriate PPE
- Tool safety

Troubleshooting Tips for Isolation

Becoming an effective troubleshooter takes practice and experience. Fortunately, modern field test equipment can make the job easier. The following are a few troubleshooting tips:

- Determine the nature of the problem, and ensure that it is cabling related. Many network problems may appear to be cabling related. Without the proper diagnostic skills and experience, one can easily misdiagnose a defective network interface card (NIC) as a cabling problem.

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Troubleshooting Tips for Isolation, continued

The first thing to do is talk to the user. Determine the following:

- Has the permanent link or channel in question ever worked?
- Has the permanent link or channel in question been tested previously?
- When and how did the problem begin?
- Is there some specific event that correlates with the beginning of the problem?

  Remember, correlation does not necessarily mean causation. Do not make assumptions. Sometimes, equipment movement, construction work, or other events can be related and may indicate possible causes of problems.
- Why is the problem believed to be cabling related? Again, assume nothing. It does not mean that a problem is cabling related just because someone believes it is. In either case, the user's response can often help locate the source of the problem.

NOTE: To the user, the fact that the user's PC or telephone does not appear to be communicating with the equipment down the hall makes defective cable a logical assumption.

- Does it affect all activity or specific applications? If only specific applications are affected on a network link, chances are the problem is not cabling related. However, some applications are more sensitive to cabling variations than others; some cabling problems may only be associated with specific applications.
- What is the scope of the problem? Is it one connection or many? If the problem is affecting a single connection, the chances are it is within that specific channel or the equipment directly connected to it. If the problem affects multiple links, it could be related to backbone cabling, a link to a shared service (e.g., network file server), or equipment (e.g., hub, server).

Troubleshooting Tips for Isolation, continued

- Look around for anything unusual. Check the work area for anything that suggests intervention. Examine the TRs for clues (e.g., sloppy wiring) or evidence of recent changes. Be alert for signs of recent construction or electrical work.
- Use a certification test set to check suspected cabling segments. The results will often provide a good indication of possible causes as well as the location of a problem. Be sure to look at the results of the individual tests.
- Break the problem into smaller parts. If performing a channel test, examine each component (e.g., permanent link, each patch cable) separately.
- Look for defective terminations or improperly installed or damaged connectors. Loose, improperly installed, or damaged connectors are a major cause of cabling problems. Check for intermittent problems by moving or bending the cable under test near the point of termination.
- Ensure that the proper outlets and other connections are employed. For example, outlets designed for category 5e/class D use will not meet category 6/class E specifications.
- Check to ensure that the appropriate type of cable for the application has been installed.
- Direct attention to the installation practices. ITS installers who do not follow proper installation practices can create a multitude of problems (e.g., not maintaining twists close enough to the point of termination and splitting pairs).
- Equipment and patch cords should be examined carefully, especially in the case of category 5e/class D or higher installations. Patch cords are easily damaged, especially at or near the point of termination. Patch cords may not be properly made. It is difficult, for example, to maintain the pair twists in close proximity to the modular connector when making category 5e or higher patch cords; therefore, it is recommended that they be purchased from a reputable manufacturer rather than made by the ITS installer.
- Check to determine if the cable has been damaged. If an equipment cable is laid across the floor, it can easily be damaged. In addition, improper installation practices, building construction, or remodeling can damage installed cable. Furniture pushed against a wall plate may create a bend radius smaller than the standards allow.
- Look for user intervention.
- Inspect for sources of interference (e.g., cable running over fluorescent luminaires or parallel with and in close proximity to air conditioning power lines may cause problems).
- Check for excessive cabling distances or utilizing extra long patch cord, resulting in exceeding channel distance.

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Copper Cabling

Overview

Troubleshooting a customer's problem in a copper cabling system involves:

- Verifying the problem.
- Isolating the source of the problem.
- Repairing the problem.
- Testing the repaired system to ensure that it functions correctly.

Verifying the Problem

Contact the user to ask the following questions:

- Who is affected by the condition?
- What are the nature, scope, and severity of the condition?
- Where are the possible areas that the condition could occur?
- When did the condition occur? Does it correlate with any other activities or abnormal conditions?
- Why does this condition exist?
- How did this condition happen (e.g., electrical outage, weather conditions, people working in the area)?

Upon arrival at the site, assess the situation. Determine the priority of the condition and the resources available to correct the problem. Consider:

- What is the priority of the restoration? A circuit serving one computer is not as critical as a backbone cable in a hospital. Consider temporarily relocating jumpers to available working pairs.
- What test equipment is available?
- What trained personnel are available?
- What method or procedure will be used to find the problem?

Isolating and Repairing the Problem

After defining the specific nature of the problem, the ITS installer can select the appropriate test equipment to isolate the difficulty. A good cable tester should help locate the sources of cabling problems (see Table 5.15).

Table 5.15
Troubleshooting

Problem	Solution
Cannot turn on tester.	• Recharge or change batteries.
Tester cannot perform or fails calibration.	• Be sure both units are turned on and batteries are field charged. • Replace tester cord.
Tester set for incorrect cable type.	• Reset tester parameters for proper cable type.
Tester set for incorrect link configuration.	• Reset tester to permanent link or channel as required.
Link/channel fails autotest.	• Check area(s) of failure: a. Fails wire map • Check that tester is set to match existing pin wiring. Examine both connections for open, split, or crossed pairs. b. Fails length • Check nominal velocity of propagation (NVP); check proper cable type selected. • Check total length of patch/equipment cords. c. Fails insertion loss • Check all cables in link/channel for suitable category/class rating. • Check length. • Check for excessive temperatures along cable pathways. d. Fails near-end crosstalk (NEXT) • Check all components for suitable category rating. • Check quality of all wire terminations. • Verify amount of pair untwist at termination points. • Look for bare copper conductors with insulation damage.
Tester will not run an autotest.	• Check settings on control knob or menu. • Check to see if unit has failed field calibration. • Check tester connections at both ends of link. • Check if too many open conductors are in link.

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Isolating and Repairing the Problem, continued

Table 5.15
Troubleshooting, continued

Problem	Solution
Tester will not store an autotest result.	• Check that a unique name is selected for test result. • Check amount of free memory available.
Tester will not print stored results.	• Check that serial interface to autotest printer and field tester is set to same parameters/emulation. • Check for sufficient power operating tester. Manufacturer typically recommends ac power adaptor attached for this function. • Check that results are selected for printout.

The results of individual tests can provide a wealth of information. When reading results, be aware that there may be more than one potential cause for a particular test result; in some cases, there may be multiple contributing causes. The following paragraphs list test results and possible associated causes.

High Insertion Loss (Copper)

Insertion loss is the loss in power of a transmitted signal as it travels along a cable. If insertion loss is too high, transmission reliability will be affected. Insertion loss increases with temperature, frequency, and cable length.

High insertion loss can be caused by:

- High temperature—Cables installed in the areas subjected to high temperature may exhibit an increase in insertion loss.
- Wrong grade or category of cable—The cable under test may be unsuitable for the data rate at which it is being used. In this case, it may be necessary to replace the cable.
- Excessive cable length—Ensure that the cable length is within the specified maximum length. Some ITS installers, afraid of waste, will leave excess cable coiled in the ceiling or TR. Excessive lengths of patch and equipment cables can be a problem.
- Incorrect equipment patch cable—Ensure that equipment and patch cables meet requirements for the desired installation (e.g., category 5e/class D, category 6/class E, and higher performance).
- Improper terminations—Ensure that all connections are terminated properly. Ensure that connecting hardware, including telecommunications outlets/connectors, patch panels, connecting blocks, meets the transmission performance requirements of the desired category/class of cabling.

Isolating and Repairing the Problem, continued

Attenuation-to-Crosstalk Ratio (ACR)

ACR is the ratio obtained by subtracting insertion loss (attenuation [dB]) from NEXT crosstalk (dB). The values for each of these parameters are recorded at a specific point of frequency and recorded in decibels. Example: If the worst-case NEXT value at 100 MHz was 30 dB and the worst-case attenuation value at 100 MHz was 20 dB, then the ACR value at 100 MHz would be 10 dB. A positive ACR value is desirable.

Incorrect Capacitance

Capacitance is the ability of an electronic component to store electrical energy. For balanced twisted-pair cables, capacitance is measured between the two wires of a pair. For coaxial cable, capacitance is measured between the center conductor and the shield.

Possible causes for an incorrect capacitance value include:

- Broken conductor in a cable—Check continuity.
- Split pairs—Investigate the pair terminations and patch cables.
- Wrong cable type for application—Determine the cable type, and replace if incorrect.
- Excessive noise—Refer to Noise in this section for more information.
- Shorted conductors—Wire map, length, or scan tests should help locate this kind of fault.
- Cable stretched during installation—If the capacitance value appears erratic, investigate for intermittent connections or noise.

Excessive Near-End Crosstalk (NEXT)

NEXT is the unwanted signal coupling between pairs. It is measured at the end of a cable nearest the point of transmission. Excessive NEXT may be attributed to:

- Mixed categories of cabling—Use components of the same category/class desired to form the length and channel.
- Improper termination practices—If proper twisting is not maintained when terminating twisted-pair cable, NEXT may increase. Ensure that the twisting is maintained as specified for the category of cable being used. Check for bare copper conductors with insulation damage.
- Split pairs—Proper pairing must be maintained. The twisting of the pairs tends to minimize interference radiating from the cable pair and that received by the cable pair. By splitting pairs (using wires from two different pairs as a signal circuit), the beneficial effects of pair twisting are lost.
- Incorrect or substandard components—The quality of the link or channel will be determined by the weakest component. If a component is poorly made or does not meet the requirements for the desired installation category/class, replace the component.
- Incorrect or defective cables and test adapters—Ensure that proper cables are utilized.
- CP too close to the TR—Industry standards typically state that the CP should be at least 15 m (49 ft) from the TR.
- Excessive EMI in the environment. Refer to Noise in this section for more information.
- Too much compression by cable ties or supports on bundles.

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Isolating and Repairing the Problem, continued

Excessive Attenuation-to-Crosstalk Ratio Far-End (ACRF)

ACRF, formerly known as equal level far-end crosstalk (ELFEXT), is a calculated result based upon far-end ACR less the cable attenuation. It is impacted by the same factors as NEXT, including incorrect cable or components, improper termination practices, or mismatched patch cords.

Excessive Power Sum Near-End Crosstalk (PSNEXT)

PSNEXT is the combined crosstalk on a tested pair from all other operating pairs and is calculated using the results of other crosstalk measurements. Issues impacting PSNEXT are the same as those impacting NEXT.

Excessive Power Sum Attenuation-to-Crosstalk Ratio Far-End (PSACRF)

PSACRF, formerly known as power sum equal level far-end crosstalk (PSELFEXT), is the calculation of the combined ACRF on a tested pair from the three remaining pairs. Issues impacting PSACRF are the same as those impacting NEXT.

Wire Map Inconsistencies

Wire map testers will check for the correct connection of each cable and pair to the proper terminating pin at each end of the installed cable.

The specific problems associated with wire mapping problems are:

- Lack of continuity to the far end—A continuous electrical pathway does not exist between the starting and terminating ends of the cable path.
- Shorts between any two conductors.
- Crossed pairs—The terminating end of one pair might be switched with the terminating end of another pair.
- Reversed pairs—Polarity of one wire pair is reversed at one end of the link.
- Split pairs—Half of one pair is terminated in the same position with half of a different pair.

Insertion Loss

Insertion loss measures the structural impedance variations of an entire cable segment, including all cables, connectors, and patch cords.

Differences in impedance may be caused by:

- Damaged cable.
- Unmatched cable and connection hardware.
- Improper termination practices.

Isolating and Repairing the Problem, continued

Excessive Propagation Delay

Propagation delay is the time required for a signal to travel from one end of the transmission path to the other end. Excessive propagation delay is most often caused by cable lengths over the standard. It can be a result of manufacturing problems with the cable.

Excessive Delay Skew

Delay skew is the difference in propagation delay between any two pairs within the same cable sheath. Excessive delay skew impacts technologies (e.g., Gigabit Ethernet) that utilize all 4-cable pairs to simultaneously transmit signals. It is most commonly a result of cable damage or manufacturing problems; however, it can be a result of substandard connection components or patch cords as well.

Excessive Return Loss

Return loss is a ratio of the power of the outgoing signal to the power of the reflected signal, expressed in dB.

Excessive return loss may be attributed to:

- Impedance mismatch in permanent link or channel components—This can be the result of noncompliant or damaged cable, inadequate cabling installation practices, too much tension on cables, kinks, or noncompliant connecting hardware and patch cords.
- Improper termination practices—Proper cable twists must be maintained when terminating cable pairs. Excessive sheath removal may cause increased return loss and kinks in cable behind faceplates.
- Incorrect or substandard components—All cable and connecting hardware must be of the same category/class and quality to enable the system to meet the anticipated specifications.
- CP too close to the TR—Typical standards state that the CP should be at least 15 m (49 ft) from the TR.

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Isolating and Repairing the Problem, continued

Incorrect Cable Length

Because of the twisting of the pairs, the actual physical length of a twisted-pair cable will appear slightly shorter than the electrically measured length.

- Length too short—A length test that displays a significantly shorter-than-actual length may indicate an open or short in the cable. It can indicate a poor termination at an intermediate connection (e.g., connecting hardware, patch panel, wall outlet).
- Length too long:
  - Check for excess cable coiled in the wall, ceiling, or TR.
  - Verify cable length runs from blueprints.
  - Replace long patch cords with shorter cords where possible.
  - Notify job supervisor or customer as required.
- Inaccurate length measurement—Ensure that the NVP setting of the cable tester is correct. To determine the proper setting, complete the NVP Setting Procedure.

Excessive Alien Crosstalk (AXT)

When category 6/class E cabling is used to support 10GBASE-T applications, it may be necessary to mitigate the alien crosstalk between the disturbed pair and disturbing pairs of category 6/class E channels and permanent links.

The following techniques can be used:

- Replace connecting hardware with augmented category 6_A components.
- Ensure that wire bundles are small, and conduit fill recommendations have not been exceeded.
- Ensure that bundle ties are not cinched tightly when dressing cables.

Isolating and Repairing the Problem, continued

Setting Nominal Velocity of Propagation (NVP)

To ensure accurate length measurements, it is necessary to establish the proper NVP value for the cable under test. This can be accomplished using any one of the following methods:

- Selection from tester cable library
- Manual input from manufacturer's specifications
- Field test procedure (See Figure 5.86)

To set up:

- Reel off a predetermined length of cable, and attach a category-specific modular jack or plug to one end (longer lengths will produce a more precise NVP; verify minimum amount with your cable tester's manual).
- A known length of installed cable may also be used by utilizing the cable's sheath markings to determine its physical length.
- Verify the length of this cabling utilizing a tape measure or the cable sheath markings.
- Attach this connectorized cable to the main unit of the tester.
- Enter the length of the cable, determine the NVP, and save.
- Ensure that the field test set is set to the appropriate units (metric or imperial units) before calibration.
- Save new NVP result per manufacture guidelines, and run a length test to verify proper results.

Figure 5.86
Calibration of nominal velocity of propagation



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Isolating and Repairing the Problem, continued

Excessive Loop Resistance

Shorting both conductors of a balanced twisted-pair at one end of a cable and measuring the total resistance of both conductors from the opposite end can determine loop resistance.

Excessive resistance can be caused by:

- Excessive cable length—Ensure that the length of the cable is within specifications for the application.
- Poor connection at termination point—Improperly terminated or damaged wall outlets, connecting blocks, and patch panels could be to blame.
- Defective shorting plug, test cable, test adapter, equipment cable, or patch cable—Test each component separately.

Incorrect Connections

Incorrect connections include crossed pairs, split pairs, opens, and shorts. When testing a channel, investigate each cabling component separately.

Possible causes include:

- Incorrectly installed or damaged cable or termination.
- Wrong patch cables—Patch cables wired to USOC specifications will create split pairs for T568A and T568B applications.
- Mismatched terminations—The wiring scheme for the T568A and T568B connectors is different.

Incorrect Impedance

Impedance mismatches are associated with:

- Poor installation techniques.
- Incorrect or defective cable.
- Incorrect or defective components.

Isolating and Repairing the Problem, continued

Noise

Noise is unwanted electrical signal on a wire that provides a random or persistent disturbance that interferes with the clarity or quality of the expected signal and alters the shape of the signal. Noise can be induced directly by a connected signal source (e.g., computer with a defective, noise-generating component). It can be radiated from an external source (e.g., electric motor, copier, electrical power cable) in close proximity to a data cable.

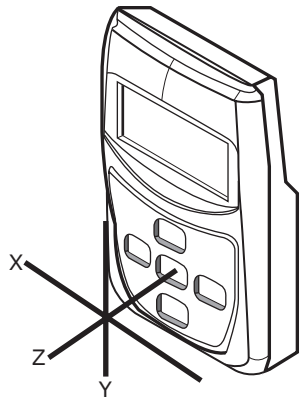
There are two types of noise to be addressed— impulse noise and continuous noise.

- Impulse noise—Refers to discrete noise spikes that occur on a regular or irregular basis. These spikes can be as high as 350 volts (V). In some instances, impulse noise can damage equipment, but, more often, it causes machine lockup (e.g., network file servers, network hubs) or corrupt data. An electrical motor, copier, laser printer, elevator, air conditioner, or any device that produces a large power disruption upon startup or shutdown can cause impulse noise.
- Continuous noise—Is usually below 3 V. While it can affect transmission on a cable, it generally does not result in hardware damage. A fluorescent light, computer, ac power line in close proximity to a data cable, and many other sources can cause continuous noise. A field strength meter may be used to measure the electric and magnetic field strength (see Figure 5.87).

The frequency of continuous noise can provide a clue to its source:

- Under 150 kilohertz (kHz)—Noise in this range is usually due to sources such as ac power lines, fluorescent lighting, and machinery.
- 150 kHz to 20 MHz—In this range, noise is often attributed to light dimmers, medical equipment, computers, copiers, and laser printers.
- Above 20 MHz—Such noise may result from radios, cellular phones, cordless phones, TV sets, microwave ovens, and broadcast equipment.

Figure 5.87
Three-axis ELF EMI handheld field tester



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Isolating and Repairing the Problem, continued

Most cable troubleshooting equipment will measure for continuous noise. Some can monitor for impulse noise. A field strength meter can be used to monitor for impulse noise.

Here are a few suggestions for the ITS installer to consider doing about noise:

- Move cables away from possible sources of interference.
- Move interference sources away from cabling. Change the location of microwave ovens, copiers, or other equipment if possible.
- Install a higher category/class of cable; if using balanced twisted-pair cable, install category 6/class E or better.

Install a screened/shielded cabling system.

- Verify that cable pair twists are maintained up to point of termination. Category 5e/class D and category 6/class E and higher categories/classes, for example, require that twists be maintained to within 13 mm (0.51 in) of the point of termination.
- Ensure that there are no split pairs.
- Consider separate cross-connect fields for data and analog voice.

Isolating and Repairing the Problem, continued

Locating Cables

If documentation is not complete, it may be necessary to follow the path of a cable to locate the ends. Many cable testers have accessories available to help with these tasks.

Testing the Repaired System

Once the repairs are finished, the final step is testing and documenting the system.

Steps—Troubleshooting Twisted-Pair Cable

Step	Troubleshooting Twisted-Pair Cable
1	Follow the general guidelines outlined in this section.
2	Complete the visual inspection to determine that the: • Location has been correctly labeled. • Correct patch cords/equipment cords have been used. • Correct cable and termination devices have been installed in accordance with the applicable standard.
3	Having completed the verification phase and determined that the trouble is within the cabling network, the fault isolation phase begins.

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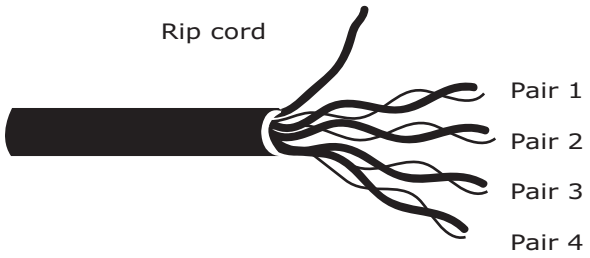
Balanced Twisted-Pair Media

Fault Isolation

The troubleshooting flowchart (see Figure 5.90) provides a comprehensive, organized approach to cable troubleshooting. However, before beginning this phase, wire properties should be reviewed.

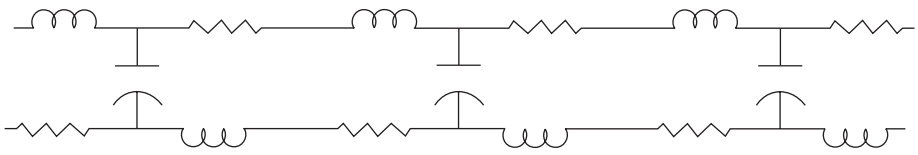
To most ITS installers, a wire pair appears as shown in Figure 5.88.

Figure 5.88
Twisted-pair wire



To a signal, however, this same wire pair appears as a transmission line (see Figure 5.89).

Figure 5.89
Schematic of a transmission line



As seen in Figure 5.89, a transmission line is composed of resistors, inductors, and capacitors. When a second pair is added, the influence of these components is felt on the second pair. Crosstalk occurs when a signal traveling down a pair exceeds the proper limits and induces a current into an adjacent pair.

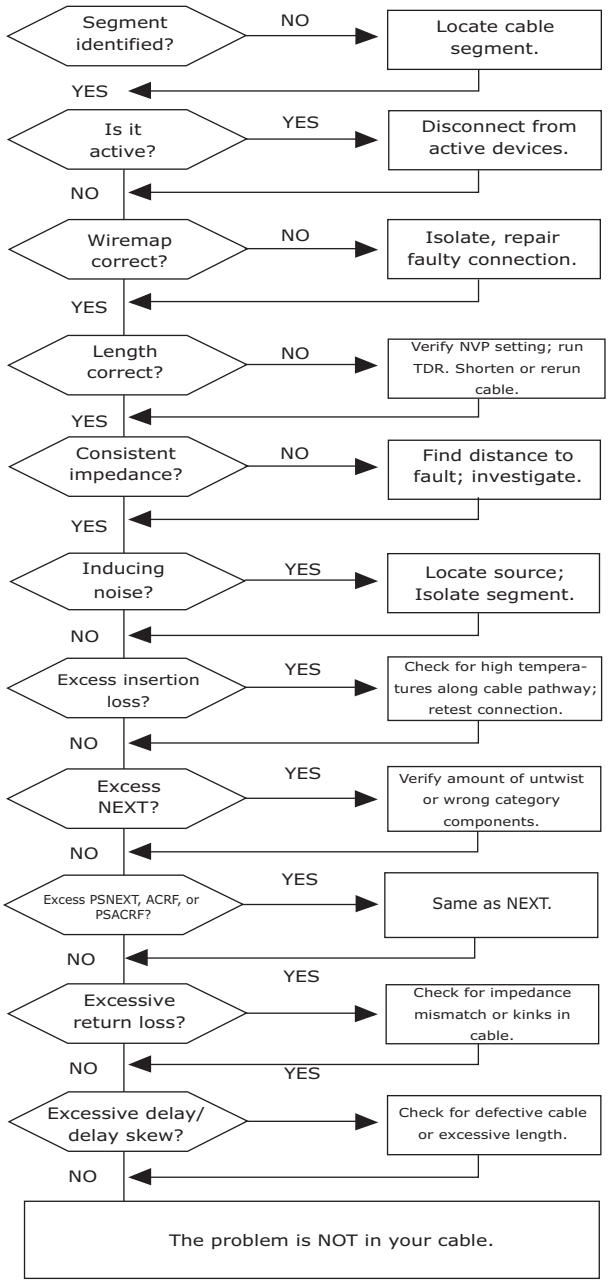
If the cable is stretched, the capacitance of the cable sheath and dielectric is changed; if stretched hard enough, the resistance (a change in wire gauge) is changed. If a coil is placed in the link, an inductor is added. By placing one or more cables together for an extended length, there is a chance of an increase in alien crosstalk. If cable ties are placed too tightly, the jacket of the cable is deformed, resulting in a change in capacitance and, therefore, a change in NEXT, return loss, and FEXT.

NOTE: When dealing with screened/shielded twisted-pair cable, it is important to verify the bonding point.

Balanced Twisted-Pair Media, continued

Figure 5.90 provides the guidelines for successful problem isolation.

Figure 5.90
Troubleshooting flowchart



ACRF = Attenuation-to-crosstalk ratio far-end
NEXT = Near-end crosstalk
NVP = Nominal velocity of propagation
PSACRF = Power sum attenuation-to-crosstalk ratio far-end
PSELFEXT = Power sum equal level far-end crosstalk
PSNEXT = Power sum near-end crosstalk
TDR = Time domain reflectometer

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Balanced Twisted-Pair Media, continued

NOTE: The range of NEXT and FEXT, including power sum, issues, and tests, are interrelated in such a way that a certification test set is required to perform the tests and display the results. Many extended crosstalk performance parameters are actually calculations made from one or more related tests. All crosstalk issues must be reviewed as part of a total performance parameter package, not a stand-alone test.

Up to this point, obvious faults have been discussed. What about the types that are more difficult to isolate?

Two of the most common are discussed below:

- Symptom: Certification test set cannot locate the remote end.
  - Possible cause: Assuming both the test set and injector are attached to the correct circuit, the most probable cause is an open in all four pairs of the cable.
  - Isolation: Switch the test set to the TDR function, and it will display the cable length. If the length is shorter than anticipated, check at that point for an open.
- Symptom: Unable to log on to the network, sluggish performance, disk errors, station freezes, or reboots.
  - Possible cause: If the cable has been checked and eliminated as the problem, it is likely that there is an intermittent noise problem. Noise may be induced into the system by an outside source such as an electrical motor (e.g., electrical pencil sharpener), lighting, ac power lines, heaters, or other equipment. This effect only occurs when the device is activated and puts a "spike" onto the line.

NOTE: Check for the location of the intermittent noise problem.

- Isolation: Using the certification test set, first check the average noise on the circuit. Ensure that two-way radios are turned off. Check for impulse noise (the spike). If these levels are high and the test set has an active time domain crosstalk capability, it should determine where the noise spike is entering the line. If it does not, use a handheld EMI field meter, or worst-case scenario, the line will have to be hand traced to locate the possible equipment that may be inducing the noise. If this test shows negative results, other potential sources of the problem may be the bonding, grounding (earthing), or electrical system.

In this case, perform a visual inspection, beginning with the connection between the bonding conductor for telecommunications (BCT) and the telecommunications main grounding busbar (TMGB) of the telecommunications bonding and grounding (earthing) network. If all connections are correct, use a multimeter to test the connections for a maximum value of 0.1 ohm.

If this test shows negative results, a strip chart recorder may be placed on the circuit to the device. If power fluctuations are evident, the branch circuit serving the equipment may have to be moved to another phase of the three-phase power feeding the building, or the unit may have to be placed on an uninterruptible power supply (UPS) system.

Balanced Twisted-Pair Media, continued

Once the problem has been successfully isolated, the final phase is to repair and test the circuit. In the case of a noise interference problem, it may not be possible to clear the problem by moving the cable or the interfering source. If this is true, consideration must be given to placing a coupled bonding conductor (CBC). The CBC provides equalization like the telecommunications bonding backbone (TBB) and provides protection via the electro-magnetic coupling with the telecommunications cables through close proximity.

NOTE: See Chapter 4: Bonding, Grounding (Earthing), and Electrical Protection for additional information.

Another possibility is to replace the balanced twisted-pair cable with a screened/shielded twisted-pair cable to correct the situation. Once the repair has been completed, the circuit should be retested.

Steps—Troubleshooting Twisted-Pair Media

Step	Troubleshooting Twisted-Pair Media
1	Disconnect active equipment so that it will not interfere with the testing. For an existing system, ensure that users have been contacted and a convenient time has been arranged to remove equipment from service if required. • Determine which equipment is connected to the line being tested. • Disconnect the equipment.
2	Connect the cable tester, and carry out the appropriate measurements. Some test sets require daily field calibration. Calibrate according to the manufacturer's specifications. • Set the tester for the correct type of cable. • Set the tester for the correct test. • Conduct the appropriate measurements.
3	If the tester is not the type to return a pass/fail reading, compare the results with the specifications for the cable. Verify that the readings fall into the acceptable range for the cable. If the original cable certification test results are available, compare the current reading/test results with the result of the original test.
4	Record the results.
5	Evaluate test results. • Determine that results do not fall into the normal range or are different from the original test results. If the results of a test are marginal or near the limit (other than length) for troubleshooting purposes, consider that test indicates a failure. Properly installed and functioning cable should be well within limits. Marginal results indicate potential problems. • Record any failing results.

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Steps—Troubleshooting Twisted-Pair Media, continued

Step	Troubleshooting Twisted-Pair Media
6	Use measurement results to determine the source of the problem. • Inspect hardware and connections. • Visually inspect the cable for damage. • Check the cable type. • Verify test settings. • Inspect the terminations. • Examine the bend radius, the pair twist, and the sheath. • Observe the color codes. • Verify pin configuration.
7	Test specific channel components, the link, and each patch or equipment cord separately.
8	Perform additional tests as necessary.
9	Take corrective action for any observed conditions that do not meet cabling standards.
10	Retest the cable to verify it passes all relevant tests.
11	Record the: • Circuit identification number and location. • Customer name and phone. • Service type. • Test results. • Repairs made. • Passing test results.
12	Perform housekeeping as needed. • Replace any cables moved during the testing. • Ensure that all cables are properly routed. • Ensure that all cables maintain at least the minimum bend radius. • Ensure that all cables have the appropriate slack. • Leave a clean space when the installation is complete. • Verify that the circuit is operational with the customer or user before leaving the site.

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Chapter 6
Optical Fiber Structured Cabling Systems

Chapter 6 supplies information technology systems (ITS) installers with detailed information about optical fiber structured cabling systems and includes the procedures for accessing and pulling cable as well as splicing, testing, and troubleshooting these systems.

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Optical Fiber Cable

Introduction

Optical fibers provide a path to support the transmission of infrared bandwidth light pulses instead of electrical signals. The two key components of an optical fiber are its core and cladding. The core is the innermost part of the optical fiber through which light pulses are guided. The cladding surrounds the core and, through the process of internal refraction, keeps the light in the core part of the optical fiber.

The refractive index of the core is higher than that of the cladding. Light traveling down the core, which strikes the cladding at a glancing angle, is confined within the core by internal reflection. In other words, the cladding creates a mirror effect to reflect light back into the core that would normally escape through the outer edges of the core.

The reference used to define the size of an optical fiber is a micrometer (µm), a unit of measurement that is one millionth of a meter. The core size of optical fiber strands is defined in µm (e.g., 9 µm, 50 µm, 62.5 µm). The cladding size is also stated in µm (e.g., 125 µm).

A mode is a path of light. An optical fiber strand mode may be:

- Multimode—Larger core with multiple paths of light.
- Singlemode—Smaller core with only one path of light.

Each of these optical fiber types carry the light in different ways; therefore, they normally would not be mixed together in a single optical fiber circuit. Some exceptions (e.g., mode conditioning patch cords) are specifically designed to allow singlemode equipment to run over multimode optical fiber cables.

Optical Fiber Cable Classification

Optical fiber strands are available as:

- Coated.
- Tight buffered.

Optical fiber cable types can include:

- Simplex (single fiber strand):
  - Zip cord (looks like the electrical cord found on small appliances and lamps; dual strands each with 3 millimeter [mm (0.12 inch [in])] jackets [typical] that are bonded together)
  - Tight buffered (fiber strands with a 900 µm buffer coating)
  - Distribution (multiple 900 µm tight-buffered strands under a single jacket)
  - Breakout (multiple 2 mm [0.079 in] through 3 mm [0.12 in] subunits individually jacketed strands under a single overall jacket)
  - Central tube (loose tube construction with a single tube containing multiple ribbons or multiples of individual 250 µm buffered fibers)
  - Loose tube (multiple tubes containing multiple ribbons or multiples of individual 250 µm buffered fibers)

Optical Fiber Cable Classification, continued

  - Ribbon (multiple 250 µm fibers bonded into a flat, color-coded ribbon)
  - Air-blown optical fiber (fibers designed to be installed with compressed air or nitrogen through specially designed tubular microduct assemblies)
- Hybrid optical fiber cable—An optical fiber cable containing two or more fiber types (e.g., multimode, singlemode).
- Composite cable—An assembly of two or more optical fiber cables of the same or different types or categories covered by one overall sheath (e.g., optical fiber, copper cables).
- Bundled cable—An assembly of two or more optical fiber cables distinguished in some fashion from other groups.

The cable jacket on an optical fiber cable serves two main functions:

- Physical protection for the fibers in the cable
- Environmental protection for the fibers in the cable

Physical protection is provided through the cable design and the use of yarns that run along-side the fiber strands in the cable and the materials used in and around the cable's jacketing. Physical protection is also provided by using different materials for the jacket layers (e.g., glass reinforced plastic [GRP] rods, corrugated steel tape under the cable's jacket, external steel wire armor [SWA]).

Environmental protection is provided through the choice of materials in the cable jacket. These materials could include water-blocking gel or tapes to stop migration of water along the inside of the cable and fire rating of the jacket for the application (e.g., polyvinyl chloride [PVC], plenum, low smoke zero halogen [LSZH]).

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Optical Fiber Cable Classification, continued

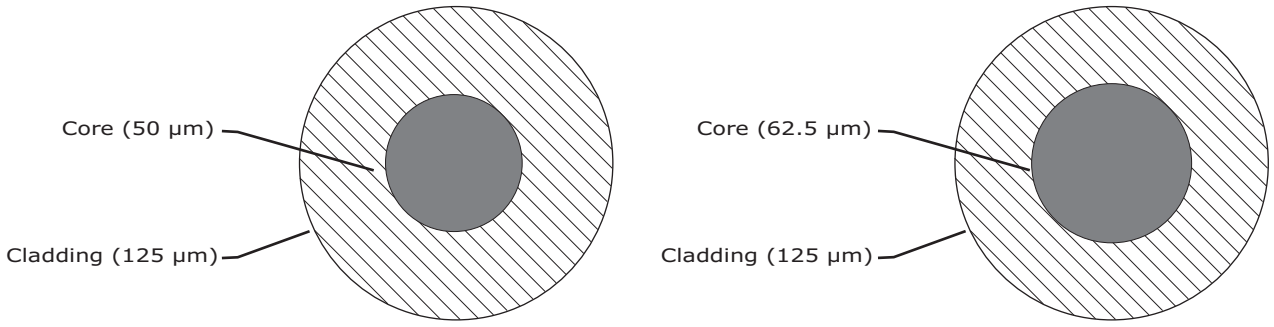
Three classification terms are used to describe optical fiber cable:

- Indoor/outdoor cable—Optical fiber cables designed to meet the requirements of both indoor and outdoor environments to ease the transition from premises to outside plant (OSP) often carry a specific fire rating based on their internal fire performance as well as construction specifications to meet the OSP environment (e.g., ultraviolet light [UV] protection, armor for rodent protection).
- Indoor cable—Cables designed to meet the requirements of indoor environments and carry a specific fire rating.
- Outdoor cable—Cables designed to meet the requirements of outdoor environments and generally carry no fire rating.

Multimode optical fiber cable (see Figure 6.1):

- Is the most common for backbone and horizontal runs within buildings and campus environments.
- Has a 50 µm or 62.5 µm core and 125 µm cladding diameter. The 50 µm multimode optical fiber is available in grades of glass:
  - OM2
  - OM3 (laser optimized)—High bandwidth, long distances
  - OM4 (laser optimized)—Higher bandwidth, longer distances

Figure 6.1
Multimode optical fiber cable



µm = Micrometer

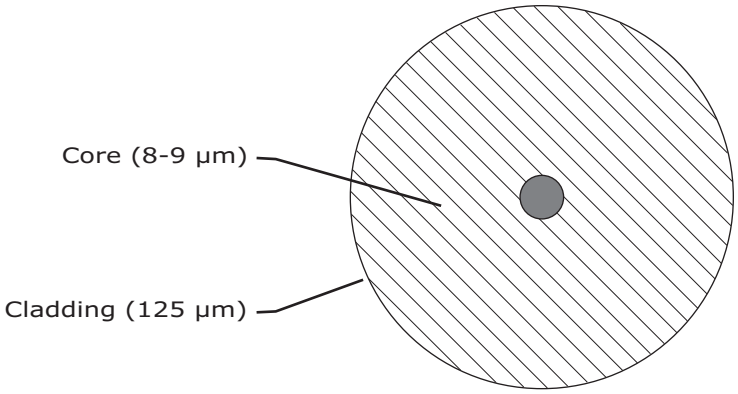
- Has a distance limitation of 2000 meters (m [6562 feet (ft)]) for structured cabling systems. Be aware that numerous applications are not capable of supporting distances anywhere near the structured cabling system's specified maximum distances. Distances supported are application dependent.
- Generally utilizes a light-emitting diode (LED) light source although vertical cavity surface emitting lasers (VCSELs) are also common.
- Supports wavelengths of 850 nanometer (nm) and 1300 nm.

Optical Fiber Cable Classification, continued

Singlemode optical fiber cable (see Figure 6.2):

- Is used in riser and campus environments.
- Has an 8 to 9 µm core, depending on the manufacturer.
- May be used for distances up to 3000 m (9842 ft) for structured cabling systems (SCSs). Distances supported are application dependent. Be aware that some applications far exceed the 3000 m (9842 ft) restrictions placed on an SCS.
- Normally uses a laser light source.
- Supports common wavelengths of 1310 nm, 1490 nm, 1550 nm, and 1625 nm.

Figure 6.2
Singlemode optical fiber cable



µm = Micrometer

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Optical Fiber Cable Classification, continued

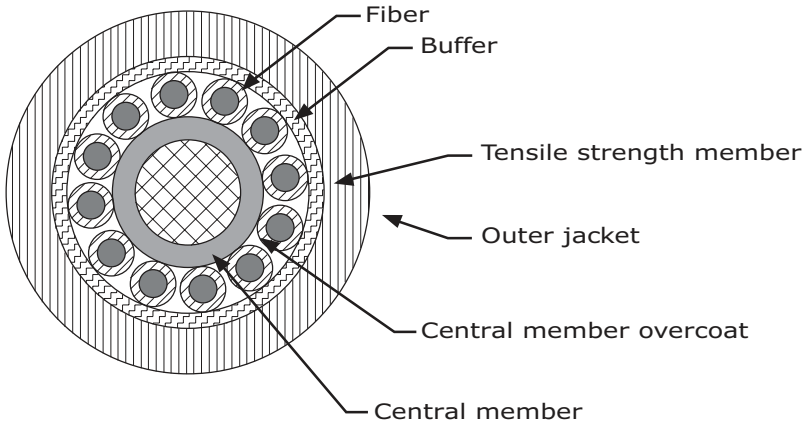
Optical fiber cables may be:

- Tight buffered.
- Loose tube.
- Ribbon cable.
- Air-blown optical fiber.

Tight-buffered optical fiber cable (see Figures 6.3, 6.4, and 6.5):

- Is primarily used inside buildings. (It may contain water blocking to be used outside.)
- Is available with various jacket types to meet building codes.
- Protects the optical fiber by supporting each strand of glass with a buffer coating extruded over the base optical fiber's 250 µm acrylate coating. The most common tight-buffer diameter is 900 µm although other diameters are available.
- Is easily connectorized.
- May be singlemode or multimode.

Figure 6.3
Tight-buffered optical fiber cable, distribution design



Optical Fiber Cable Classification, continued

Figure 6.4
Tight-buffered optical fiber cable, breakout design

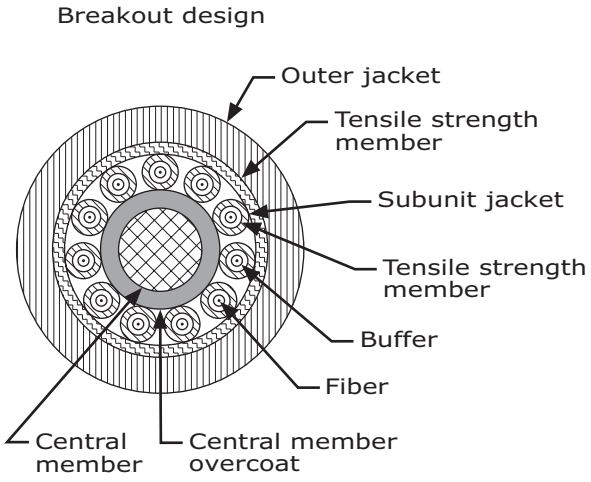
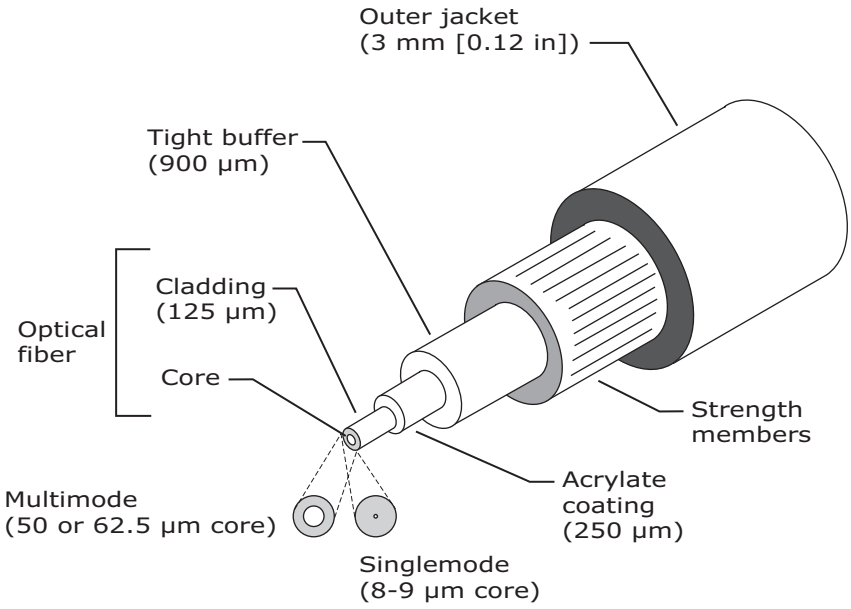


Figure 6.5
Single-stranded tight-buffered optical fiber cable



in = Inch
µm = Micrometer
mm = Millimeter

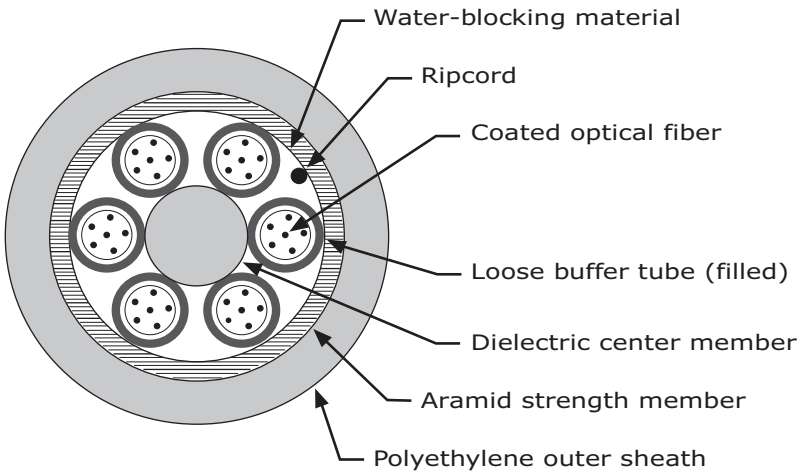
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Optical Fiber Cable Classification, continued

Loose-tube optical fiber cable (see Figures 6.6, 6.7, and 6.8):

- Is used primarily outdoors.
- May contain water-blocking material (water-absorbent tapes or gel that swell when exposed to moisture) for use outside.
- Allows the cable jacket to expand and contract with changes in temperature without affecting the fibers.
- Has a shorted cable jacket length to the fiber length inside (helix factor).
- May be singlemode or multimode.
- Often uses loose tube optical fiber with a diameter of 250 µm although other diameters are available.
- May require furcation tubing or fan-out kits to build up the fiber strand's diameter to allow direct connectorization.

Figure 6.6
Loose-tube optical fiber cable



Optical Fiber Cable Classification, continued

Figure 6.7
Side view of a loose-tube optical fiber cable

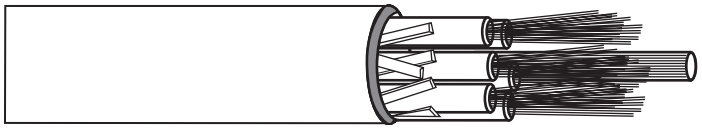
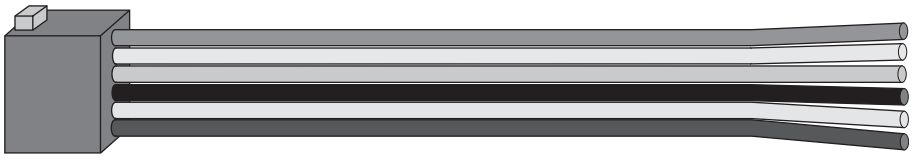


Figure 6.8
Loose-tube furcating harness



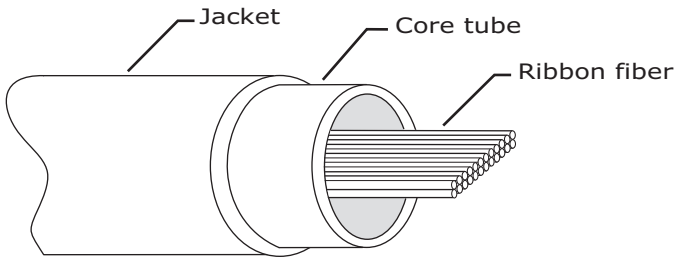
900 µm Outer diameter furcation tubing

µm = Micrometer

Ribbon optical fiber cable (see Figure 6.9):

- Is used either indoors or outdoors.
- Consists of up to 24 strands bundled together in a single line of color-coded ribbon.
- Has multiple ribbons within buffer tubes that provide potentially high optical fiber counts in a small diameter cable.
- May consist of singlemode, multimode, or a combination of the two.
- Can be quickly spliced when using special equipment (e.g., mass fusion, mechanical splicing).

Figure 6.9
Ribbon optical fiber cable



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Air-Blown Optical Fiber Cable

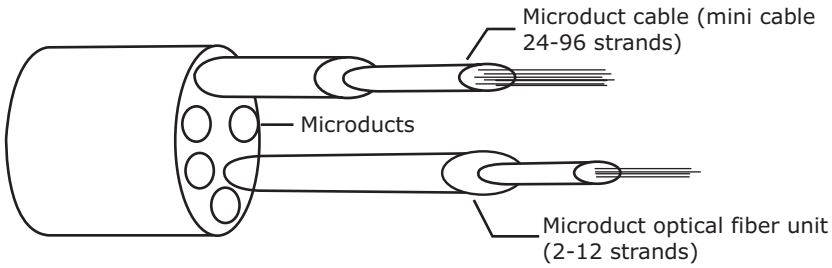
Overview

Air-blown optical fiber systems utilize microduct optical fiber cables, microduct fiber units, microducts, and protected microducts (see Figure 6.10). These systems are designed and manufactured for an expected operating lifetime of at least 20 years.

It is possible to install or remove the microduct optical fiber cable or microduct fiber unit in or from the microducts by blowing during the operational lifetime. When considering recovering a product for potential reuse, care must be taken to minimize stress on the product and ensure that the product is carefully handled and packaged in accordance with the manufacturer's guidelines.

Good practice is to test all previously recovered products adequately before they are redeployed.

Figure 6.10
Air-blown optical fiber cable



Optical Fiber Cable and Strand Color Codes

There are some places in the world where standards cover the color-coding of optical fiber cables. Where there is no applicable standard, it will be the cable manufacturer who dictates the color sequence and grouping of the fibers. It may be that two different sources of cable are used on a job, which means there may be a different color code for the fibers. The information technology systems (ITS) installer should map out the color code and state which fiber is joined or terminated at each point in the channel.

Optical Fiber Cable and Strand Color Codes, continued

An example of a cable color standard is as follows (see Table 6.1):

- Strands 1 to 12 shall be uniquely color coded.
- Strands 13 to 24 shall repeat the same color code as 1 to 12 with the addition of a black tracer.
- The black tracer may be a dash line or a solid line.
- The black strand has a yellow tracer.

Table 6.1
Optical fiber color code chart

Optical Fiber	Optical Fiber Color	Color Number	Color Tracer
1	Blue	13	Blue/black tracer
2	Orange	14	Orange/black tracer
3	Green	15	Green/black tracer
4	Brown	16	Brown/black tracer
5	Slate	17	Slate/black tracer
6	White	18	White/black tracer
7	Red	19	Red/black tracer
8	Black	20	Black/yellow tracer
9	Yellow	21	Yellow/black tracer
10	Violet	22	Violet/black tracer
11	Rose	23	Rose/black tracer
12	Aqua	24	Aqua/black tracer

Optical fiber cables larger than 24 strands shall be color coded by means of binder tapes, ribbons, or threads consisting of two binders—one to match the base color and one to match the tracer color. Refer to the manufacturer's specific color scheme for details.

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Optical Fiber Cable and Strand Color Codes, continued

While it may seem that the majority of interior optical fiber cables have orange jackets, there is no mandatory standard to identify the color coding for optical fiber jackets (see Table 6.2).

NOTE: Compliance to the color code is voluntary; many manufacturers do not follow the standard-based recommendations.

Table 6.2
Color coding of outer cable sheaths

Cables with Optical Fiber Type	Color of Sheath
Singlemode optical fiber	Yellow
Multimode optical fiber with 50 µm core diameter	Orange
Multimode optical fiber with 50 µm core diameter (laser-optimized)	Aqua
Multimode optical fiber with 62.5 µm core diameter	Orange
Multimode optical fiber with 100 µm core diameter	Orange
Dispersion-shifted singlemode optical fiber	Red
Polarization maintaining singlemode optical fiber	Blue

µm = Micrometer

According to standards, horizontal optical fiber cable normally is multimode. Backbone optical fiber cable may be multimode (62.5/125 µm or 50/125 µm) or singlemode.

Optical Fiber Cable Attenuation

Multimode and singlemode optical fiber cables should perform as shown in Table 6.3.

Table 6.3
Optical fiber cable transmission performance parameters

Channel Attenuation (dB)

	Multimode		Singlemode	
Channel	**850 nm**	**1300 nm**	**1310 nm**	**1550 nm**
OF-300	2.55	1.95	1.80	1.80
OF-500	3.25	2.25	2.00	2.00
OF-2000	8.50	4.50	3.50	3.50

nm = Nanometer
dB = Decibel

NOTES: The information transport capacity of the optical fiber, as measured by the optical fiber manufacturer, can be used by the cable installer to demonstrate compliance with the standards for premise distribution cable.

Table 6.3 assumes the measurement is for a complete channel between end equipment and consists of the optical fibers and a maximum of two mated pairs of connectors. The connectors are allowed to contribute a maximum of 1.5 decibel (dB) of the total attenuation. The remainder attenuation is from the loss associated within the fiber strands themselves based on their maximum allowed length and light sources of varied wavelengths (e.g., OF-500 has a maximum length allowed of 500 m [1640 ft] with a loss of 1.5 decibel/kilometer [dB/km] using a 1300 nm light source; 1.5 dB for connectors plus .75 dB for .5 kilometer [km] length equals 2.25 dB).

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Optical Fiber Connectors

Overview

Connectors provide certain critical functions, including:

- Minimal power loss when mating to other cables or equipment.
- Secure optical fiber retention within the connector.
- Secure connector retention within equipment or adapter.
- Protection for the end of the optical fiber.
- The ability to connect to and disconnect from other cables or equipment.

Makeup of a Connector

Two important qualities of a connector are the ability to:

- Latch securely.
- Connect to other cables or equipment with low loss.

This is achieved by the connector mechanism, which usually consists of a:

- Ferrule (flat or preradiused end).
- Key (assures consistent connector orientation within adapters).
- Latching ring or latching mechanism.

Coupling of Optical Fibers

There are two ways to connect two fibers together:

- Plug to plug:
  - Each fiber is connectorized with a male connector. A female optical adapter is used to interface the two male connectors together (e.g., a patch panel with female adapters is used to join a cable installed into the rear of the panel to a patch cord plugged into the front of the panel).
- Plug to jack:
  - One of the fibers is connectorized with a female jack. The jack can then be snapped into a patch panel or faceplate.
  - The second cable is connectorized with a male plug. The male plug is then inserted into the female jack. The female adapter used in the plug to plug arrangement is not needed in a plug to jack configuration.

Connectors

The three groups of connectors are:

- Present usage types.
- Ribbon optical fiber.
- Legacy types.

Connectors presently used are:

- Straight tip (ST) compatible—A keyed, contact, moderate loss, not a pull or wiggle-proof connector.
- Subscriber connector (SC)—A keyed, contact, moderate loss, pull and wiggle-proof connector.
- Small form factor (SFF)—A smaller connector that allows higher density of connectors in patch panels and equipment ports. This also allows a lower per port cost for hubs and switches and a duplex connector size of a modular jack.

  Some common SFFs (see Figure 6.11) are:

  – LC connector—A simplex connector that can be converted to a duplex configuration using two connectors and a clip to create a keyed duplex connector assembly. It is keyed, contact, low loss, pull, and wiggle proof. It can be terminated many different ways, including quick cure adhesive, cleave and crimp, and hot melt.

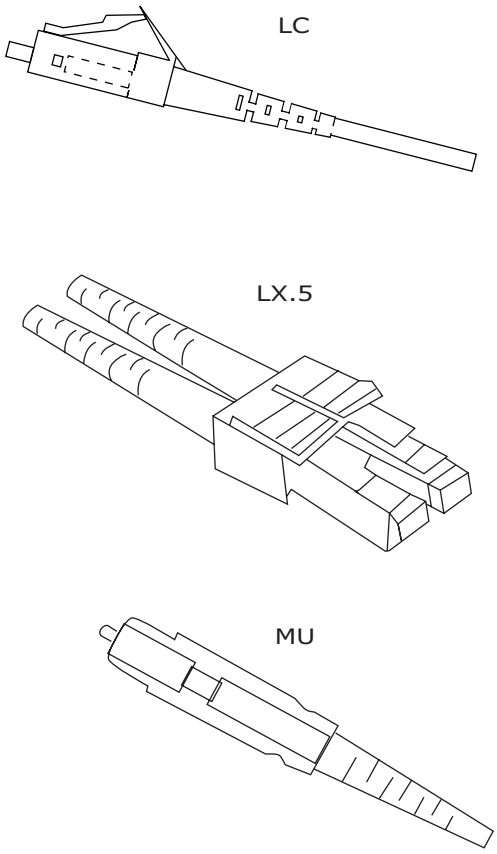
  – Multiple use (MU)—A simplex connector that resembles an SC, but the dimensions are one-half the size of the SC. It is keyed, contact, moderate loss, pull, and wiggle proof. It can be assembled as a duplex, triplex, or quadruple connector.

  – LX.5—A connector similar to the LC connector with a built-in dust cover.
- Array connectors—Array connectors terminate 6 to 72 optical fibers in a single ferrule. The connectors may be used to connect to equipment in data centers or prewired optical fiber cassettes. These connectors are often preterminated at the factory. Multifiber push-on/multifiber termination push-on (MPO/MTP) are two examples of high-density optical fiber connectors.

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Connectors, continued

Figure 6.11
Common small form factor connectors



LC = Connector
MU = Miniature unit

Legacy-Style Connectors

Figures 6.12 and 6.13 demonstrate array optical fiber connectors with alignment pins. The individual optical fibers between the alignment pins are not visible in these figures. The array optical fiber adapter provides a means for coupling two array optical fiber connectors.

Figure 6.12
Array-style optical fiber connector and adapter—example of Type-A multifiber push-on configuration

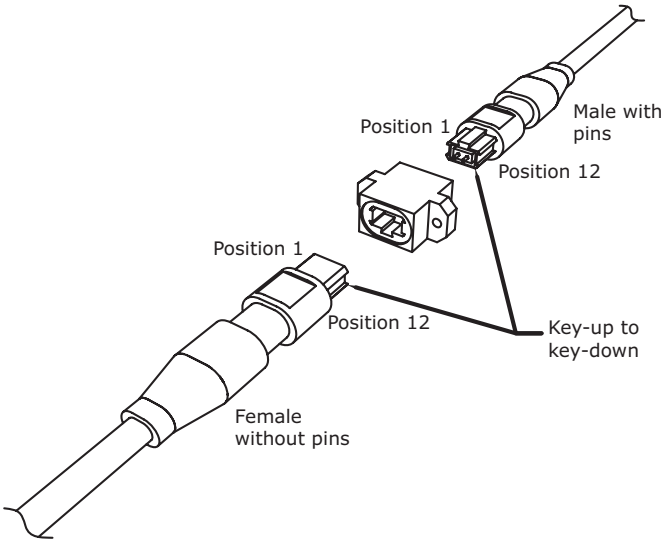
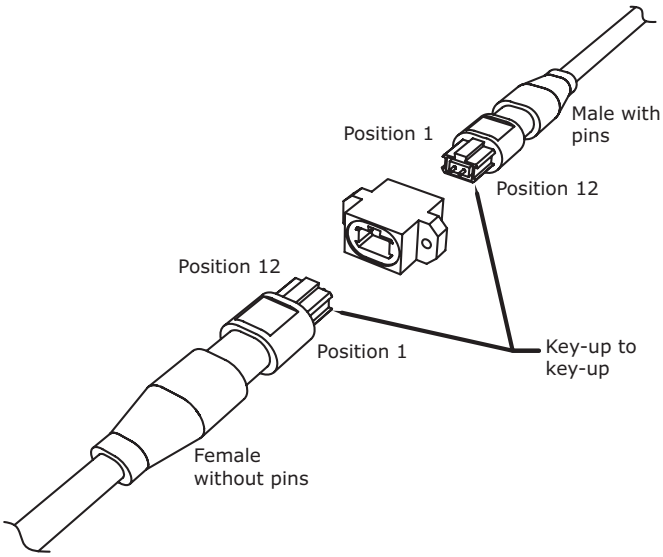


Figure 6.13
Array-style optical fiber connector and adapter—example of Type-B multifiber push-on configuration



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Legacy-Style Connectors, continued

Some legacy-style connectors include:

- Subminiature version A (SMA) 905.
- SMA 906.
- Biconic.
- Enterprise systems connection (ESCON).
- Fiber distributed data interface (FDDI), media interface connector (MIC).
- Fiber connector (FC).
- Mechanical transfer registered jack (MT-RJ).
- Opti-jack.

These connectors are rarely used today and were used infrequently in legacy systems.

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Pulling and Installing Optical Fiber Cable

Cable Bend Radius

Optical fiber cables are much lighter in weight and smaller in size than copper backbone cables and may or may not require additional tools during installation. The ITS installer should always observe the manufacturer's recommendations regarding pulling tension, bend radii, and support requirements.

All cables have a minimum bend radius that must be maintained both during the pulling process and after the cable is installed so that the cable is not damaged (see Table 6.4). Prior to beginning the pull, verify that the minimum bend radius will be maintained for all cables.

Table 6.4
Cable bend radius

Cable	Minimum Radii
Optical fiber (up to four strands at rest)	25 mm (0.98 in)
Optical fiber (up to four strands during pull)	51 mm (2 in)
Backbone optical fiber at rest	10 times the outside cable diameter
Intrabuilding optical fiber during installation	15 times the outside cable diameter
Interbuilding optical fiber during installation	20 times the outside cable diameter

in = Inch
mm = Millimeter

The minimum cable bend radius must be verified prior to determining which tools will be needed on the job as additional tools (e.g., pulleys, wheels, additional personnel) may be needed to maintain the proper radii during the pull.

The type of equipment needed depends on the direction of the pull. If pulling from the bottom up, a winch may be needed. If placing in a high-rise building from the top down, a reel brake may be needed. A reel brake or cable brake is a mechanical device used for stopping or slowing the cable to help prevent a freewheeling reel, thereby keeping it from unreeling too fast.

Locations for Accessing and Pulling Cable

Determine if a loading dock, forklift, or other mechanical device is available to off-load large cable reels at the delivery site. While many delivery trucks are equipped with lift gates, some larger reels cannot be handled in that manner.

The ITS installer must make plans for locations to store cable that is waiting placement and must have a method for moving cable reels from the storage point to the pulling location. This includes a pathway suitable for the material and its conveyance (e.g., wide doorways; elevators equipped to handle the weight; a room adequate in size and layout to set up reel supports, pulleys, and associated equipment).

Communications with coworkers is an essential part of every cable placement. Each person involved in the pull should have a designated responsibility. Everyone should be prepared to alert the person in charge of pulling the cable about possible safety concerns and problems with the actual placement.

Cable can easily twist, kink, or bind during placement, and the pull must be stopped to allow corrective action to be taken.

Communication in this instance consists of two major components:

- The means to communicate (e.g., radios, intercoms, other electronic devices)
- A commonly understood set of commands

Terms such as “back,” “forward,” and “the other way” can mean different things to people standing apart on a work site. Ensure that the placement crew agrees upon a standard set of commands, the methods to be employed, and the responsibility of each person for communications.

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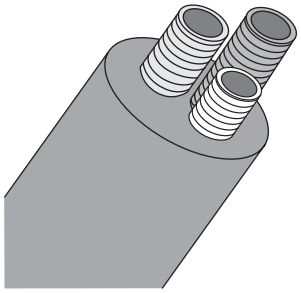
Steps—Optical Fiber Cable

Step	Pulling Cable—Optical Fiber
1	Ensure that only tested and accepted lengths of optical fiber cable are installed. • Three test instruments typically are used to test optical fiber on the reel, each offering varied levels of confirmation of strand integrity: – Visual fault locator (VFL) – Optical loss test set (OLTS) – Optical time domain reflectometer (OTDR) • Any connections made to the fiber on the reel may require the use of a bare optical fiber adapter or an optical fiber pigtail equipped with a reusable mechanical splice to the unterminated optical fiber on the reel. • Using either the VFL or OTLS will require access to both ends of the cable on the reel. Cable will have to be ordered with access to both ends on the reel. The VFL will require a connection to one end of the cable and access to the other end to visually verify that light generated by the VFL appears at the distant end of each strand. This provides continuity information, but it does not indicate any minor damage or amount of attenuation through each strand. **WARNING**: Never look directly at the end of a previously installed optical fiber cable because a laser light source, which is not visible to the human eye, may be present. This can cause permanent damage to the eye. • The OLTS will require a connection to both ends of the cable. Once the OLTS has been calibrated, the light source can be connected to one end of a strand and the power meter connected to the opposite end of the strand. This test will show continuity and a rough estimate of the amount of attenuation. The attenuation measurements will not be accurate because of the varying quality of each connection via bare fiber adapters or mechanical splices to the fiber strands. • The OTDR will require a connection to one or both ends of the cable, depending on your test configuration. When the OTDR is only connected to one end of a strand, it will show the initial connection to the test jumper and all anomalies on the fiber being tested as well as its length. The one drawback of this method is that you are not certain your test pulse is making it to the remote end of the fiber. You could have a break 50 m (164 ft) from the end that is buried under layers of fiber on the reel. This type of damage would have happened at the factory and is extremely rare. Testing from one end is an acceptable method for most installations.

Steps—Optical Fiber Cable, continued

Step	Pulling Cable—Optical Fiber
1 cont.	• When the OTDR is connected to one end of a strand and a long optical fiber jumper (landing cable) is connected to the distant end, the OTDR will show the initial connection to the test jumper, the distant connection of the fiber to the jumper cable, the overall length and all anomalies on the fiber being tested. The additional jumper on the distant end verifies full continuity when the distant connection is detected by the OTDR. Testing from one end with the additional connection at the remote end will require additional time and materials for the second connection to be made. Maintain the test results for inclusion in the client's documentation package.
2	Install and secure innerducts. • Verify the optical fiber cable and innerduct flammability requirements (e.g., plenum, nonplenum) and place the innerducts, if required, depending on the specific location (e.g., vertical shaft, cable tray, open ceiling), with the appropriate support. If secured with tie wraps in a plenum area, use plenum-rated tie wraps. • Innerduct can be ordered with or without a pull rope already placed inside. It is recommended to order innerducts with a pull rope preinstalled. If ordered without a rope, follow the procedure for installing a pull string in a conduit. • Where optical fiber cables will be used, consider placing three innerducts (two 38 mm [1.5 in] and one 26 mm [1 in]) inside each 103 mm (4 trade size) conduit designated for optical fiber to ensure physical cable protection (see Figure 6.14). An innerduct is a smaller flexible pathway used as an independent pathway or within the conduit available in: – Various diameters (typically 26 to 51 mm [1 to 2 in]). – Various reel lengths. – Short sections. Each innerduct should be equipped with a pull cord. Channelized innerducts compartmentalized into separate sections are also available. Fabric innerducts may also be considered as a pathway to install cables within larger conduits.

Figure 6.14
Four-inch conduit with three innerducts

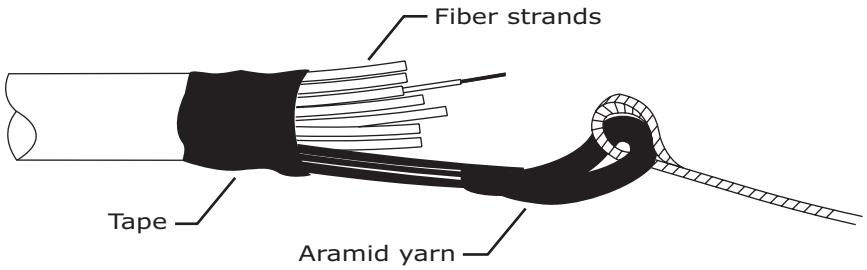


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Steps—Optical Fiber Cable, continued

Step	Pulling Cable—Optical Fiber
2 cont.	• Attach the optical fiber cables to the pull rope for pulling the optical fiber cable through the innerduct. Two methods of connection are commonly used. The most common method is to remove the sheath for about 305 mm (12 in) length from the optical fiber cable and place the exposed aramid yarn strength member through a loop in the rope. Secure it with tape as shown in Figure 6.15. This is the preferred method for tight-buffered cables.

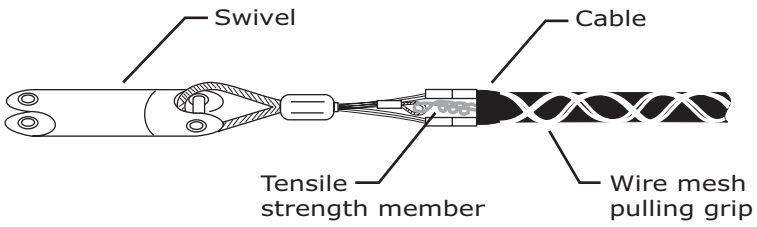
Figure 6.15
Connecting aramid yarn



- The second method is to place the optical fiber cables in a multiweave wire mesh grip of the appropriate size that has a swivel pulling eye to which the pull rope is attached (see Figure 6.16). This is the preferred method for loose-tube cables. If this method is used for tight-buffered cables, the multiweave wire mesh grip must include a mechanism to secure the aramid yarn to the grip.

  NOTE: Special consideration should be given to preconnectorized cables. Such cables may be ordered with factory-installed protective pulling eyes. Preconnectorized cables often use specialized protective pulling socks. These typically consist of a combination of protective foam or hard shell that surrounds the connectors and then is covered with a durable cloth sock equipped with a pulling loop. Once the cable is pulled into place, the pulling sock is easily removed to gain access to the optical strands of fiber and the connectors.

Figure 6.16
Multiweave wire mesh grip with swivel pulling eye



Steps—Optical Fiber Cable, continued

Step	Pulling Cable—Optical Fiber
3	Install without innerduct. • When optical fiber cable is installed without an innerduct, ensure that the run is as straight as possible. • Ensure that coworkers are placed at transitions to relieve excessive tension during the pull. This ensures that the optical fiber cable does not rub against obstructions that can nick or cut the jacket.
4	Pull optical fiber cable. • Feed the optical fiber cable into the innerduct. Normally, the optical fiber cable can be pulled by hand. When pulling tight-buffered cable, avoid placing all the pulling tension on the cable's outer jacket. When making the attachment to the cable by tying the pull rope to it or using a mesh grip, be sure to always make a secure attachment to the cable's strength member. One way to ensure that you are transferring the pulling tension to the cable's jacket and strength member is pulling the cable using a mandrel. Wrap the cable around a mandrel a minimum of four wraps, and pull via the mandrel. This will transfer the pulling tension to the aramid yarns beneath the jacket. Ensure that the mandrel is of sufficient diameter to support the minimum cable bend radius. It is a recommended practice to cut off any cable that was wrapped around the mandrel as it may have been damaged during the pulling operation. Use pulling lubricants as recommended by the cable and duct manufacturers. Make sure all lubricants are compatible with the cable's outer jacket composition. • Do not exceed the recommended pull tension or the recommended bend radius of the optical fiber cable.
5	Always leave a service loop. • The service loop is used to relieve all tension on the optical fiber cable before it is routed into its final termination enclosure and to provide slack for future moves or changes. The innerduct should be routed to a point that allows the cable to be coiled into a service loop and routed to its point of termination. • To provide maximum protection, you may want to bring the optical fiber cable with the innerduct into a point of termination using the grommets provided in the optical fiber cabinet. Secure the optical fiber cable to the cabinet, ladder rack, cable tray, or backboard. The optical fiber strands should be stored and dressed inside the cabinet. • The optical fiber cable service loop should be long enough to reach the farthest corner of the telecommunications room (TR), plus floor to ceiling, in case equipment relocation or enhancements are made in the future and the optical fiber must be relocated within the TR. Additional service slack stored inside the cabinet should be 3 m (10 ft).

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Steps—Optical Fiber Cable, continued

Step	Pulling Cable—Optical Fiber
6	Secure the cable to the cabinet per the manufacturer's specifications. • All optical fiber cables should be anchored in the termination cabinet by using the aramid yarn or other strength members of the cable to act as a strain relief as stated in the manufacturer's instructions. • Care should be taken to not over tighten tie wraps around optical fiber cable when dressing. Keep them loose enough so that they can be turned from side to side using finger pressure. • Maintain proper bend radii during and after the cable pull. For instance, the bend radius requirements of some optical fiber cables are: – 10 times a cable's outside diameter (OD) when the cable is at rest. – 15 times an intrabuilding cable's OD under stress. – 20 times an interbuilding cable's OD when the cable is under stress.
7	To identify cables, place unique identification numbers (e.g., from the installation drawings) at each end of the cable showing the point of origin and destination.
8	Document the job on the posted floor plans. • Indicate clearly what type of cables were installed (e.g., 24-strand, plenum-rated multimode optical fiber). • Show clearly which tray or conduit was used and which innerduct, if applicable. • Describe on the floor plan the purpose of the installed cables (e.g., backbone from main cross-connect [MC (campus distributor [CD])] to third floor TR).
9	Perform job wrap-up tasks.

Blowing Optical Fiber

Installation and Operating Conditions

Three key considerations when planning, designing, or specifying a blown system are the:

- Details of the installation process.
- Equipment to be used.
- Prevailing operating conditions—The operating environment within and immediately surrounding the microduct assembly to which the optical fiber-bearing product (microduct optical fiber cable or microduct optical fiber unit) will be exposed.

These items are the primary factors that differentiate microduct optical fiber cables and microduct optical fiber units for installation by blowing from one another as well as from other types of optical fiber cable products.

Different manufacturers or suppliers might provide the microduct optical fiber cable or microduct optical fiber unit cable and the associated microduct or protected microduct. This is accounted for in the family specifications and product specifications, which are designed to ensure the interoperability of products.

Specifically of interest are the:

- Installation compatibility.
- Mechanical durability.
- Fire performance.

Installation Conditions

The installation performance of a blown system is dependent on many factors, including the:

- Type of installation equipment used.
- Compressed airflow rate.
- Ambient air conditions (e.g., humidity, temperature).
- Shape and length of the route.

The physical characteristics of the microduct optical fiber cable, microduct optical fiber unit, or microduct (e.g. dimension, weight, stiffness) will affect how the product performs under these varying conditions.

Installation Process

Air-blown optical fiber is a strain-free method of installing optical fiber cables in tubes. It relies on the flow of compressed air or nitrogen passing over the entire length of the cable to create a fluid drag, which gently carries the cable down the tube.

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Installation and Operating Conditions, continued

In addition to the fluid drag, it is common to have a set of rollers or a caterpillar drive, which simultaneously pushes the optical fiber cable into the tube.

Air-blown optical fiber may be used in an inside or outside plant environment. The installation of protected tube bundles is accomplished using traditional cable installation methods.

The tube bundles may be:

- Pulled into conduit.
- Placed using aerial methods.
- Placed in the inside riser system.
- Placed in the inside plenum environment.

Blowing Optical Fiber Units or Minicables

Establishing Optical Fiber Pathway

Air-blown optical fiber is a process that establishes a pathway by coupling tubes from the:

- Feeder network to the distribution network.
- Distribution network to the individual drop.

The coupling of tubes to create an end-to-end pathway can be equated to splicing dedicated optical fibers in a conventional installation. The optical fiber is blown into the preestablished pathway as service is required. There shall be no splices in the air-blown optical fiber route without the agreement of the network designer or owner.

Any combination of optical fiber types and counts may be blown into the same tube cable, depending upon the application.

Testing Primary Tubes or Tube Bundles

When the optical fiber pathways are established, conduct three basic tests to verify each tube prior to blowing optical fiber into the tube:

- Airflow testing—Checks that the correct airflow has been established over a given length of microduct. This also checks that the tubes have been coupled together in the correct sequence.
- Pressure testing—Checks that there are no connectors or tube leaks in the route.
- Continuity testing—Checks that the bore of the tube is not reduced for any reason.

Blowing Optical Fiber Units or Minicables, continued

Blowing Optical Fiber

Blowing the optical fiber units or minicables requires the following equipment:

- The blow head. It provides the means by which the optical fiber is fed into the tube and allows air pressure to be applied. The blow head also controls the blowing operation.
- A source of compressed air. The source can be an electrical- or gas-operated compressor or canisters of compressed air or nitrogen. The selection of the source of compressed air shall be dependent upon the application. Blowing speeds and distances will be affected by the choice of the compressed air source. Air pressure is typically between 150 and 220 pounds per square inch (psi).
- Air pressure test equipment. Prior to blowing optical fiber into a tube, a tube and air pressure test should be conducted to verify the selected tube as described in the section above. If the speed or distance is lower than expected, a static test set can be used to determine whether friction is creating static electricity, which will adversely affect the blowing operation.

Tube Management

Tube management is a critical aspect of air-blown optical fiber installation. Closures, cabinets, and other accessories used in conventional optical fiber installation will, in many cases, be used in air-blown optical fiber installations. The capacity for tube management is an added dimension that must be considered. In specific applications where conventional products cannot be used, specific accessories designed for tube management are available.

Tube Couplers

A full range of tube couplers is available to complete the installation of the air-blown optical fiber pathway. The requirements of the inside or OSP design as well as local codes and standards shall determine the coupler used.

Couplers are available for:

- Straight-through connections.
- Water blocking.
- Gas blocking.
- Reducing couplers (e.g., for changes in ODs while maintaining inside diameter [ID]).
- Couplers for midpoint blows.

The appropriate tool for cutting primary tubes and making sure they are perfectly round is critical to achieving an adequate seal.

Optical Fiber Connectorization and Testing

When the installation of the air-blown optical fiber is completed, the connectorization and testing shall follow the same procedures established for conventional optical fiber.

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Optical Fiber Cable Splicing

Overview

In customer premises applications, most optical fiber cabling designs plan for uninterrupted, continuous pulls providing for terminations at each end of the optical fiber cable. This is typically the most economical and convenient solution.

However, optical fiber cable splices cannot always be avoided because of some of the following conditions:

- Cable plant layout
- Length
- Raceway congestion
- Requirements for a transition splice between nonlisted OSP cables and listed cable at the building's entrance point
- Unplanned requirements (e.g., damaged cable)

There are two primary splicing methods for optical fibers—fusion and mechanical. Both methods can be performed in single fiber and mass fiber (typically 12 fibers) arrangements. Both methods are field proven and have excellent long-term reliability when completed according to the manufacturer's instructions.

Fusion splices use expensive fusion splicing equipment and precision cleavers that can be purchased or rented. The fibers are cleaved (cut) as close to a precise 90 degree angle as possible and then aligned and fused together to form an almost invisible union with minimal loss and reflectance. Fusion splices have a low consumables cost per splice (e.g., fiber cleaning products, heat shrink supporting tube).

Mechanical splices use inexpensive equipment. The fibers are cleaved as with the fusion splicing, but this time, they are not fused together. A mechanical splicing module filled with index matching gel is used to precisely align and retain the fibers via mechanical pressure applied to the sides of the fibers. Mechanical splices can be undone, adjusted, and then locked back into alignment if initial tests show higher than acceptable loss in a splice. Splice loss is low, but reflectance may be a concern in certain applications.

Mechanical splices require a splicing module for each strand, giving them a consumables cost that far exceeds the cost of the consumables associated with each fusion splice. One advantage to the mechanical splice is the low investment cost compared with the high initial cost of renting or buying a fusion splicer.

Splices and stripped fiber cables are protected and secured by a splice closure. When a splice enclosure is used for splicing inside a building, it is generally secured to a rack or wall. In both cases, the splice closure or enclosure contains the optical fiber splices in splice trays or organizers, typically in groups of 6, 12, 24, or more optical fibers per splice tray or organizer.

As the cost of splicing equipment has decreased, many companies are using fusion splicers as their primary means of optical fiber splicing. The benefits of fusion splicing compared with mechanical splicing are reduced loss (attenuation) and reflectance.

ITS distribution designers will almost always specify fusion splicing and special connectors for singlemode optical fiber cable.

Overview, continued

Mechanical splices that provide low splice loss (attenuation) characteristics are available. They are easy to work with and provide an economical approach to long-term interconnection of optical fiber cables. Typically, mechanical splices are used on optical fibers of the same size and type (e.g., 50/125µm multimode). Mechanical splices can be used on both multimode and singlemode cables, and they can be used to connect optical fibers with different buffer sizes (e.g., 250 µm used in loose-tube cables, 900 µm used in tight-buffered cables).

The decision to use mechanical or fusion splicing should generally be made by the ITS designer in response to an understanding of the client's needs and after the preparation of a detailed loss budget.

NOTE: Do not assume all splices on a given project will be the same (mechanical or fusion). Verify the type of splice required at each point and for each cable with the ITS designer before beginning the job.

Planning is critical to the splicing operation. Several items must be considered, including cable placement, mounting location for the splice closure or enclosure, and selection of the splice hardware and splice method. Generally, the ITS designer who prepares the drawings, and many times ensures the parts are ordered, also performs the planning.

When the parts are on the work site, the ITS installer must set up the splicing operation properly to accommodate a straight, butt, or branch arrangement. A straight splice has a cable entering the closure on one end and exiting on the opposite end. A butt arrangement has all the cables entering and exiting the enclosure from the same end. A branch arrangement has a single cable entering one end and multiple cables exiting the opposite end of the enclosure. This is the point at which the ITS installer must position the cable, mount the splice hardware, and ensure that the proper materials are used.

The size and type of splice hardware are determined by the:

- Environment in which the hardware will be placed.
- Number of optical fibers and cables to be spliced.
- Type of cable (ribbon, loose tube, tight buffered) to be included.
- Splice trays designed to hold the particular splicing method chosen.

Based on the splice hardware used and the type of cable being spliced, the ITS installer must determine the proper amount of each cable element to be stripped (e.g., outer jacket, strength members, buffer tube, subunit jacket) before splicing can begin.

This is a critical issue because the cables must be properly secured to the closure, and the buffer tubes or subunit elements must be correctly routed from the splice hardware entrance point to the splice trays. Leaving too much buffer tube or subunits may cause difficulty in storage of these elements after splicing is complete. Leaving too little buffer tube or subunit elements may cause difficulty in providing an acceptable work area for completing the splice. Guidelines are generally available as part of the hardware assembly instructions.

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Safety

Follow the hardware and manufacturer's guidelines when performing splicing operations. The items listed below should be observed:

- Follow all safety guidelines.
- Wear a hard hat when in a construction area.
- Wear safety gloves when opening cable sheath.
- Ensure that there is adequate lighting.
- Properly discard small pieces of optical fiber to ensure that they do not accidentally penetrate the skin.
- Follow good housekeeping procedures.

NOTE: ITS installers should be familiar with the safety requirements in Chapter 2: Safety Procedures in this manual.

Optical Fiber Cable Splicing Examples

The following pages give examples of splicing procedures.

WARNING: The ITS installer must follow the selected manufacturer's procedures specific to the components and tools used.

The splicing of optical fiber may be broken down into four major functions:

- Cable preparation
- Optical fiber strand preparation
- Optical fiber strand splicing
- Optical fiber strand closing

Cable Preparation

Cable preparation involves four steps.

Step	Preparing Cable
1	Remove the cable sheath. The type of hardware in which the optical fiber cable and splices will be housed determines strip length. Consult the manufacturer's instructions for the specific optical fiber hardware.
2	Bond any metallic components of the cable.
3	Place the cable into the splice enclosure. Refer to the splice case manufacturer's instructions for the procedure (see Figures 6.17 and 6.18).
4	Determine the amount of optical fiber that will be placed into the splice tray. This length is determined by the optical fiber length that will be stored inside the splice tray (see Figure 6.19). Although the length varies, depending on the splice hardware, the typical length is from 1 m (3.28 ft) to 3 m (10 ft).

Figure 6.17
Optical fiber splice trays in an enclosure (butt arrangement)

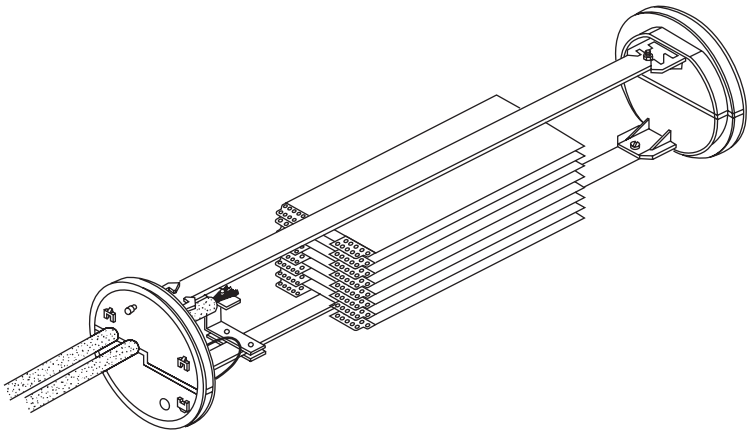
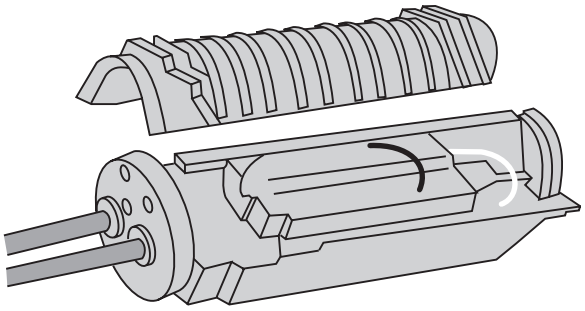


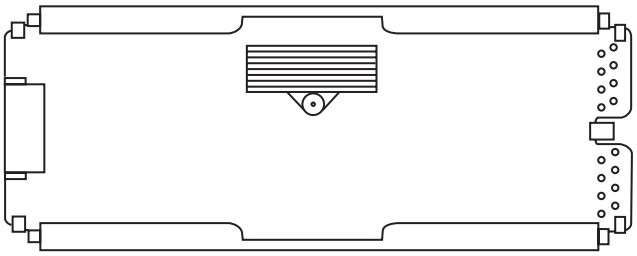
Figure 6.18
Optical fiber closure



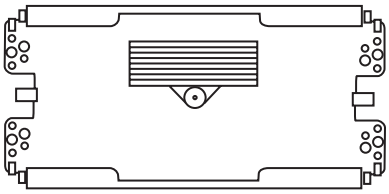
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Cable Preparation, continued

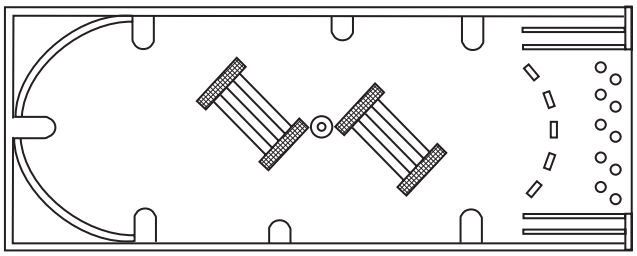
Figure 6.19
Splice trays



Splice tray (12-fiber splice capacity)



Splice tray (12-fiber splice capacity)



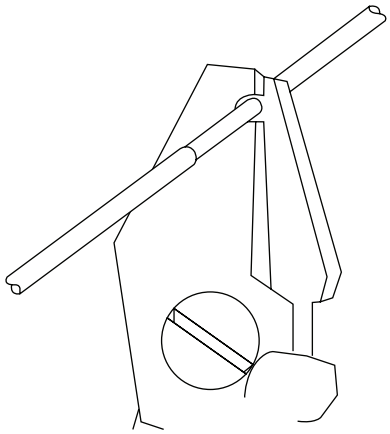
Splice tray (12-fiber splice capacity)

Optical Fiber Strand Preparation

Optical fiber strand preparation involves:

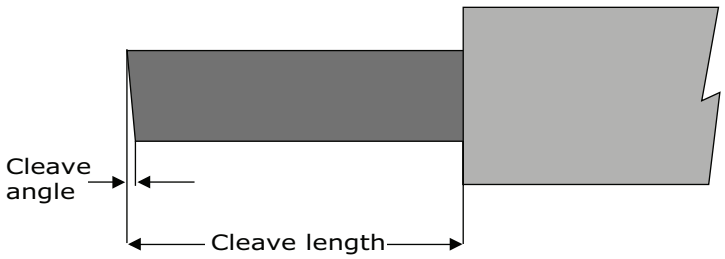
- Removal of the acrylate coating or buffering from the optical fiber strand—Refer to the splice manufacturer's instructions for the procedure and the amount to be removed (see Figure 6.20).

Figure 6.20
Optical fiber stripper tool



- Cleaving of the optical fiber (see Figures 6.21, 6.22, and 6.23)—Refer to the splice manufacturer's instructions for the correct cleave length and maximum cleave angle.

Figure 6.21
Cleave angle and length



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Optical Fiber Strand Preparation, continued

Figure 6.22
Optical fiber cleaver

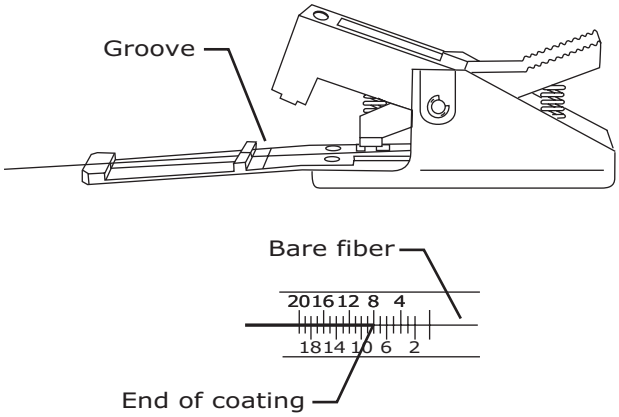
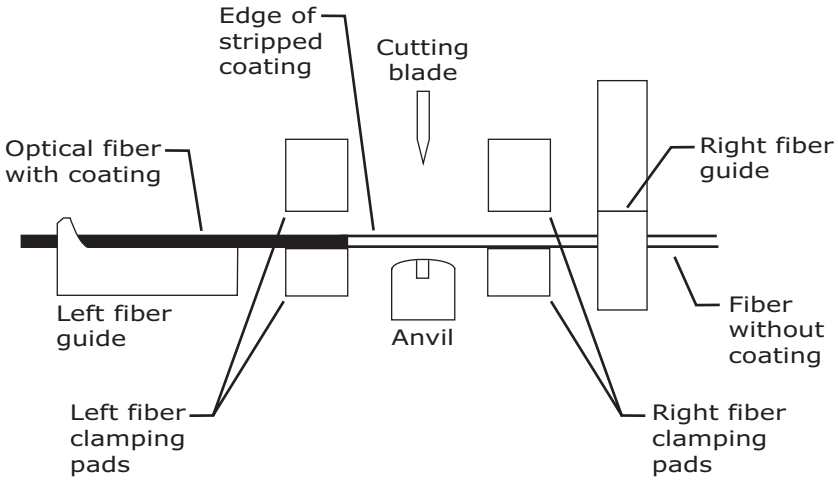


Figure 6.23
Cleaving optical fiber



Optical Fiber Strand Splicing

Splicing, whether fusion or mechanical, is defined as the permanent joining of the individual strands (see Figures 6.24 and 6.25). The splice or splicing equipment manufacturers provide detailed procedures for each type of splice.

Figure 6.24
Fusion splicer

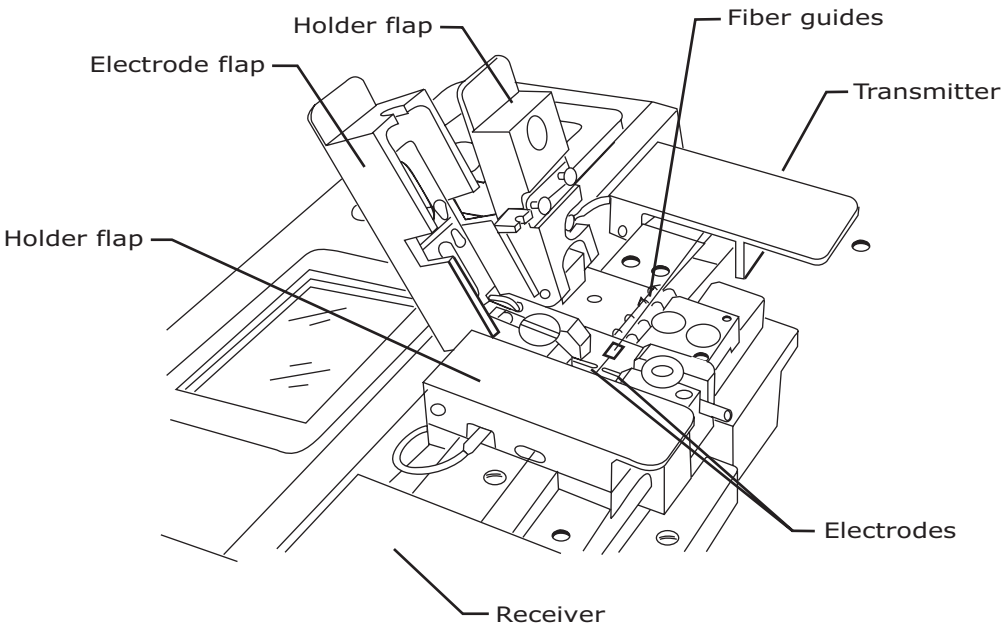
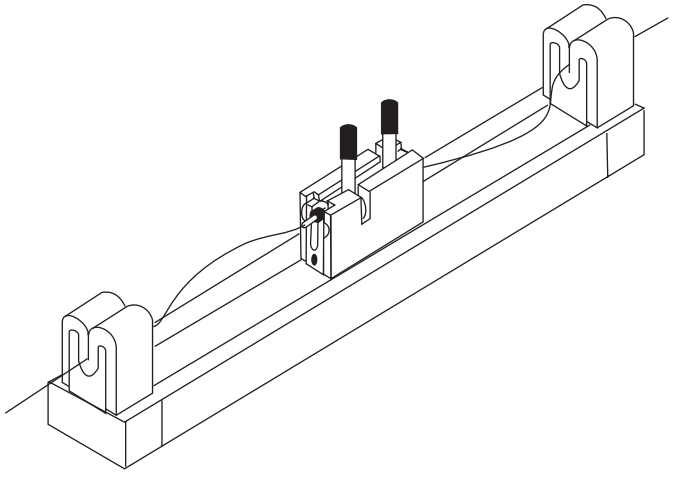


Figure 6.25
Mechanical splice open position



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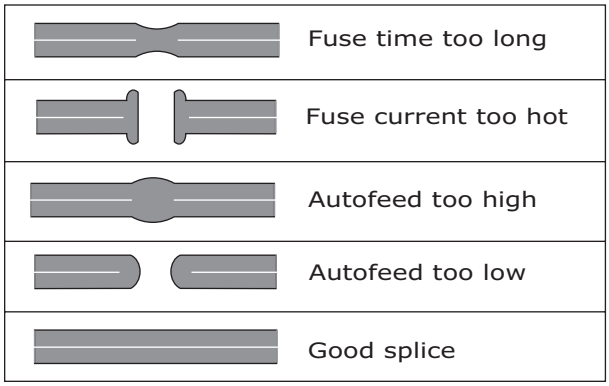
Optical Fiber Strand Splicing, continued

Figure 6.26 and Table 6.5 show examples of unacceptable fusion splices. In common occurrences, it is a protrusion, a break neck-down, or the optical fibers are not joined. Break and redo the splice if this occurs.

If this problem persists, refer to the operating instructions, which indicate whether the autofeed is too high or too low, the fusion time is too long, or the current is too high.

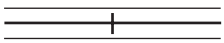
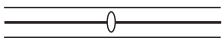
Refer to the manufacturer's instructions on how to change these settings.

Figure 6.26
Common occurrences



Optical Fiber Strand Splicing, continued

Table 6.5
Typical fusion results

Splice Appearance	Cause	Remedy
Constriction 	Dirty electrodes, arc burning irregularly	Clean electrodes.
	Fusion current too high	Reduce in steps of 0.2 to 0.3 mA.
	Feed too small	Increase in steps of 1 µm.
	Prefusion time too long	Standard value 0.2 s, change only in exceptional cases. Reduce in steps of 0.05 s.
	Prefusion current too high	Standard value 14.5 mA, change only in exceptional cases. Reduce in steps of 0.1 mA.
	Separation too great	Reduce separation in steps of 0.5 µm.
Enlargement 	Feed too large	Reduce in steps of 1 µm.
Not fused through 	Fusion current too small	Increase in steps of 0.2 to 0.3 mA.
	Prefusion time too short	Standard value 0.2 s, change only in exceptional cases. Reduce in steps of 0.05 s.
Seeds or inclusions 	Dirty end faces before splicing	Clean end faces before fusion. Possibly increase cleaning current by 0.2 to 0.3 mA or increase cleaning time by 0.1 s.
	Bad cleave	Check cleave before fusion.
	Fusion current too high	Reduce prefusion and main fusion currents.
	Prefusion time or current too low	Increase prefusion time in steps of 0.1 s.
Match-stick heads 	Electrodes dirty, arc burns irregularly	Clean electrodes.
	Fusion current much too high	Reduce in steps of 0.5 to 1.0 mA.
	Prefusion time much too low	Set standard value of 0.2 s.
	Prefusion current much too high	Set standard value of 14.5 mA.
	Feed too small	Increase feed in steps of 1 µm.
	Separation too large	Reduce separations in steps of 1 µm.

mA = Milliampere
µm = Micrometer
s = Second

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Optical Fiber Splice Closing

Place the completed splice into the splice tray, and close the splice case according to the manufacturer's instructions.

Step	Splicing Optical Fiber (Fusion or Mechanical)
1	Determine appropriate splicing method (fusion or mechanical). Determining factors include: • Availability of equipment. • Experience of the ITS installer. • Cost. • Time. • Customer preference.
2	Acquire the proper closure or transition splice box and the appropriate tool kit, if required.
3	Organize closure or splice box hardware. NOTE: In some installations, splice enclosures may already be installed.
4	Perform the splice. NOTE: Always consult the manufacturer's documentation for recommendations on the best splicing methods. • Document the sheath length markings. Some cables are marked with relative markings in meters or feet. This will aid in future troubleshooting. • Determine the method and length of the sheath removal and assembly. • Cleanliness is critical. The type of hardware in which the optical fiber cable and splices are housed will determine the strip length. Consult the manufacturer's instructions for the specific optical fiber hardware.
5	Secure the splice in the protective device. Both fusion and mechanical splices often use splice trays to protect and organize the splices. • Mechanical splicing: – Splicing modules provide fiber protection. – Splice modules snap into organizational trays in multiples of six. • Fusion splicing: – Fusion splices require additional support and protection over the fused area. The method of choice is often 40 mm (1.57 in) or 60 mm (2.36 in) heat shrink tubes. – The heat shrink tubes snap into special organizational trays similar to the mechanical modules.
6	Store the excess optical fiber, and place the splice in the tray.
7	Label the splice according to customer specifications. Record the labeling information for transfer to the permanent record. If cables are rerouted as part of a repair process, document the changes on the as-built drawings.
8	Close the tray, and place it in the splice housing.

Optical Fiber Splice Closing, continued

Step	Splicing Optical Fiber (Fusion or Mechanical)
9	Test the cable according to standards and customer specifications. NOTE: When utilizing an OTDR to test splices, the splices should be tested from each optical fiber end and averaged (bidirectional average). See Optical Fiber Tests section in this chapter. Follow the procedures for testing the cable link on which the splice resides. **WARNING:** Never look into an optical fiber when testing. The light can cause eye damage. NOTE: The maximum splice loss shall not exceed 0.3 dB, regardless of the methodology used (e.g., mechanical or fusion splice). Typically, a fusion splice will be less that 0.1 dB.
10	Perform the following housekeeping as required: • Replace any cables that were moved. • Ensure that all cables are properly routed. • Ensure that all cables maintain at least the minimum bend radius. • Ensure that all cables have the appropriate slack. • Leave a clean space when the installation is complete.

Conclusion

In today's infrastructure design, far less splicing is required than in the past because of advances in cable technology. There are, however, some situations in which cables must be spliced. The ITS installer must be aware of the full range of methods and expected outcomes.

When splicing optical fiber cable is required, the ITS installer should consider investing in the necessary splicing equipment and in-depth training from a manufacturer, distributor, or training organization (e.g., BICSI).

The ITS installer must fully understand the constraints, limitations, and expectations of the job and should be prepared to work with the ITS designer to resolve any differences between the design and the products and processes that are to be used.

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Optical Fiber Cable Terminations

Overview

Optical fiber cables transport light generated by a laser or an LED to carry signals. Laser light can be very intense, and it is invisible to the human eye.

WARNING: Never look into the end of an optical fiber cable. Most optical fiber transmission light is invisible, but it can burn the retina of the eye before the cabling installer realizes that the light is present. Light sources for test equipment may be just as hazardous as the regular system light source.

When performing any installation, splicing, or termination process, there will be optical fiber glass fragments, shards, or short pieces of optical fiber that need to be handled and disposed of properly.

NOTE: See Chapter 2: Safety Procedures for more information on safety issues.

The ITS installer should only use manufacturer-approved tools when performing any installation, jointing, splicing, or termination process. The ITS installers should always have a microscope and cleaning materials with them for inspection and cleaning of the optical fiber, connectors, adapters, and active equipment ports.

Two types of connection processes for optical fiber connectors are:

- Scribe and polish.
- Cleave and secure.

Scribe and polish optical fiber connectors require the technician to insert the prepared fiber into the connector, then scribe and cleave the optical fiber that is protruding from the connector's ferrule. The connector end face is then polished.

Cleave and secure connectors contain a prepolished fiber stub with index-matching gel. The cleaned fiber is cleaved to length and then inserted into the connector and locked in place.

When using prepolished connectors, the cleaved optical fiber should be terminated immediately after cleaving to reduce the possibility of contamination of the freshly cleaved optical fiber. If contamination occurs, there will be a degradation of the signal.

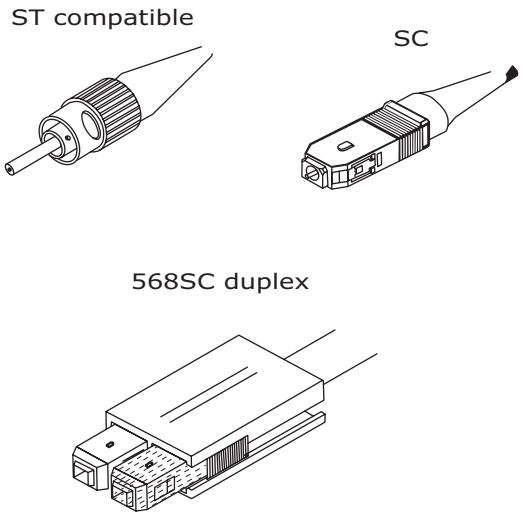
Specific termination kits are required for optical fiber connectors. Selection of the proper kit is dependent on the cabling system, type of cabling, specific connector requested by the customer or selected by the ITS designer or installer, and the hardware to house the terminated optical fibers.

The most common connectors for multimode optical fiber cable are the ST, SC, and LC connector, which are normally field terminated. Other connectors may be specified for installation (e.g., angle polished connector). The angled polish type of connector is normally factory terminated because of the angle complexity of the polished end face. Short lengths of optical fiber cables are connectorized on one end with a connector at the factory, and the opposite end is spliced in the field onto an installed cable. This process is known as a pigtail splice.

Overview, continued

Field termination kits are available. SFF connectors are now commercially available. ITS installers should follow the manufacturer's installation requirements for the specific connectors that are to be installed (see Figure 6.27).

Figure 6.27
Optical fiber connectors



SC = Subscriber connector
ST = Straight tip

BICSI recommends that Table 6.6 be used for developing an administration solution.

Table 6.6
Connector/adaptor color code

Fiber Type	Connector Color	Adapter Color	Cable Color
62.5/125 µm	Beige	Beige	Per manufacturer
50/125 µm	Black or beige	Black	Per manufacturer
50/125 µm laser enhanced	Aqua or beige	Aqua	Per manufacturer
Singlemode	Blue	Blue	Per manufacturer
Singlemode APC	Green	Green	Per manufacturer

APC = Angle polished connector
µm = Micrometer

When two SC connectors are used to configure the 568SC duplex connector using 50/125 µm or 62.5/125 µm multimode optical fiber, the adapter is beige in color. When the 568SC connector adapter is used for singlemode optical fibers, the adapter is blue.

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Overview, continued

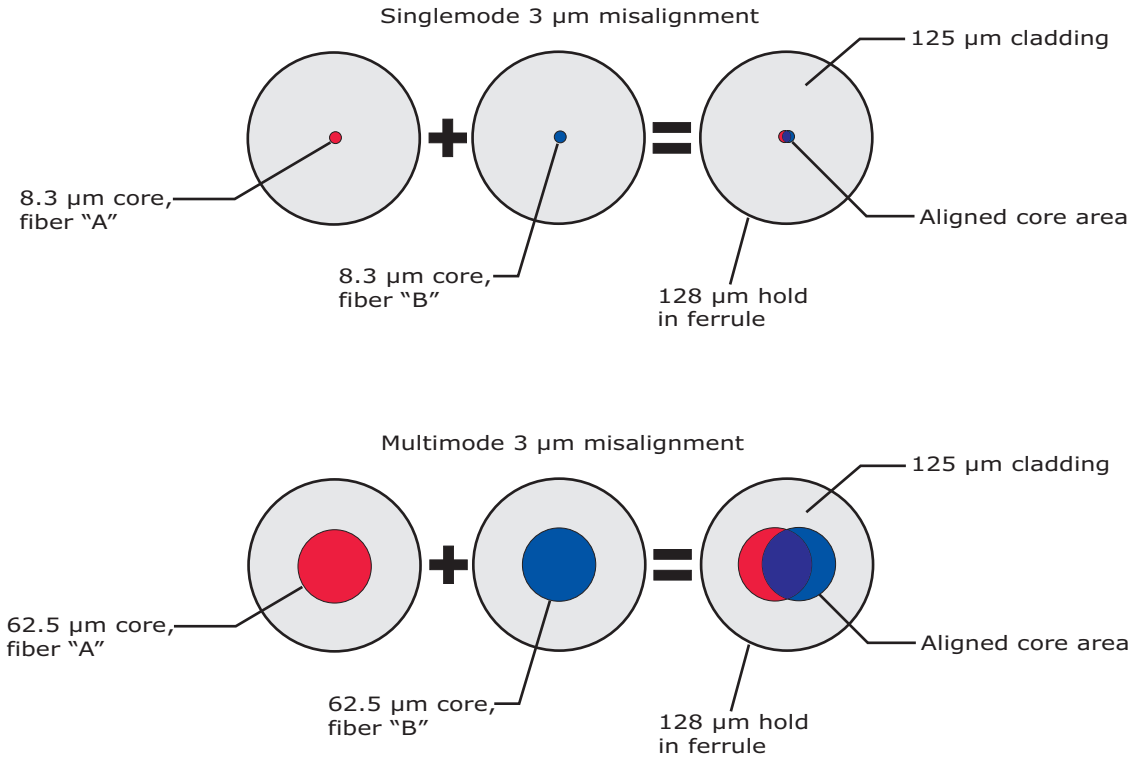
Termination procedures for optical fiber connectors in the field vary by manufacturer. Listed below are the various methods:

- Heat-cured epoxy termination—This method requires placing assembled connectors into a curing oven, which is a time-consuming process. Typical curing ovens hold four to six connectors at a time. Larger capacity ovens are available for faster terminations when terminating large quantities of connectors. The curing cycle for heat-cured connectors can be as long as 20 minutes.
- Heat-activated adhesive—These connectors use an adhesive that softens when placed in an oven. Adhesives that soften when exposed to heat require an oven and a cooling rack. These adhesives offer the opportunity to reheat a defective termination for a second chance.
- UV light-cured termination—These connectors have clear translucent components that allow the UV light to penetrate through the connector body and ferrule to ensure that the epoxy cures properly. UV-cured terminations are cured under a UV light; the process takes less than a minute.
- Crimp termination—Enhancement of optical connectors has resulted in the development of crimp-style connectors that require no curing process. The fiber is secured within the connector by mechanical pressure within the connector body. The fiber within the ferrule is free floating.
- Prepolished connectors—These connectors have an internal vise-like system that holds the optical fiber in place when activated. A small piece of optical fiber is already installed in the connector's ferrule, which has been polished at the factory. The ITS installer simply prepares the optical fiber, cleaves it to length, and inserts it into the rear of the connector until it is butted up against the factory-installed optical fiber. The connector has index-matching gel to enhance light transfer.
- Anaerobic termination—These connectors typically use a two-part chemical application. The first is the adhesive, and the second part is the primer or catalyst. When the catalyst makes contact with the adhesive, a hardening of the adhesive occurs. Typically, the hardening takes 10 to 20 seconds.

Overview, continued

Precise alignment of the optical fiber core within the optical fiber adapter must be maintained to ensure that the maximum transfer of light pulse energy is obtained. Alignment is much more critical in singlemode application than in multimode application. If a singlemode-mated pair was misaligned by 3 µm, there would be a loss of almost 1/3 the light. The same 3 µm misalignment for multimode would only result in 1/20 of the light being lost (see Figure 6.28).

Figure 6.28
Optical fiber terminations



µm = Micrometer

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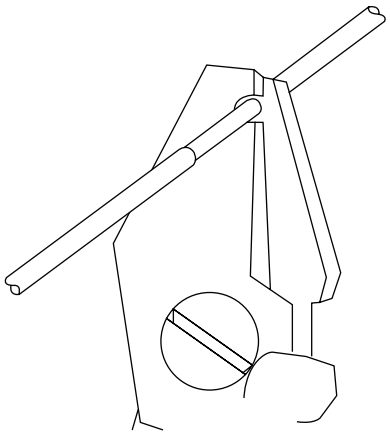
Overview, continued

To reinforce and make the strand easier to handle, an acrylate coating is applied to the outside of the cladding. This increases the original 125 µm diameter of the cladding up to 250 µm. When the optical fiber strands are being manufactured, the cladding is 125 µm. A primary coating of acrylate is applied to the cladding, building it up to 245 µm. When the fiber is going to be used in a loose tube cable, it will require an additional layer (secondary coating) of colored acrylate that will increase the strand's diameter from 245 µm up to 250 µm.

The fiber's unique outer coloring will allow it to be distinguished from other fibers in the tube. If the fiber is going to be used in tight-buffered cable, it will also get a secondary coating, building it up to 250 µm, but it will be neutral in color because it will be receiving a third layer (tight buffering) that will have a unique color and increase its diameter to 900 µm.

This coating must be removed to specific dimensions along the optical fiber prior to connectorization. Removal of the coating is accomplished by use of an appropriate stripper and then followed by a cleaning process (see Figure 6.29).

Figure 6.29
Optical fiber stripping tool



Depending upon the type of connectorization specified or required, optical fiber termination may require additional work space for terminating equipment and materials.

The terminating area must be evaluated for the necessary power needs; the availability of a table, cart, or workbench; and room to access the cable ends. A dust-free environment is critical to ensure that the terminated optical fiber ends will be kept clean.

Steps—Optical Fiber Preparation

Step	Task
1	Inspect the cable to ensure that there is optical fiber and aramid yarn visible at the end out of the jacket. If none is visible, cut back jacket as necessary (only applies to patch cordage, zip cords, and breakout cables).
2	Cut the cable of optical fiber to the required length, taking into account any optical fiber spools or optical fiber management requirements.
3	Using the measuring guide, mark the cable sheath per the manufacturer's instructions.
4	Select the proper size boot for the buffered optical fiber or jacketed optical fiber. This provides support for the optical fiber at the back of the connector, which is important.
5	Slide the boot onto the cable, small end first.
6	Use the proper sheath removal tool to remove the marked length of jacket.
7	Using scissors/snips, trim aramid yarn per the manufacturer's instructions.
8	Using the buffer removal tool, remove the buffer per the manufacturer's instructions.
9	Clean optical fiber two times with lint-free cloth moistened in reagent grade alcohol or manufacturer-recommended cleaning solution.

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Steps—Field Polished Connector Installation

Step	Task
1	Remove and discard rear dust cap on connector (if present).
2	Remove and save the front cap. It will protect the finished connector.
3	Prepare the connector for installation per the manufacturer's instructions.
4	Slowly insert the prepared optical fiber strand into the rear of the connector.
5	Allow the strand of glass to enter the connector, followed by the buffer, until it seats inside of the connector and the glass protrudes from the tip of the connector ferrule per the manufacturer's instructions. The back of the connector assembly should be 3 mm (0.12 in) or less from the outer jacket on the 3 mm (0.12 in) cable.
6	Allow connector adhesive to set or secure mechanical connection per the manufacturer's instructions.
7	When used, install and secure the crimp collar using the recommended crimp tool per the manufacturer's instructions onto the aramid yarns per the manufacturer's instructions. This may be a double-crimp process.
8	Move the connector boot up the optical fiber strand, and seat it fully against the connector housing. NOTE: Push the boot straight. Do not twist or bend as this may damage the optical fiber.

Steps—Scribing and Polishing the Connector

Step	Task
1	Using a scribe, score the strand of glass where it exits the end of the ferrule.
2	Grasp the scored optical fiber with your finger tips, and pull it gently straight in-line with the ferrule, away from the optical fiber strand. Use tweezers to remove short optical fiber lengths.
3	Discard the excess optical fiber properly in an appropriate container designed for optical fiber shards.
4	Air polish the end of the connector by holding the end of it against the correct grade of lapping film and making circles against the paper. Do this while holding the paper in the air with nothing behind it as it pushes against the optical fiber. Stop when the optical fiber quits making scratching noises against the paper and the sharp scratches widen. Do not over air-polish the connector. Some of the adhesive bead needs to be left on the tip of the ferrule to ensure a quality polish in Step 6.
5	Test the connector in the polishing puck for freedom of movement inside of the polishing puck. Clean the polishing puck or remove adhesive from the sides of the ferrule as needed.
6	Using the correct grade of lapping film, make two or three figure eights, approximately 80 mm (3.15 in) high, to ensure that the optical fiber stub is flush with the adhesive bead.
7	Polish the connector on the lapping film, making figure eights, or until the adhesive bead is removed and the end of the connector is smooth.
8	Wipe the end of the connector with a lint-free wipe that contains reagent-grade alcohol or manufacturer-recommended cleaning solution.
9	Quickly wipe the end of the connector three times with a dry, lint-free wipe before the cleaning solution evaporates, leaving a residue on the connector.
10	Visually inspect the connector with a microscope or a video probe for chips, scratches, and damage to the cladding/core. It is desirable to check the end face geometry with a suitable analyzer (e.g., interferometer).
11	For a multistep polish, insert the cleaned connector into the second puck, which is positioned on the lapping film. If the connector is not cleaned when moving from the first coarse-grade film to the second, finer-grade film, cross contamination of the lapping film will occur. A poor polish and possible damage to the connector end face may result.
12	Make figure-eight patterns per manufacturer's instructions on the finer lapping film.
13	Clean the end of the connector with a lint-free wipe that contains reagent-grade alcohol or manufacturer-recommended cleaning solutions.

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Steps—Scribing and Polishing the Connector, continued

Step	Task
14	Wipe the end of the connector three times with a dry, lint-free wipe.
15	Visually inspect the connector. IMPORTANT: Inspect the end face of the connector to see if there are any scratches or chips, which would detract from the overall finish and performance. Do not get oil on the end of the connector.
16	Insert the connector into the end of the microscope, and observe the connector.
17	If the observation indicates acceptable results, install the dust cap, and lay it aside.
18	If the results are not satisfactory, it may be necessary to repeat Steps 11 through 16. If the connector was underpolished, additional fine polishing will help. Never go back to the course lapping film as this will undercut the fiber inside the ferrule, and it will not be possible to polish out the defects. If it is fractured or overpolished, the connector will need to be replaced, requiring the installer to begin at Step 1.

Inspection and Cleaning Optical Fiber Connectors

Overview

Achieving an efficient connection between optical fiber connectors requires three basic principles:

- Core alignment
- Physical contact
- Pristine connector interface

To ensure that these requirements are met, it is critical that optical fiber connectors are properly inspected and cleaned before they are mated. This section provides some basic concepts on inspecting and cleaning optical fiber connectors for efficient installation and maintenance of an optical fiber network.

Visual inspection will identify a variety of defect types (e.g., contamination, scratches, pits, chips) on the optical fiber end face, which can affect the performance of an optical fiber interface. Although each of these defect types can have an effect on the performance of the interface, contamination is the number one cause for troubleshooting in optical networks.

Contamination compromises the quality of connector end faces and can also prevent physical contact between connectors. In a multimode application, this can severely affect connector performance as a single 5 μm particle of contamination on the optical fiber core can contribute to significant attenuation.

In a singlemode application, a 1 μm particle can have the same effect on attenuation. In addition to attenuation, contamination will also increase reflectance, potentially causing return loss and may damage system electronics.

Some forms of contamination (e.g., particles of dirt, other debris) on the connector end face can become embedded into the glass when the end faces are mated. These particles are either embedded permanently, or they leave behind residual pits. These are permanent forms of damage that can only be alleviated by repolishing or replacing connectors. Many of these problems can be alleviated by utilizing proper tools and practices to inspect and clean optical fibers.

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Inspection and Cleaning Tools

Inspection Overview

Inspecting optical fiber connectors requires a microscope designed specifically for viewing optical fiber connectors. These microscopes range in power from 100× to 800× magnification and allow users to view the end face of an optical fiber connector to detect whether a defect exists and where it is located relative to the fiber core (see Figure 6.30).

A typical microscope has a field of view (FOV) of at least 250 µm. This allows the entire fiber (125 µm) to be viewed as well as a portion of the ferrule surrounding the fiber.

Figure 6.30
Fiber connector end face

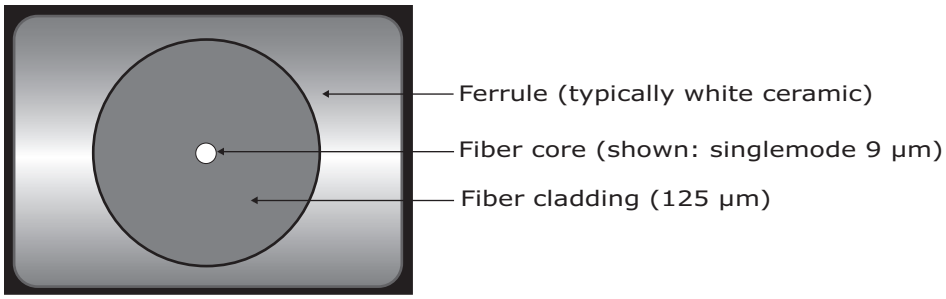
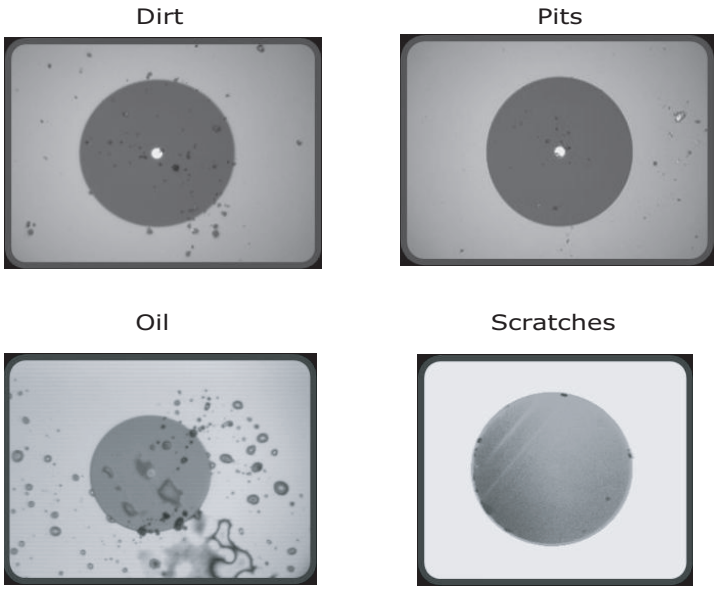


Figure 6.31 shows examples of what various defects look like on the end face of an optical fiber connector when viewed through an optical fiber microscope.

Figure 6.31
Defects on end face



Microscopes

Two types of optical fiber microscopes used in field applications are:

- Direct-view microscopes.
- Video microscopes.

Direct-view microscopes are typically used to inspect male interfaces (e.g., patch cords, connectors) that have been recently terminated and polished in the field.

To inspect an optical fiber end face, the ferrule of an optical fiber connector is inserted into an adapter at one end of the microscope while the user views the connector through an eyepiece at the other end. The connector end face is then illuminated to enable viewing.

There are two primary methods by which the end face is illuminated:

- Coaxial—This lighting method is typically used for identifying scratches and fine details in the optical fiber surface.
- Oblique—This lighting method provides a clear view of core condition and cleanliness.

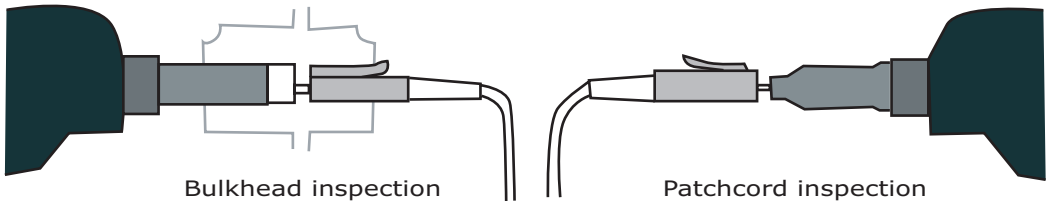
A field technician should be aware of these lighting methods as each has advantages for different applications in the field.

IMPORTANT: When using a direct-view microscope, be sure that it is equipped with a laser safety eye filter, which prevents damage to the eye in case the optical fiber being viewed is actively transmitting a laser signal.

Video microscopes utilize a display device by which the fiber end face can be viewed on a screen as opposed to looking through an eyepiece. Most video microscopes utilize a handheld probe, which is capable of inspecting both male and female connector interfaces (see Figure 6.32):

- To view the male interface, insert the ferrule of an optical fiber connector into an adapter tip on the probe.
- To view the female interface, insert the probe tip into an optical adapter.

Figure 6.32
Handheld probes



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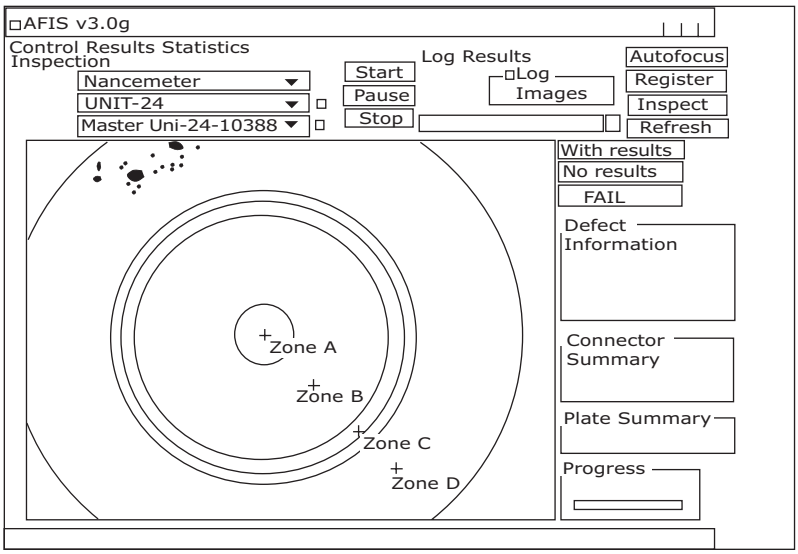
Microscopes, continued

Although most handheld probes connect with a dedicated display (see Figure 6.33), some probes also can be connected to other devices to display the image (e.g., computer, OTDR).

Software programs also can be used in conjunction with a computer or OTDR that enable several other features, including:

- Image capturing.
- Automated pass/fail analysis.
- Documentation reports.
- Data archiving.

Figure 6.33
Probe and display



Cleaning Overview

A variety of different products and tools can be used for cleaning optical fiber connector end faces. As with inspection, selecting the proper tools depends on the application. By following proper methods for inspection and cleaning, a technician can maintain connector end faces with a few different products and tools.

Since both sides of a mated pair must be clean before connecting, there are different tools available for cleaning each end.

Patch cord (male interface) cleaning tools include:

- Wipes, cards, and solvents.
- Cassette cleaners.
- Automated cleaning systems.

Optical adapter (female interface) cleaning tools include:

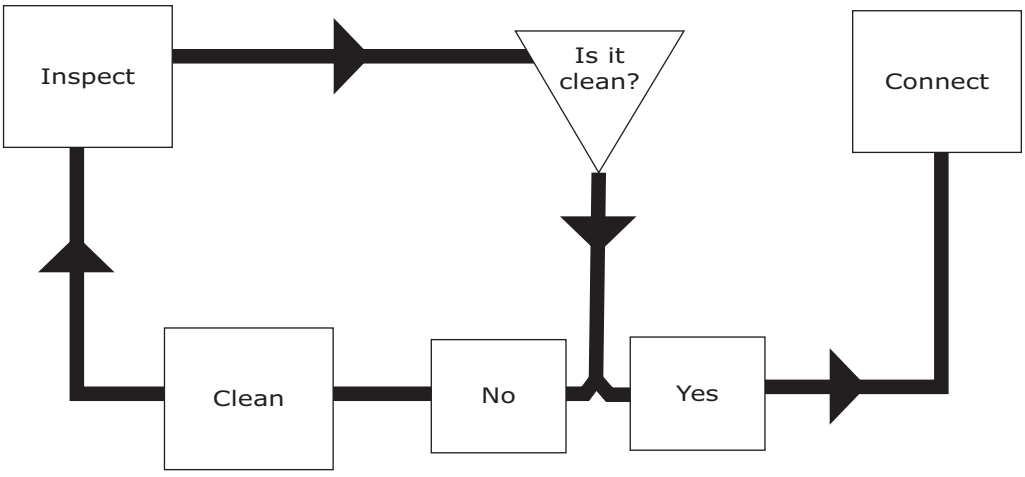
- Swabs:
  - Commonly used in low-volume applications.
  - Risk scratching fiber end faces and leaving debris.
- Moving media devices.
- Automated cleaning systems.

Inspecting and Cleaning Practices

Many of the problems caused by contamination can be mitigated by following proper inspecting and cleaning practices (see Figure 6.34).

Since contamination is located nearly everywhere (e.g., airborne, hands, optical adapters, dust caps), every optical fiber connector should be proactively inspected before it is connected. If defects on the end face are found, the optical fiber connector must be cleaned or replaced then reinspected to confirm that the end face is acceptable. Once this is confirmed, the optical fiber connectors can be mated.

Figure 6.34
Example of inspecting and cleaning practices



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Inspecting and Cleaning Practices, continued

The following should be checked:

- Optical fiber connectors—To ensure the best efficiency of an optical fiber network, each optical fiber connector should be inspected prior to mating to visually ensure that it meets the acceptable criteria before connection.
- Test cords—Since test cords are often mated frequently, they are also highly likely to become contaminated. Inspecting test cords before mating should prevent cross contamination of debris between the test cords and the system connectors. If not carefully inspected and cleaned as required, the test cords may cross contaminate and damage (e.g., embed debris) multiple system connectors, requiring rework or replacement.
- Test equipment—Similar to test cords, the ports on test equipment can also become easily contaminated. Inspecting the ports on test equipment before mating for a test ensures that contamination will not be passed onto the test cord connectors.

Look for dirt, scratches, pits, and chips.

In common evaluation, criteria zones are often used to prioritize evaluation criteria. Examples of common zones are:

- Zone A: Core Zone.
- Zone B: Cladding Zone.
- Zone C: Ferrule Zone.

Different failure criteria for defects and contamination are specified for each zone:

- Quantity and size
- Location relative to core

Inspection of fiber end faces is critical at every stage of handling optical fiber and includes:

- Installation:
  - Post polish inspection
  - Typically male interfaces
  - May require documentation
  - Requires video microscope and software
- Testing:
  - Both sides (patch cord and optical adapter)
  - Documentation and reporting
- Troubleshooting and maintenance:
  - Both sides (patch cord and optical adapter)
  - Documentation and reporting

Inspecting and Cleaning Practices, continued

Inspecting both sides (male and female) of a mated interconnect is the only way to ensure that the mated connection will be free of contamination. Inspecting only the patch cord is a common mistake during inspection. This oversight neglects one-half of the interconnect. Although the connector behind an optical adapter is one-half of an interconnection, it is the source of more than half of the contamination problems experienced in the field.

Inspecting a patch cord is an important part of optical fiber inspection. Although a standard optical fiber microscope is sufficient for patch cord inspection, it is not able to inspect connectors located behind the optical adapter.

Cleaning Materials and Methods

If inspection reveals contamination, the optical fiber should be cleaned. Specific tools are available for different applications.

The following sections describe cleaning materials and methods currently available to clean optical fiber connectors. A list of advantages and disadvantages is included.

Dry Wipes

The use of fabric or paper wipes to provide combined mechanical action and absorbency may be used to remove contamination. The wipe should be used on a resilient surface. The wiping material should be lint free and absorbent.

An advantage is that it is an easy method to clean exposed ferrules or terminal. Some disadvantages are:

- Damage to the end face may be caused if a wipe lying on a hard surface is used (e.g., wipe must be either held in hand or used on a soft surface or resilient pad).
- Only lint-free wipes should be used.
- A static charge on the end of the ferrule may be created.
- All cleaning media must be protected from contamination until just prior to use.

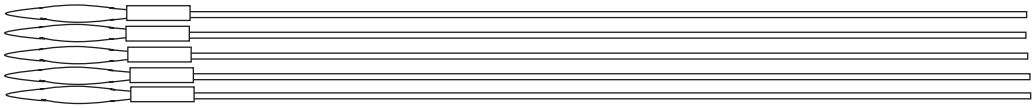
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Cleaning Materials and Methods, continued

Dry Swabs

Purpose-built swabs designed to clean the connector end faces within an alignment sleeve may be used (see Figure 6.35).

Figure 6.35
Dry swabs



A typical optical fiber connector cleaning swab advantage is that the swab facilitates cleaning of the end face within the alignment sleeve of the adapter, connector, or optical device.

Some disadvantages of the cleaning swab include:

- Mechanical action alone may not remove all contamination because of the physical constraints of the alignment sleeve limiting wiping ability.
- Different sizes of swabs are required to clean different styles of connectors.
- Caution must be taken when cleaning transceiver lenses because of possible damage.

Solvents with Wipes or Swabs

The use of a solvent with a wipe or swab provides a combination of chemical and mechanical action to clean optical fiber connector end faces.

Some advantages of typical optical fiber cleaning solvents include:

- Provides more aggressive cleaning of contamination.
- Can be very effective against oils and dried-on contaminations.
- Can release ionic bonds (static charge) if a conductive solvent.

Some disadvantages include:

- Some cleaning solvents can leave a residue.
- Special very fast-drying (highly volatile) solvents are recommended for cleaning within alignment sleeves.
- Binders and glues used in the manufacture of some wipes and swabs may be released by the cleaning fluid and deposited on the connector end face.
- Solvent compatibility should be tested, particularly when cleaning coated lenses or fibers.
- Some solvents are flammable liquids requiring Department of Transportation (DoT) markings. These solvents are more costly to ship and may require special storage.
- Aerosol containers require special paperwork to ship.
- Open containers are easily contaminated.

Cleaning Materials and Methods, continued

Cleaning Machines

A cleaning machine is a device that provides automated or semiautomated mechanical or chemical action to clean the connector end face.

These devices are new in optical fiber. Any machine that is to be considered should be tested to verify its effectiveness and nondamaging functionality.

One advantage is that it may provide improved efficiency, consistency, and cost effectiveness.

One disadvantage is it typically has a higher initial cost.

Canned Air

Canned air can be used to remove large particulate or speed the drying of solvents; however, it is not recommended for cleaning connector end face exposed or within alignment sleeves.

It is ineffective against oils, including fiber prints, and does not remove grime and hazing carried by condensation. It is useful in removing dust and debris from the work area prior to connecting optical fiber cables.

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Cleaning Materials and Methods, continued

Cleaning Materials

Table 6.7 provides comparisons of materials used in swabs.

Table 6.7
Swabs

Property	Molded Nibs	Fabric Covered Stick	Foam Stick
Tip construction	Molded, seamless, sintered polymer	Woven, microdenier fabric	Open-cell, expanded foam
Material purity	Cleaning tip contains no blowing agents, binders, or adhesives. No out-gassing.	Cleaning tip consists of layered woven, fiber-based fabric with adhesive binders.	Cleaning tip consists of expanded foam made with blowing agents.
Tip bonding method	Mechanical crimp	Adhesive/glue	Thermal/heat set
Solvent resistance	Excellent, no physical effect	Good, possible adhesive diffusion/ decomposition	Possible out-gassing and foam-cell decomposition
Absorbency	High	High	High
Abrasiveness	Low	Low	Low
Dimensional consistency	Excellent	Poor	Moderate
Cleaning method	Linear fibers of sintered polymer wick cleaning and contamination away from the surface	Lint-free cloth absorbs debris	Open-cell foam collects debris solvent

Cleaning Materials and Methods, continued

Solvents

If solvents are to be used, they must be compatible with the materials to be cleaned. Manufacturer's handling, safety, and storage instructions must be followed (see Table 6.8).

Table 6.8
Solvents

Property	Hydrofluorocarbon/ Hydrofluoroether (HFC/HFE)	Alcohol or Alcohol Blend	Hydrochloro-fluorocarbon (HCFC)	Hydrochlorofluorocarbon/ Hydrofluoroether (HCFC/HFE) and Alcohol
Flammability	None	Highly	None	None
Volatile organic chemical (VOC) content	None	100%	100% (liquid packaging)	Check with manufacturer
Ozone safe	Yes	Yes	No, depleting	Yes
Ground shipping	Nonhazardous, nonregulated	Regulated, flammable	Nonhazardous, nonregulated	Check with manufacturer
Air shipping	Nonhazardous, nonregulated	Regulated, flammable	Nonhazardous, nonregulated	Check with manufacturer
Leaves residue	No	Water marks	No	No
Ability to clean oil	Poor	Fair	Excellent	Excellent
Ability to dissolve water-soluble oils	Poor	Fair	Fair	Excellent
Ability to remove ionic bond (static cling)	Poor	Excellent	Poor	Excellent
Compatibility with glass/ ceramic	Excellent	Excellent	Excellent	Excellent

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Cleaning Materials and Methods, continued

Table 6.8, continued
Solvents

Property	Hydrofluorocarbon/ Hydrofluoroether (HFC/HFE)	Alcohol or Alcohol Blend	Hydrochloro-fluorocarbon (HCFC)	Hydrochlorofluorocarbon/ Hydrofluoroether (HCFC/HFE) and Alcohol
Hygroscopic	No (will not mix with water)	Infinitely; will absorb large amounts of water from the air along with contaminants/ minerals dissolved in the water, which tend to leave residues when dry	No (will not mix with water)	Mildly (will absorb small amounts of water to speed drying and dissolve light water-based oils)
Drying rate	10–25% faster than isopropyl alcohol (IPA)	Fast compared with water	10–25% faster than IPA	10–25% faster than IPA
Specific gravity	High (results in a heavy liquid that floats particles and contaminants from the fiber and ferrule surface)	Relatively low (heavy particles sink)	High (results in heavy liquid that floats particles and contaminants from the fiber and ferrule surface)	High (results in heavy liquid that floats particles and contaminants from the fiber and ferrule surface)
Purity	Very high (dries without residue)	Varies by grade used (up to 30% water by weight) and storage conditions. Unsealed containers often result in contaminated fluid, purity decreases immediately when exposed to air due to highly hygroscopic property.	Very high (dries without residue)	Very high (dries without residue)
Fluid shelf life	Unlimited (fluid is stable)	12 months	Unlimited (fluid is stable)	Unlimited (fluid is stable)
Plastics compatibility	Excellent	Excellent	Good	Excellent
Metals compatibility	Excellent	Excellent	Excellent	Excellent

Cleaning Materials and Methods, continued

Some lessons learned include the following:

- IPA is a hygroscopic substance. That is, IPA will absorb moisture from its surroundings, including the air. Therefore, a container of IPA left open to the air can easily become diluted and contaminated. Contaminated IPA can leave a residue on the end face of the connector, contributing to the reduced performance of the optical fiber link.
- Never touch the cleaning surface of a wipe or swab. Skin oils can be transferred to the connector end face, contributing to the reduced performance of an optical fiber link.
- Repackaging wipes or swabs into your own containers may contaminate the cleaning products.
- Cleaning wipes or swabs removed from packaging and left out before use can pick up contaminates from the air or handling.
- Never assume that a new optical fiber product is clean. These products may have been contaminated in some way before receiving them.
- If in doubt of the cleanliness or effectiveness of optical fiber cleaning products, try the "do no harm" test:
  - Take a clean connector (contamination free as viewed with an optical fiber microscope).
  - Clean it with cleaning materials.
  - Reinspect the end face with a microscope to see if the process added any contamination to the connector end face.
  - Repeat the process several times.
  - It is not unusual for cleaning products to occasionally leave some contamination on the end face.
  - Remember, you are looking at microsize particles, which can be drifting in the air in your surroundings.

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Cleaning Materials and Methods, continued

- Use of canned air to directly clean the end face of an optical fiber connector or port is not recommended. First, typically canned air can dispel some oils, which are outgassed by the main seal in the valve of the can. This is particularly true during the first few seconds of spraying after the can has not been used. Furthermore, the high-velocity air could force some hard contaminates onto the surface, potentially damaging it.
- Most canned air consists of a propellant that cools as it leaves the confines of the container. Therefore, it can chill the optical component, causing moisture in the air to condense on the surface and likely depositing contaminants.
- Canned air may be used to clean any dust or debris from an area where cabling installers are working with optical fiber connections. Be sure to let the dust settle before opening ports or inserting connectors.
- Wiping connector end faces on clothing is not cleaning the end face. Detergents contain surfactants and brighteners, which can remain on the fabric and be deposited on the end face. Lint is also left on fabric when removed from the dryer. Therefore, even clean clothes are not clean enough for this task.
- All cleaning materials must be packaged in a way that does not adversely affect the cleaning properties of the cleaning material:
  - Lint-free wipes must be packaged so that the wipe does not become contaminated in transport, storage, or use.
  - Liquid cleaners must be packaged so that they cannot be contaminated.
- Hermetically sealed containers that dispense solvents only when being used are best.
- Propellants in aerosols should not contribute to the contamination problem.

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Optical Fiber Testing

Overview

Accurate characterization and testing of installed premises optical fiber cabling are crucial to ensuring overall network integrity and performance. An optical fiber cabling channel may consist of a single passive optical fiber link segment with a cord at each end or multiple segments (e.g., spliced, cross-connected, interconnected) with a cord on each end. When referring to a single optical strand with terminations on each end (e.g., horizontal cable, patch cord), this is a passive optical fiber link segment.

The optical fiber type, link length, the number and quality of terminations and splices, cable stresses, and operational wavelength can all affect attenuation measurements. For example, severe cable bends, poorly installed connectors, or even the presence of dirt on a connector's end face can negatively influence link attenuation.

If good components are used, terminated, and inspected with a tight cleaning regime, the testing will serve to confirm that all is well for the user. If there are any low results or failures, the most likely cause will be a problem with the inspection and cleaning regime used. It is rare that a fault is found with the components used.

The attenuation measurement result should always be lower than link loss budget, which is based on the acceptable worst case for the number of terminations, splices, wavelength, and cable length. Documenting the test results provides information that demonstrates the acceptability of the cabling system or its ability to support specific networking technologies.

Before the installation commences, the ITS installer and the client should determine what is to be tested and what will constitute a pass and a fail scenario from the results obtained.

Optical Fiber Tests

The following types of tests are run when validating optical fiber:

- Continuity testing:
  - Visual light source check —Typically provides a safe red tracer light (optical fiber flashlight) over the optical fiber to verify continuity between each end of an optical fiber and verifies that light can pass over the optical fiber. This method of inspection is not typically conducted if OLTS measurements are being made. When OLTS measurements are made, transmit/receive polarity is verified. When OLTS measurements are not part of polarity testing, these visual light source checks may be used to verify polarity in a channel. This tool is invaluable when troubleshooting. One type of visual light source is a VFL.
  - VFL—Provides a powerful LED or laser light source that is not safe to view. VFLs will cause the end of the fiber to glow red or green, depending on the wavelength of the VFLs. It is not necessary to look into the fiber end as it is when performing the visual light source check above. This method of inspection is not typically conducted if OLTS measurements are being made. When OLTS measurements are made, transmit/receive polarity is verified.

NOTE: The VFL may utilize a laser light and therefore is not safe to look into.

Optical Fiber Tests, continued

- Microscopes:
  - Direct view—Typically, 100× to 800× magnification, a microscope is used to inspect the end face of connectors for contamination, chips, and scratches. It must be fitted with a receptor for the connector type being inspected. A manual for general field use and electronic versions for both field and workshop that can capture the image and record the end face are available.
  - Video—Utilize a display device by which the fiber end face can be viewed on a screen as opposed to looking through an eyepiece. Most video microscopes utilize a handheld probe, which is capable of inspecting both male and female connector interfaces.
- OLTS—This test set measures the amount of signal that is lost or absorbed over the cable length. In addition to the optical fiber itself, bad splices, dirty terminations, or flaws in the cable can cause signal loss. Some OLTSs can provide optical fiber length measure ments. Basic units can test a single optical fiber in one direction and at one wavelength. More sophisticated units are capable of testing two optical fibers simultaneously. Some also provide dual wavelength testing prompts to swap the transmit and receive connectors during a bidirectional test.

NOTE: Instructions in this chapter will focus on the basic OLTS.

- OTDR—Identifies the optical fiber cable length between any two points along the optical fiber length, attenuation rate, insertion loss of connectors, splices, and presence of any severe bends (macrobends) or breaks. An OTDR will provide installed component loss figures from analysis of the output graphs. The OTDR can also be used to view the overall loss of a link or channel. An OTDR injects pulses of light into the optical fiber and evaluates the reflected signals to the OTDR.

Interferometer—This tool is used to inspect the end face of the optical fiber connector for radius of curvature, offset of polish, and optical fiber height. Interferometers can produce images and data to submicron accuracy using the principle of wave interference.

The primary field tests performed include testing of length, optical attenuation, and polarity in optical fiber cabling, as a minimum. Additional testing that may be considered includes an OTDR test.

Optical fiber testing may be conducted for the following reasons:

- Preinstallation testing
- Acceptance testing
- Configuration testing
- Preventive maintenance testing
- Troubleshooting

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Preinstallation Testing

Preinstallation testing may be performed on a reel of optical fiber cable after it is received from a supplier and before it is installed on the job.

The benefits of preinstallation testing are verification of the following:

- Cable is the component required.
- Cable has not been damaged during shipment.
- Cable contains no factory defects.
- Attenuation of the optical fiber matches the factory test report, which should be shipped with each reel of cable (if shipped by the manufacturer).

If a defect is determined during preinstallation testing, contact the shipper, supplier, or manufacturer for resolution.

Preinstallation should start with a check that the cable is as ordered and the correct fiber type. Manufacturer specification sheets should always be on-site with the installation team. Preinstallation testing can be performed with a visual light source (e.g., optical fiber flashlight [depending on the length of optical fiber], VFL, OLTS, OTDR). An optical fiber cable on a spool or reel should be ordered prewound so that both ends of the cable are accessible for testing.

Using a visible light source will verify end-to-end continuity. One such visible light source is a VFL. The VFL is a visible red laser source (630 to 665 nm). VFL can often identify breaks or bends in cables (e.g., if the jacket is transparent to the laser). When using a visual light source for preinstallation testing, it will not provide attenuation results as would an OLTS or OTDR.

NOTE: If continuity testing alone is all that is required, a VFL may be less costly than using an OLTS or OTDR.

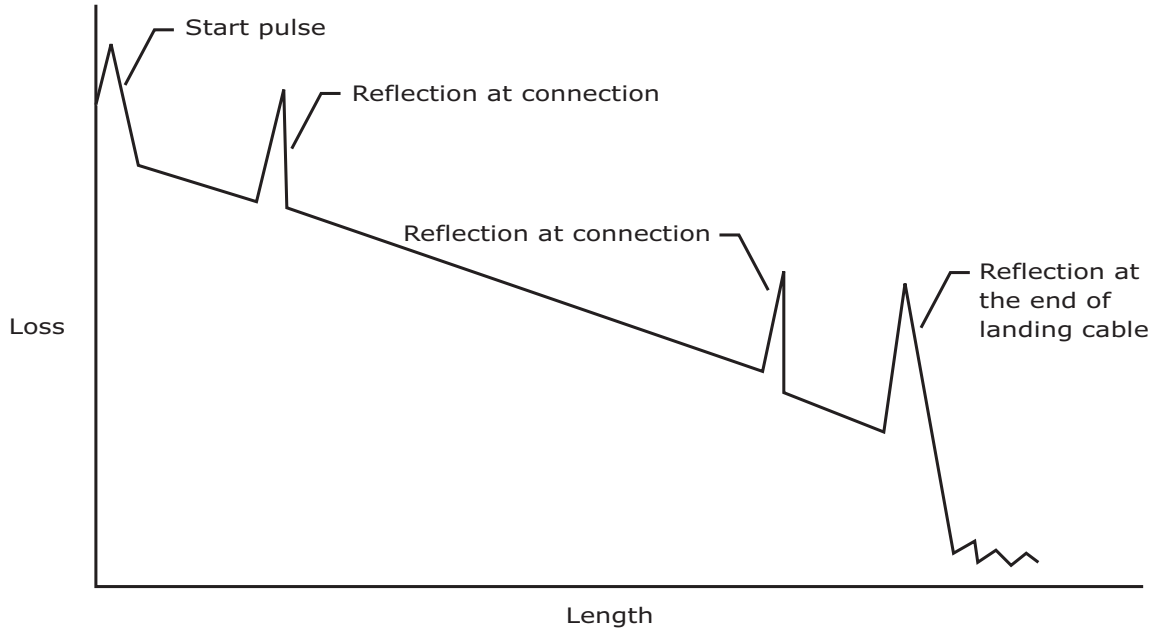
Preinstallation testing utilizing an OLTS requires the testers to be connected to the fibers under test. This can be accomplished by using temporary bare fiber adapters on the unterminated fibers. Another method is to use pigtail slicing where one end of the cable is preconnectorized, and the other end is temporarily spliced onto the fiber with reusable mechanical splices or silicone laboratory splices. The OLTS measures the attenuation (end-to-end signal loss) of the optical fiber. The OLTS cannot determine the nature or location of the defect within the cable. If the value is not within the expected range, it may simply be the result of poor temporary connectorization. All strands with poor test results should be tested with an OTDR to ensure that the fiber is not damaged.

Preinstallation Testing, continued

Preinstallation testing utilizing an OTDR typically requires access to both ends of the cable to accurately measure the cable's attenuation and length. One end of the cable will be connected to the OTDR using a launch cable, and the other end will be connected to a landing cable. The OTDR will show the launch cable, the optical fiber link segment under test, and the connection to the landing cable on the far end, ensuring that the entire optical fiber link segment is continuous.

The OTDR measurements should be used to verify the cable information supplied by the manufacturer on the side of the reel. If one end of the fiber is buried at the center of the reel, the OTDR may be used to test the optical fiber, but results may be misleading. Without a launch and landing cable at each end, the OTDR may be providing the entire length of the cable or just the length to the first cut in the cable. It is best to have access to both ends of the cable being tested to ensure the entire cable length is being tested (see Figure 6.36).

Figure 6.36
Components of an optical time domain reflectometer trace



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Preinstallation Testing, continued

An OTDR can approximate measurements such as:

- End-to-end attenuation. This should be compared with the test report on the reel, being careful to understand the test method used by the cable manufacturer.
- Distance to a point of high attenuation. This could be a defect in the optical fiber strand, an optical fiber break, or the end of the cable. This form of testing would come into play, for example, when identifying the location where a forklift may have damaged the cable during shipment. The OTDR will show the distance from the beginning of the reel to the damaged area in either meters or feet. The length markers on the cable sheath can be used to assist in locating the damaged section.

NOTE: The optical lengths of certain cables (e.g., stranded loose tube) will be slightly longer than the cable sheath because of the optical fiber lay within the cable sheath.

- Optical loss per unit of measure (decibel/kilometer).
- Loss per event along the optical fiber (e.g., splice, mated connector).
- Length of the optical fiber.

Acceptance Testing

Testing installed optical fiber cabling for attenuation with an OLTS, as described in this manual, and verifying the cabling length and polarity constitute acceptance testing.

Cabling channel loss criteria specified by applications and reiterated in the various cabling standards, such as those for 1000BASE-SX and 10GBASE-SX, have caused these channel losses to become extremely important. Furthermore, the physical length requirements for these applications have diminished; for example, for 10GBASE-SX the maximum channel is 300 m (984 ft), which can only be achieved using 50/125 µm laser-optimized optical fiber.

Most LAN or campus applications, which use optical fibers, do so over a circuit of two optical fibers. One optical fiber is used in one direction as a transmitter, and the adjacent optical fiber at the same end is used as a receiver. All optical fiber systems must be installed and verified that polarity of the system is followed. For example, the polarity of duplex or multioptical fiber cabling systems should be verified to ensure that a transmitter on one end of the optical fiber channel connects to a corresponding receiver on the other end.

Every optical fiber segment has a transmit connector on one end and a receive connector on the opposite end. Every junction, patch panel, or work area faceplate will mate a transmit connector to a receive connector and will continue in this flip-flop pattern until final connection into the equipment at each end.

Acceptance Testing, continued

After the installation of the optical fiber link, the link should be tested before it is put into service. An OLTS is used to measure the attenuation of the link as it emulates a transmitter and receiver and may measure actual power in decibels referenced to milliwatts (dBm) or a ratio of the input power to output power measured in dB.

The benefits of acceptance testing are that it:

- Verifies that the total attenuation of all passive components in the link is within the design parameters (e.g., loss calculation).
- Establishes accountability when circuits are configured with multiple link segments connected together and installed by more than one vendor.
- Provides a benchmark for comparing future measurements.

Acceptance testing of optical fiber is most often performed with an OLTS. The OLTS may have the ability to measure and record optical fiber length. Additionally, some OLTSs can measure two optical fibers at one time, thereby verifying polarity at the same time.

Two people are required to perform the OLTS test when optical fibers have lengths that would preclude one person from easily reconfiguring both ends of the OLTS. The two people would need some form of communication (e.g., optical fiber talk set, portable two-way radios, telephones).

Acceptance testing of a new installation using an OLTS should be performed only on individual passive link segments and not on a link that has one or more jumpers. This is in view of the fact that the circuit may be reconfigured in the future, and the attenuation value for each link segment would be needed by the customer or technician to properly design the new configuration. The results of each measurement should be recorded on the optical fiber passive link record.

NOTE: See Example A: Optical Fiber Performance Calculations Worksheet at the end of Section 5.

Configuration Testing

Configuration testing of optical fiber is most often performed with an OLTS. The OLTS may have the ability to measure and record optical fiber length. Additionally, some OLTSs can measure two optical fibers at one time, thereby verifying polarity at the same time. The benefits of configuration testing are the same as acceptance testing.

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Preventive Maintenance Testing

Preventive maintenance testing is the periodic testing of a link and the subsequent comparing of the measured attenuation to the original acceptance test values. This is a preventive maintenance measure to find potential problems before they cause an out-of-service condition.

Preventive maintenance testing is normally performed at night or on weekends to minimize disruption to the users. For singlemode optical fiber, out-of-band testing may be accomplished at the 1625 nm window.

The benefits of preventive maintenance testing are:

- Lower out-of-service downtime.
- Planned testing time instead of unplanned out-of-service.
- Greater network reliability.

Preventive maintenance testing may be performed with an OLTS or an OTDR or both. Testing links rather than passive link segments is acceptable for preventive maintenance testing. If a discrepancy is found while testing a link, the individual passive link segments may be tested with an OTDR to identify the problem.

Bear in mind that the repeatability for mating a connection has a tolerance, which will affect the repeatability of a result. Typically, the component standards allow for a total deviation of 0.2 dB.

Optical Fiber Cabling—Optical Loss Test Set (OLTS)

Overview

Performing optical fiber cable testing is a process of verifying that the optical fiber cable functions as expected. To determine whether the specifications are met, testing includes the following:

- External physical inspection of each cabling link
- End face cleanliness inspection for each fixed connector and cord
- Polarity confirmation
- Verification of the cabling labeling
- Actual testing of each optical fiber's optical condition (e.g., attenuation)

Field testing of optical fiber cable covers the following activities:

- Turning on test equipment (allowing it to warm up)
- Setting the test equipment to measure specific wavelengths
- Selecting proper test cords and adapters
- Reference calibrating the test equipment to be used and recording the result
- Disconnecting active electronic equipment from the channel (if necessary)
- Connecting OLTS to each end of the optical fiber to be tested
- Recording the measured test result values
- Calculating the expected attenuation versus the measured attenuation
- Documenting the results

If the test fails, the cable link segment should be corrected so that it can pass.

NOTE: For test sets that automatically calculate measurements and compare the measured data with a standards database, it is important that the right parameters are set within the OLTS and the procedure to establish a proper reference is taken prior to commencing testing.

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Attenuation

Attenuation is the amount of signal lost or absorbed through the components and any joints or mating through connectors. All values of attenuation for cable, connectors, and splices provided in any standard or specification are stated as being the maximum allowed loss values accepted by the component and cabling standards.

Table 6.9 lists the attenuation coefficients, by wavelength, for horizontal and backbone singlemode and multimode optical fiber cable.

Table 6.9
Attenuation coefficients—multimode and singlemode cables

Cable Type	850 nm	1300 nm	1310 nm	1550 nm
OM1 62.5/125 µm	3.5 dB/km	1.5 dB/km	N/A	N/A
OM2 50/125 µm	3.5 dB/km	1.5 dB/km	N/A	N/A
OM3 50/125 µm laser enhanced	3.5 dB/km	1.5 dB/km	N/A	N/A
OS1 LAN	NA	NA	1.0 dB/km	1.0 dB/km
OSP	NA	NA	0.5 dB/km	0.5 dB/km

µm = Micrometer
dB = Decibel
km = Kilometer
N/A = Not applicable
OM = Optical multimode
OS = Optical singlemode
OSP = Outside plant

Connector insertion loss is often stated in cabling component standards as 0.75 dB per mated pair for both multimode and singlemode product sets. However, as noted earlier, this represents the worst loss acceptable under certain standards. The worst loss often carries a caveat or statement that 100 percent of the connections shall be better than 0.75 dB and 95 percent of the connections shall be better than 0.5 dB. BICSI recommends this practice for ITS installers. Through the use of good inspection and cleaning techniques, all products should be better than 0.5 dB per mated connector pair.

The splice insertion loss allowance for LAN cabling standards is 0.3 dB per splice, irrespective of whether it is a mechanical splice or fusion splice, multimode or singlemode. Using different types of splice or splicing tools can reliably improve the performance of the finished splice.

Attenuation, continued

Table 6.10 provides guidance for the typical loss values achievable for a splice using different types of splices and best practices with quality splicing tools.

NOTE: The ITS installer must meet or exceed the requirements of the cabling standard (0.3 dB maximum loss) and any specific performance limits from the contract. In addition, the ITS installer must ensure that link attenuation is within the projected loss budget for the applications to be supported.

Table 6.10
Splice insertion loss guidelines and objectives

Cable Type	Multimode and Singlemode Mechanical	Multimode Fusion	Singlemode Fusion
OM1 62.5/125 µm	0.3 dB	0.1 dB	0.05 dB
OM2 50/125 µm	0.3 dB	0.1 dB	0.05 dB
OM3 50/125 µm laser enhanced	0.3 dB	0.1 dB	0.05 dB
OS1 LAN	0.3 dB	N/A	0.05 dB
OSP	0.3 dB	N/A	0.05 dB

µm = Micrometer
dB = Decibel
N/A = Not applicable
OM = Optical multimode
OS = Optical singlemode
OSP = Outside plant

Bandwidth

Bandwidth for optical fiber circuits cannot be measured in the field or proven through calculation by the ITS installer. Verification of bandwidth can only be done at the point of manufacture of the glass optical fiber. Therefore, the ITS installer can only validate the bandwidth through specification of components and cross-checking that the correct specified components have been supplied and installed. There is no bandwidth statement available for singlemode optical fiber.

Bandwidth for singlemode optical fiber is characterized through the effects of the optical core creating a color change of the signal it is carrying. This is called chromatic dispersion.

Bandwidth has become the most significant performance aspect for multimode cables since the introduction of high-speed applications (e.g., 1 gigabyte [GB] Ethernet, 10 GB Ethernet), which for use on multimode optical fiber at 850 nm demands the use of VCSELs to drive the application into the optical fiber.

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Bandwidth, continued

As each 850 nm VCSEL is smaller (28 µm to 32 µm) than the multimode optical core it is being driven into (50/125 µm or 62.5/125 µm), the bandwidth statement required to support a VCSEL would be different than that for the optical fiber being used. The term used to define this quality in multimode optical fiber is laser enhanced. Optical fiber that has been constructed to support VCSELs and lasers will have bandwidth performance qualities for normal LEDs and VCSELs.

The minimum classification of optical fiber bandwidth is shown in Table 6.11.

Table 6.11
Optical fiber bandwidth

Multimode	850 nm OFL	850 nm RML	1300 nm	1310 nm	1550 nm
FDDI 62.5/125 µm	160 MHz•km	NA	400 MHz•km	N/A	N/A
OM1 62.5/125 µm	200 MHz•km	NA	500 MHz•km	N/A	N/A
OM2 50/125 µm	500 MHz•km	NA	500 MHz•km	N/A	N/A
OM3 50/125 µm Laser optimized	1500 MHz•km	2000 MHz•km	500 MHz•km	N/A	N/A

µm = Micrometer
FDDI = Fiber distributed data interface
km = Kilometer
MHz = Megahertz
N/A = Not applicable
OFL = Overfilled launch
OM = Optical multimode
RML = Restricted mode launch

Test Configuration Methods

In order to perform testing on optical fiber, the ITS installer must be aware of both the expected test results (loss calculation) and the procedures required to conduct the testing. Using an OLTS, there are three methods for configuring the test equipment and the cable under test.

The differences in the methods are the number of test jumpers that are connected between the light source and the power meter when the two units are referenced or zeroed out and the number of connectors added and measured between the test referencing and the testing. All test cords used should be referenced cords when performing multimode testing. This will ensure repeatability and as true a loss as can be measured in the field.

Test Configuration Methods, continued

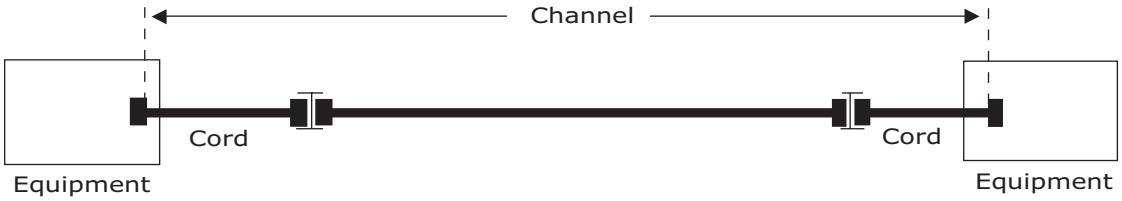
The term referenced or zeroed out refers to the need to eliminate from the results the attenuation losses induced by the test cords and connectors prior to starting the testing. Connect the test jumpers between the light source and power meter. Turn on the units so they can warm up and stabilize. If the power meter is displaying -19.7 dBm, this can be recorded as your initial reference value. This value would have to be subtracted from all future tests to determine the loss of the optical fibers being tested. Most of today's power meters have the ability to be referenced or zeroed out automatically by simply pushing a reference button. This will take whatever amount of light entering the power meter (-19.7 dBm) and switch the meter's display over to 0 dB. Any future test will display the actual amount of loss in dB without the need to subtract any previously documented reference values.

As with copper, there are two states in an optical fiber solution—the link and the channel. For most LAN installations, the ITS installer would be leaving a link or series of links for the end user to configure with cords into channels. If the ITS installer has to configure the links and test as a channel, the test regime and tester setup procedure will be different to that used for the link testing.

In a channel, connectors that are plugged directly into the equipment at each end are considered to have no loss; it is only the loss of the glass or optical channel between the two connected pieces of equipment that is measured—the effects of individual component attenuation losses are amortized across the whole channel.

A channel is where both ends of the optical fiber are connected or will be connected directly to the equipment using additional cords on both ends. The objective of the test is to determine the loss value of the cable, connectors, splices, or cross-connects in the channel without including the loss associated with the first and last connectors since they connect directly to the equipment (see Figure 6.37).

Figure 6.37
Channel



A connector that is plugged into a transmitter port has a core that will accept the light being directed toward the connector's end face. Light within the cone of acceptance enters the core while light outside the cone is lost. The receiving equipment has a photosensitive component that the connector directs its light toward without any precise alignment required. The only connector loss within a channel is associated with the mated connectors that are not inserted into the equipment.

It is important that the method to be used for testing is identified prior to the start of testing and the same method is used consistently throughout the installation.

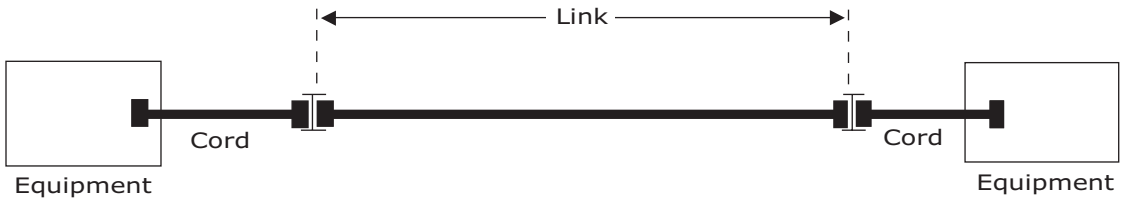
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Test Configuration Methods, continued

There are three different calibration procedures for testing with the OLTS. Each calibration procedure has a specific application based on the configuration of the link or channel under test. Optical fiber links may be broken down into three simplified configurations:

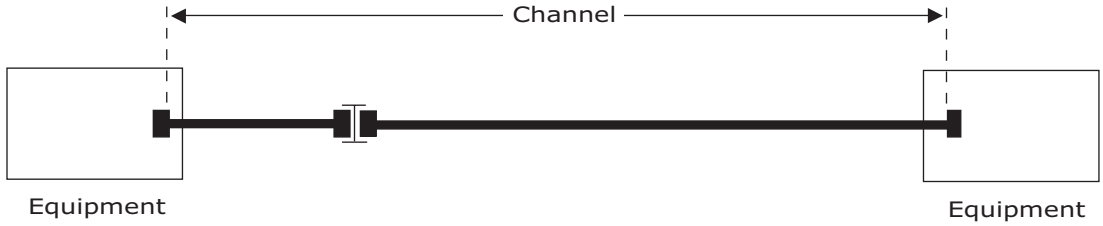
- Dual interconnections—Optical fiber cabling link segment with an optical fiber interconnection to active equipment at each end. The cabling is attached at each end to a patch panel or work area faceplate (see Figure 6.38). Equipment cords are connected from the equipment to both ends of the optical link segment to complete the circuit. This is the most popular configuration for testing backbone and horizontal cabling. This configuration measures the loss of the optical fiber link segment and two connections (two mated connector pairs).

Figure 6.38
Link



- Single interconnection—Optical fiber cabling link segment with an optical fiber interconnection to active equipment at only one end. The optical fiber cabling is connected to a patch panel at only one end of the link, and the opposite end is a direct connection where the cable is connected directly to the equipment without the use of an adapter or equipment cord (see Figure 6.39). This measures the loss of the optical fiber link segment and one connection (one mated pair of connectors).

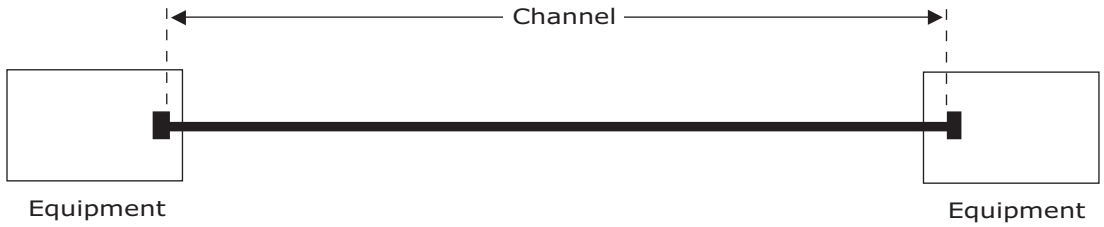
Figure 6.39
Interconnect channel



Test Configuration Methods, continued

- Dual direct connection—The dual direct connection is where both ends of the optical fiber are connected directly to the active equipment. This configuration would not have any loss associated with connectors since both connectors are directly connected to the end equipment (see Figure 6.40).

Figure 6.40
Dual direct connect



Test Configurations

There are three test configurations for OLTS:

- Method A–two jumpers
- Method B–one jumper
- Method C–three jumpers

The three test methods differ in how the reference reading (the starting point) is established rather than the actual physical connection of the cable and test equipment.

For testing, all three methods physically use a light source, power meter, two jumpers and for multimode, the correct mandrel (mode filter)—one to attach each test component to the cable under test.

The testing methods differ in the number of jumpers that are connected together to establish the reference reading for the test equipment. The choice between methods is primarily a matter of how the optical fiber loss will be experienced by the transmission equipment.

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Mode Filter

Multimode cable has many paths for light to follow, which are called modes. The modes near the outside edge of the glass are called high-order modes. It should be noted that high-order modes should be dissipated prior to a connection point; therefore, necessitating the mandrel wrap on the test jumper that is connected to the light source. The mandrel is used during the test set calibration and remains throughout the entire testing process.

Before testing multimode optical fiber, a mandrel wrap is installed 1 m (3.28 ft) from the light source on the transmit test jumper only at the light source end. The purpose of the mandrel is to remove the higher order modes from the optical fiber and stabilize the light before it is used in the optical fiber to be tested.

The installation of the mandrel wrap is performed by wrapping a length of optical fiber around a round mandrel (rod) for a total of five complete nonoverlapping wraps. If the mandrel does not have an integral retention mechanism to secure the optical fiber, the wraps may be secured by tape around the mandrel.

The mandrel must be applied to the test cords before the reference calibration of the light source to the power meter and for all subsequent loss measurements of the optical fiber. A mandrel wrap is never installed on the receive test jumper (optical power meter). Table 6.12 shows mandrel diameters for typical cabled optical fiber types.

Table 6.12
Acceptable mandrel diameters for common multimode cable types (five wraps)

Cable Type (Diameter)				
Optical Fiber Core/Cladding Size (µm)	**900 µm Buffered Optical Fiber (mm)**	**2.0 mm Jacketed Cable (mm)**	**2.4 mm Jacketed Cable (mm)**	**3.0 mm Jacketed Cable (mm)**
50/125	25	23	23	22
62.5/125	20	18	18	17

mm = Millimeter
µm = Micrometer

NOTE: The mandrel diameters are based on nominal values of 20 mm (0.8 in) and 26 mm (1 in) reduced by the cable diameter and rounded up.

Link attenuation does not include any active or passive devices other than cable, connectors, and splices (e.g., optical bypass switches, couplers, repeaters, optical amplifiers).

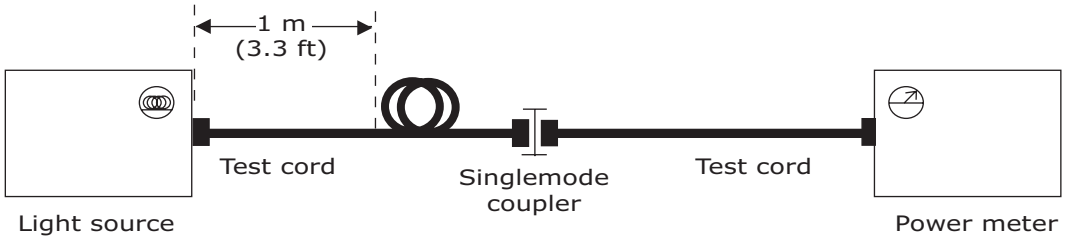
Mode Filter, continued

Method A Referencing

The objective of method A referencing is to simulate the loss the active equipment will experience through the cable, any splices, and one mated pair but not the loss of connectors on each end (see Figure 6.39 for interconnection channel configuration). This method is also used to test individual link segments, where it is desired, to record the loss of the connectors on each end of the cable (e.g., patch cord testing).

This method requires two 2 m (6.6 ft) test cords with connectors at one end of each cord compatible with OLTS units. The other end of each test cord may be fitted with the tested connector set. Both ends of the tested cabling must have the same connector type and a singlemode coupler of the connector type that is suitable for the tested cabling (see Figure 6.41). If the connectors are different at each end of the cabling to be tested, this is not a suitable test method.

Figure 6.41
Establishing reference, two-jumper method



ft = Foot
m = Meter

All test cords are to be inspected with a microscope for damage and dirt, which is followed up with an appropriate action.

One 2 m (6.6 ft) test cord is connected to the light source. For multimode only, a mandrel appropriate for the test cord cable size should be installed 1 m (3.28 ft) from the light source with five complete wraps around the mandrel to remove the higher order modes. The other test cord is connected to the power meter; no mandrel is applied to the power meter test cord. The two cords are joined together with a singlemode coupler to provide better alignment of the two test cord cores.

NOTE: The zero or reference measurement is the reading taken of the sum of the test cords and the connector as read at the power meter.

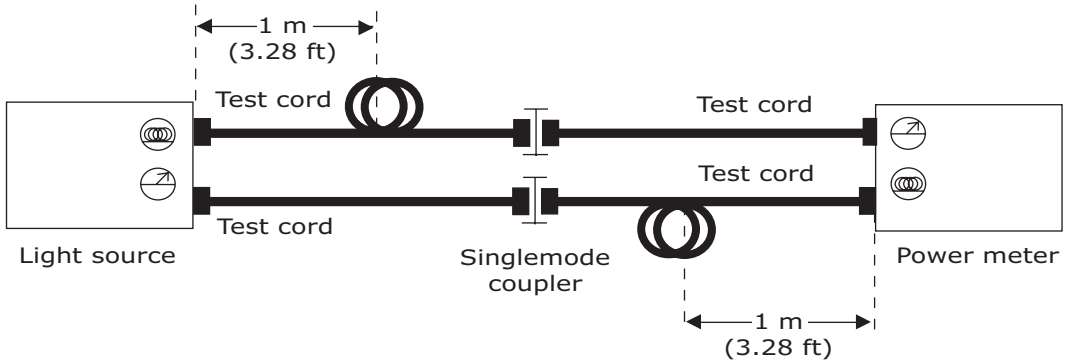
Once the test is completed, the test cords are not to be removed from the light source. If the test cords are disconnected, the reference procedure must be rerun to reset the reference.

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Mode Filter, continued

The single-direction method A can be used to perform bidirectional testing by applying the mandrels for multimode testing to the cord tests coming from the light source (see Figure 6.42).

Figure 6.42
Establishing reference, optical loss test set

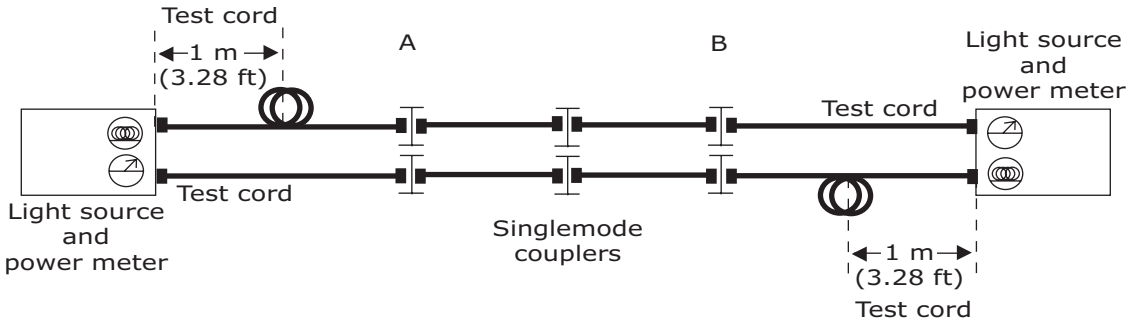


ft = Foot
m = Meter

To reference an OLTS for testing fixed connectors (e.g., MT-RJ), employ the method A configuration (see Figure 6.43). Convert the test cord connector to be tested by using short leads terminated at one end in the connector.

All of the couplers should be singlemode and then split to test each leg of the optical fiber circuit made only at points A and B. Once the test is completed, the test cords are not to be removed from the light source. If the test cords are disconnected, the reference procedure must be rerun to reset the reference.

Figure 6.43
Method A optical loss test set testing configuration



ft = Foot
m = Meter

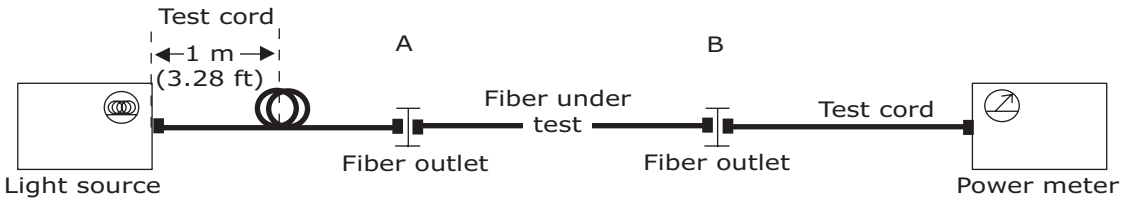
Mode Filter, continued

Method A Testing

This method requires two test cords be disconnected from the coupler and inserted into the optical fiber outlets presented at each end of the link being tested (see Figure 6.44).

NOTE: The expected loss results are the sum of one mated connector pair plus the loss attributed to the optical fiber.

Figure 6.44
Method A testing



ft = Foot
m = Meter

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Mode Filter, continued

Method B Referencing

The objective of method B referencing is to simulate the loss the active equipment will experience through the cable, any splices, and two mated pairs but not the loss of connectors on each end (see Figure 6.37 for channel configuration).

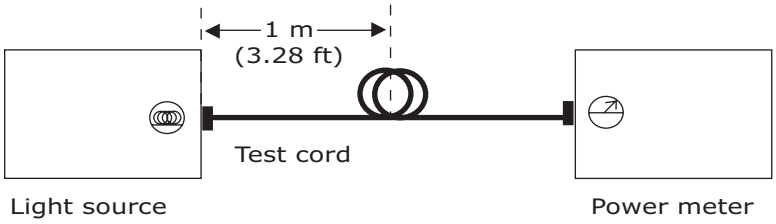
This method requires two 2 m (6.6 ft) test cords with connectors at one end of each cord compatible with OLTS units (see Figure 6.45). The other end of each test cord may be fitted with the tested connector set. If the connectors are different at each end of the cabling to be tested, this method is suitable to test it.

All test cords are to be inspected with a microscope for damage and dirt, following up with appropriate action. One 2 m (6.6 ft) test cord is connected to the light source. For multimode only, a mandrel appropriate for the test cord cable size should be installed 1 m (3.28 ft) from the light source with five complete wraps around the mandrel to remove the higher order modes.

NOTE: The zero or reference measurement is the reading taken of the sum of the test cords and the connector as read at the power meter.

Once the test is completed, the test cord must not be removed from the light source. If the test cord is disconnected, the reference procedure must be rerun to reset the reference.

Figure 6.45
Method B referencing



ft = Foot
m = Meter

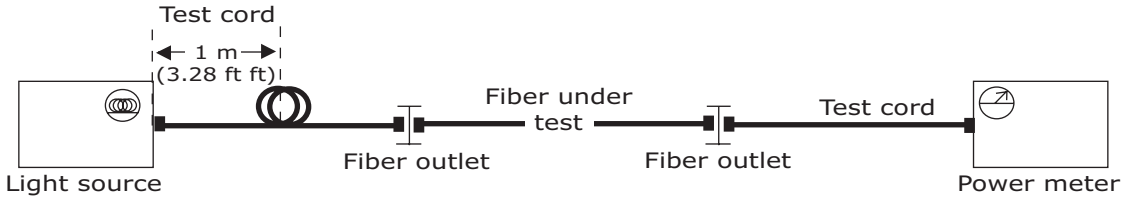
Mode Filter, continued

Method B Testing

This method requires the referenced test cord be disconnected from the one power meter and inserted into the optical fiber outlets presented at one end of the link being tested. A second test cord is then used to link the other outlet to the power meter and included in the test results (see Figure 6.46).

NOTE: The expected loss results are the sum of two mated connector pairs plus the loss attributed to the optical fiber between the two mated connector pairs plus the loss of the test cord that was not used to establish the zero reference.

Figure 6.46
Method B testing



ft = Foot
m = Meter

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Mode Filter, continued

Method C Referencing

The objective of method C referencing is to simulate the loss the active equipment will experience through the cable or any splices but not the loss of connectors on each end (see Figure 6.40 for dual direct connect configuration). This method is also used when an extremely long OSP cable is tested and the loss of optical fiber and all the splices needs to be measured but not the loss of connectors on each end.

This method requires two 2 m (6.6 ft) test cords and one short (less than 1 m [3.28 ft]) test cord with connectors at one end of each of the 2 m (6.6 ft) cords compatible with OLTS units. The other end of each test cord may be fitted with the tested connector set.

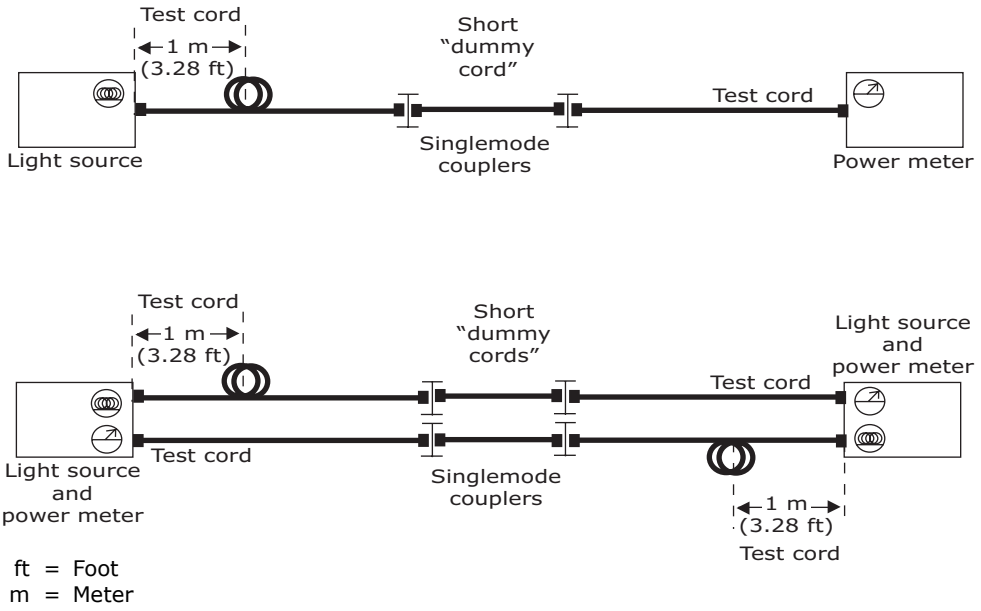
NOTE: The short cord, also known as a dummy cord, should be a suitable connector to mate onto the end connectors of the 2 m (6.6 ft) test cords. This process can be used if different connector styles are at each end of the cabling.

All test cords are to be inspected with a microscope for damage and dirt, following up with appropriate action. One 2 m (6.6 ft) test cord is connected to the light source. For multimode only, a mandrel appropriate for the test cord cable size should be installed 1 m (3.28 ft) from the light source with five complete wraps around the mandrel to remove the higher order modes. The other test cord is connected to the power meter; no mandrel is applied to the power meter test cord. The two cords are connected into the cord using the singlemode couplers to provide better alignment of the two test cord cores (see Figure 6.47).

NOTE: The zero or reference measurement is the reading taken of the sum of the test cords and the connector as read at the power meter.

Once the test is completed, the cord is removed from the reference setup. The test cords are not to be removed from the light source. If the cords are disconnected, the reference procedure must be rerun to reset the reference.

Figure 6.47
Method C referencing



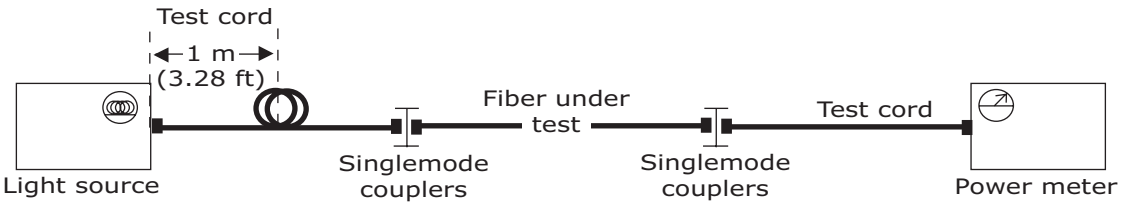
Mode Filter, continued

Method C Testing

This method requires the short cord be disconnected from the couplers, leaving the couplers in place on the 2 m (6.6 ft) test cords. The two test cords are mated to the equipment cords presented at each end of the channel being tested (see Figure 6.48).

NOTE: The expected loss results are the loss attributed to the optical fiber along with any mated connector pairs in the channel.

Figure 6.48
Method C testing

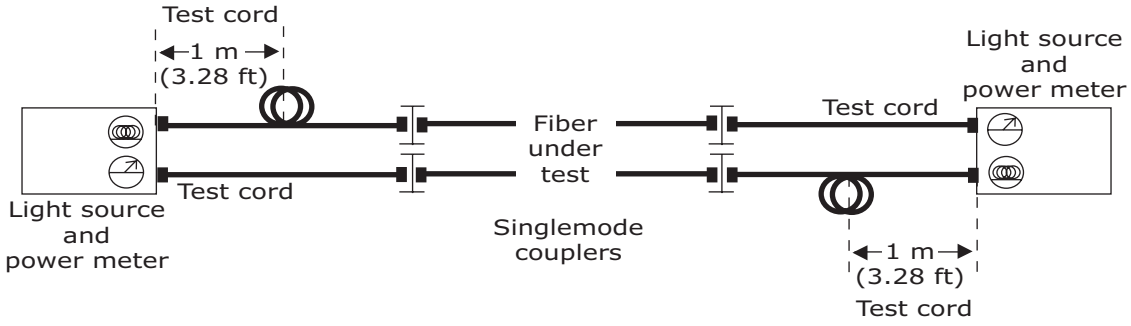


ft = Foot
m = Meter

Perform bidirectional testing by applying the mandrels for multimode testing to the test cords coming from the light source (see Figure 6.49).

Once the test is completed, the test cords are not to be removed from the light source. If the test cords are disconnected, the reference procedure must be rerun to reset the reference.

Figure 6.49
Method C testing with optical loss test set



ft = Foot
m = Meter

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Test Equipment

Some typical test equipment is described in the following sections.

Two-Way Radio

Many cable testing and troubleshooting procedures require two technicians—one positioned at each end of a cable link or data channel. Radios can cause interference with the tester during an autotest. Limit radio transmissions to when the tester is not performing tests.

Connector Viewing Microscope

Every connector must be inspected for dirt and damage. These scopes are available with magnifications between 100× and 800×. It is recommended that a 100× to 200× microscope be used. When higher power scopes are used, they tend to make the smallest defect look much worse than it actually is, and good connectors are often damaged when the installer tries to polish out what they perceived as defects. The microscope should be fitted with filters to prevent damage to the operators' eyes if they inadvertently look into the end of an active optical fiber.

Small cameras and screen-based microscopes are available. Camera and screen microscopes also have the ability to view inside couplers at patch panels and outlets to see the end face of the connector being presented on the hidden side without the need to open or disturb the remaining optical fibers at the outlet.

Cleaning Material

The ITS installer must always have cleaning material available.

Visual Light Source

The visual light source is used to check the continuity and polarity of the optical fiber.

Visual Fault Locator (VFL)

The VFL is a red laser source (630 to 665 nm) that, in addition to identifying or tracing cabled optical fibers, can aid in troubleshooting faults on optical fiber cables.

The VFL can often identify breaks or bends in cables (if the jacket is transparent to the laser), faulty connectors, some types of splices, and other causes of signal loss.

WARNING: Never look into optical fiber strands unless you personally confirm that the strands are disconnected from potential laser or light sources. These sources can cause eye damage.

Optical Loss Test Set (OLTS)

The light source and power meter provide a way of testing and troubleshooting optical fiber cable for power loss.

Interferometer

The interferometer is used to test the physical shape of the connector end face.

Safety

Refer to Chapter 2: Safety Procedures for further information.

Test Measurement Documentation

Optical Fiber Link Record

This is a paper document or computer database where the link attenuation measurements and length are recorded and the link attenuation calculations are performed. This is a permanent record and should be retained for future reference.

NOTE: See Example B: Optical Fiber Link Attenuation Record at the end of Section 5.

For those field test sets that record the test data in digital format, download and save the test data according to the field test set manufacturer's procedures.

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Optical Time Domain Reflectometer (OTDR)

Overview

This section covers the testing of optical fiber cables using an OTDR. In the case of certification testing, testing with an OTDR remains an optional, but very helpful addition, in the case of future troubleshooting. The wavelength used in creating the OTDR trace should be the same as that used with the OLTS when measuring link loss.

The OTDR trace characterizes elements along an optical fiber link, including:

- Optical fiber segment length.
- Attenuation uniformity and attenuation rate.
- Connector location and insertion loss.
- Splice location and splice loss.
- Other power loss events (e.g., sharp bend) that may have been incurred during cable installation.

The OTDR trace does not replace the need for OLTS testing, but the trace is used for supplemental evaluation of the cabling link. Typical applications include:

- Acceptance testing.
- Preventive maintenance testing.
- Preinstallation testing.
- Troubleshooting.

Tools and Equipment

An OTDR is an electronic–optical instrument that is used to characterize optical fibers. It locates defects and faults and determines the amount of signal loss at any point in an optical fiber.

An OTDR takes thousands of measurements along an optical fiber. The measurement data points can vary in distance between them. The data points are displayed on the screen as a line sloping down (e.g., commonly known as a trace), from left to right, with distance along the horizontal scale and a reduced signal level on the vertical scale. By selecting any two data points via movable cursors, the operator can read the distance and relative signal level between them.

Applications

OTDRs are widely used in all phases of an optical fiber system's life, ranging from construction to maintenance to fault locating and restoration.

An OTDR is used to:

- Measure overall (end-to-end) loss for system acceptance and commissioning.
- Measure section loss (individual optical fiber reels) for incoming inspection and verification of specifications.
- Measure splice loss (both fusion and mechanical splices) during installation, construction, and restoration operations.
- Measure reflectance of cable connectors and splices to determine the level of reflections, which must be kept low.
- Locate optical fiber breaks and defects.
- Indicate optimum optical alignment of optical fibers in splicing operations.
- Detect the gradual or sudden degradation of optical fiber by making comparisons to previously documented optical fiber test.

Theory of Operation

The OTDR uses the effects of Rayleigh scattering and Fresnel reflection to measure the characteristics of an optical fiber. By sending a pulse of light (the optical in OTDR) into an optical fiber and measuring the travel time (the time domain in OTDR) and strength of its reflections (the reflectometer in OTDR) from points inside the optical fiber, it produces a characteristic trace, or profile, of the length versus returned signal level on a display screen.

The trace can be analyzed on the spot, printed out immediately for documentation of the system, or saved to a computer disk for later analysis. A trained operator can accurately locate the end of the optical fiber, determine the location and loss in a splice, and estimate the overall loss of the link or channel.

Rayleigh Scattering

When a pulse of light is sent down an optical fiber, part of the pulse is blocked by microscopic particles (called dopants) in the glass and scatters in all directions. This is called Rayleigh scattering. Some of the light (about 0.0001 percent) is scattered back in the opposite direction of the pulse (back toward the source) and is called the backscatter. Since dopants in optical fiber are uniformly distributed throughout the optical fiber because of the manufacturing process, this scattering effect occurs along its entire length.

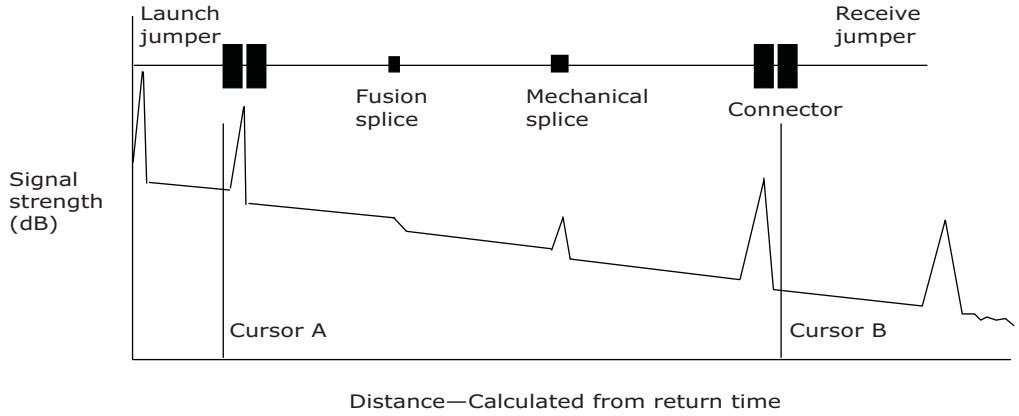
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Theory of Operation, continued

Rayleigh scattering is the major loss factor in optical fiber. Longer wavelengths of light exhibit less scattering than shorter wavelengths because of the width of the optical waveform produced. For example, light at 1550 nm loses 0.2 to 0.3 dB/km of optical fiber length because of Rayleigh scattering; light at 850 nm loses 4.0 to 6.0 dB/km from scattering. A higher density of dopants in an optical fiber will create more scattering and thus higher levels of attenuation per kilometer. An OTDR can measure the levels of backscattering accurately and use the OTDR to measure small variations in the characteristics of optical fiber at any point along its length (see Figure 6.50).

The Rayleigh scattering effect is like shining a flashlight in a fog at night—the light beam is diffused or scattered by the particles of moisture. A thick fog will scatter more of the light because there are more particles to obstruct it. The fog can be seen because the particles of moisture reflect small amounts of the light back. The light beam may go a long way into the fog if it is not very thick, but in a dense fog, the light attenuates quickly because of this scattering effect.

Figure 6.50
Optical time domain reflectometer test configuration—end-to-end attenuation



dB = Decibel

Theory of Operation, continued

Fresnel Reflection

Whenever light traveling in a material (e.g., optical fiber) encounters a different density material (e.g., air), some of the light (up to four percent) is reflected back toward the light source while the rest continues in the material. These sudden changes in density occur at the ends of optical fibers, at optical fiber breaks, and (sometimes) at splice points.

The amount of the reflection depends on the magnitude of change in material density (described by the index of refraction [IOR]—larger IORs mean higher densities) and the angle that the light strikes the interface between the two materials. This type of reflection is called a Fresnel reflection, which is used by the OTDR to precisely determine the location of optical fiber breaks.

Backscatter Level Versus Transmission Loss

Although the OTDR measures only the backscatter level and not the level of the transmitted light, there is a close correlation between the backscatter level and the transmitted pulse level. The backscatter is a fixed percentage of the transmitted light.

If the amount of transmitted light drops suddenly from point A to point B (e.g., caused by a tight bend, a splice between optical fibers, a defect), the corresponding backscatter from point A to point B will drop by the same amount. The same loss factors that reduce the levels of a transmitted pulse will show up as a reduced backscatter level from the pulse. The ratio of backscattered light to transmitted light also is known as the backscatter coefficient.

Optical Time Domain Reflectometer (OTDR)

The OTDR consists of a laser light source, a coupler/splitter, an optical sensor section, a controller section, and a display section.

Laser Light Source

The laser sends out pulses of light on command from the controller. The duration of the pulse (the pulse width) can be selected by the operator for different measuring conditions. The light goes through the coupler/splitter and into the optical fiber under test. Some OTDRs have two lasers to allow for testing optical fibers at two different wavelengths.

Coupler/Splitter

The coupler/splitter has three ports—one each for the source, the optical fiber under test, and the sensor. It is a device that allows light to travel only in specific directions—from the laser source to the optical fiber under test and from the optical fiber under test to the sensor.

Light is not allowed to go directly from the source to the sensor. Thus, pulses from the source go out into the optical fiber under test. The returning backscatter and Fresnel reflections are routed to the sensor.

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Optical Time Domain Reflectometer (OTDR), continued

Optical Sensor Section

The sensor is a photodetector that measures the power level of the light coming in from the optical fiber under test. It converts the optical power in the light to a corresponding electrical level—the higher the optical power, the higher the electrical level output.

OTDR sensors are specially designed to measure the extremely low levels of backscattered light. The sensor section includes an electrical amplifier to further boost the electrical signal level.

The power of Fresnel reflection is about 40,000 times higher than that of backscatter and is greater than the sensor can measure; it overloads the sensor, driving it into saturation. The electrical output level is subsequently clipped at the sensor's maximum output level.

Whenever a test pulse encounters the end of an optical fiber (whether at a splice or at the end of the optical fiber), it causes the sensor to be blinded for as long as the pulse occurs. This blind period is known as the dead zone.

Controller Section

The controller is the brain of the OTDR and performs the following:

- Notifies the laser when to pulse
- Obtains the power levels from the sensor
- Calculates the distance to scattering and reflecting points in the optical fiber
- Stores the individual data points
- Sends the information to the display section

A major component of the controller section is a very accurate clock circuit, which is used to precisely measure the time difference between when the laser pulses and when the sensor detects returning light.

By multiplying this round-trip pulse travel time by the speed of light in optical fiber (e.g., speed of light in free space corrected by the IOR), the round-trip distance is calculated. The distance from the OTDR to the point (one-way distance) is half of the round-trip distance.

While backscattering occurs all along an optical fiber, there is a continuous flow of light back into the OTDR. The controller samples the level measured by the sensor at regular time intervals to find its data points. Each data point is described by its sequence time, which relates to distance from the OTDR, and power level.

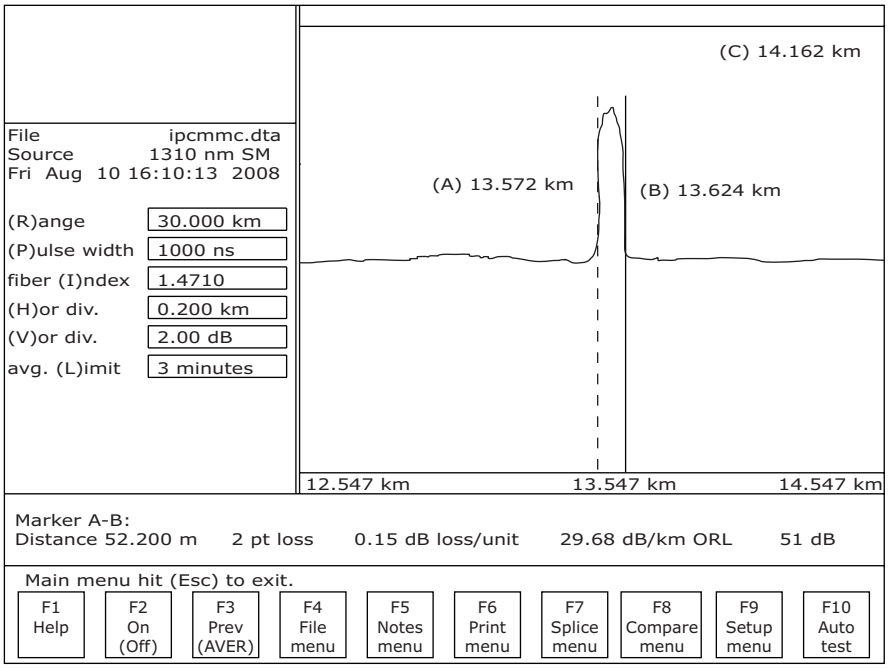
Optical Time Domain Reflectometer (OTDR), continued

Since the original pulse becomes weaker as it travels down the optical fiber because of loss induced by Rayleigh scattering, the corresponding returned backscatter level becomes weaker farther down the optical fiber. Therefore, the data points generally have decreasing power levels from start to end. When a Fresnel reflection occurs, the power level of the corresponding data point for that location suddenly goes up to its maximum level—way above the level of the backscatter just prior to it.

When the controller has gathered all its data points, it plots the information on the display screen (see Figure 6.51). The first data point is displayed at the left edge of the graph as the starting point of the optical fiber. Its vertical position is based on its power level; a higher power is plotted higher on the graph. Subsequent data points are placed to the right. The resultant trace is a sloping line that runs from the upper left toward the lower right. The slope of the line indicates its loss-per-unit-distance (dB/km) value. Steep slopes mean larger dB/km values. Data points corresponding to backscatter level make up the line.

Fresnel reflections look like spikes coming up from the backscatter level. A sudden shift of the backscatter level indicates a point loss, which may indicate either a fusion splice or a stress point in the optical fiber where light is escaping.

Figure 6.51
Optical time domain reflectometer trace



dB = Decibel
km = Kilometer
nm = Nanometer
ns = Nanosecond

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Optical Time Domain Reflectometer (OTDR) Specifications

Display Section

The display section is typically a liquid crystal display (LCD) screen that shows the data points that make up the optical fiber trace and displays the OTDR setup conditions and measurements. Most OTDR displays connect the data points with a line to give a better look at the overall trace. The operator can manipulate cursors on the screen to select any data point on the optical fiber trace.

When the cursor is on a data point, the distance to that point is displayed on the screen. An OTDR with two cursors will display the distances to each cursor and the difference in back-scatter levels between them in dB. The operator can choose the type of measurement being made with the cursors (e.g., two-point loss, dB/km, splice loss, reflectance). The measurement results are shown on the display.

Dynamic Range

The dynamic range of an OTDR determines the length of optical fiber that can be measured. It is listed as a dB value—larger values mean longer distance measurement capability. A test pulse needs to be strong enough to get to the end of the optical fiber to be tested.

The sensor has to be adequate to measure the weakest backscatter signals that come from the end of a long optical fiber. The combination of the total pulse power of the laser source and the sensitivity of the sensor determines the dynamic range.

Dynamic range for an OTDR is determined by taking the difference between the backscatter level at the near end of the optical fiber and the upper level of the average noise floor at or after the optical fiber end.

Increasing the total pulse output power of a laser source can be accomplished in two ways—either increase the absolute amount of light emitted or increase the pulse duration (pulse width).

There are limits to each of these procedures:

- A laser diode has a natural maximum output level that cannot be exceeded. A higher output level means a shorter component life; the laser might burn out faster.
- When the pulse width is increased, other performance characteristics (e.g., dead zone) are affected. Longer pulse widths produce longer dead zones.
- Sensors have natural limitations to their ability to measure low light levels. At some point, the electrical level sent out by the sensor, which corresponds to the optical power level detected, becomes lost in the electrical noise and sensor measurements. Electrical shielding within an OTDR is critical to decrease the adverse effects of ambient electrical noise in the instrument.

Additionally, when a sensor is operating at its peak sensitivity, its level accuracy is decreased. To improve accuracy at lower light levels, an OTDR will use averaging techniques to combine the measurements from thousands of pulses. The use of averaging will improve the sensitivity of a sensor and therefore can improve an OTDR's dynamic range.

Optical Time Domain Reflectometer (OTDR) Specifications, continued

Dead Zone

Dead zone refers to the space on an optical fiber trace following a Fresnel reflection in which the high return level of the reflection covers up the lower level of backscatter.

An OTDR's sensor is designed to measure the low backscatter levels from an optical fiber and becomes blinded when a larger Fresnel reflection hits it. This blind period lasts as long as the pulse duration. When the sensor receives the high levels of backscatter, which may follow immediately after a reflective event, the dead zone includes the duration of the reflection plus the recovery time for the sensor to readjust to its maximum sensitivity. High-quality sensors recover more quickly than lower-quality sensors and thus achieve shorter dead zones.

The dead zone effect can be illustrated by considering what could happen while looking at a starlit sky: with no other lights around, the eyes become sensitive and are able to see very dim stars (like backscatter). If a flashlight is shined in the eyes, the overpowering light (like a Fresnel reflection) is blinding, and the eyes are no longer able to see the stars. The eyes will not be able to see anything but the bright light for as long as it is in the eyes (pulse duration). After the light is removed, eyes slowly readjust to the darkness, becoming more sensitive, and are able to see the low light level of the stars again. The OTDR sensor acts to a great extent like eyes in this example. The period of blindness is the dead zone.

Since the dead zone is directly related to the pulse width, it can be reduced by decreasing the pulse width. Decreasing the pulse width lowers the dynamic range. An OTDR ITS designer must make a compromise between these two characteristics. Likewise, the OTDR user must choose a pulse width depending on whether it is more important to see closely spaced events or see farther out in an optical fiber.

Importance of Dead Zone

Dead zones occur in an optical fiber trace wherever there is an optical fiber connector and at some defects (e.g., cracks) in the optical fiber. There is always at least one dead zone in every optical fiber—where it is connected to the OTDR. This signifies that there is a space starting at the beginning of the optical fiber under test where no measurement can be made. This space is directly related to the pulse width of the laser source.

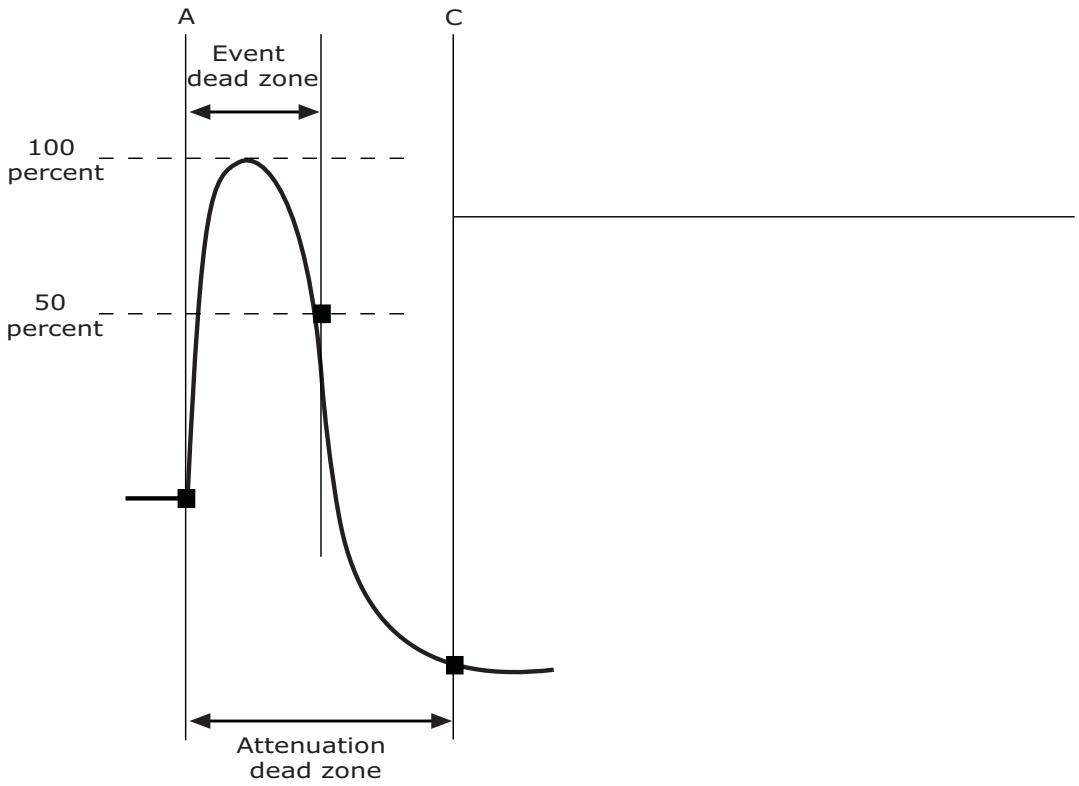
Typical pulse widths in OTDRs range from 30 nanoseconds (ns) to 10,000 ns. In distance, this is from 6 m (19.7 ft) to more than 1600 m (5249 ft) long. If it is necessary to characterize the part of the optical fiber that is close to the near end, select the shortest pulse width possible. A second point is the end of the optical fiber. By the time the receiver has recovered, there is nothing to reference but the noise level of the field test set. Therefore, it becomes imperative that a method is established to overcome this limitation.

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Optical Time Domain Reflectometer (OTDR) Specifications, continued

Dead zones are characterized as an event dead zone or an attenuation dead zone. An event dead zone is the distance after a Fresnel reflection before another Fresnel reflection can be detected. An attenuation dead zone is the distance after a Fresnel reflection until the back-scatter level can be detected. Event dead zones are always shorter than attenuation dead zones. Figure 6.52 shows how the two dead zones are measured.

Figure 6.52
Dead zone measurements



Optical Time Domain Reflectometer (OTDR) Specifications, continued

Resolution

There are two resolution specifications:

- Loss resolution—Loss resolution is the ability of the sensor to distinguish between levels of power it receives. Most OTDR sensors can display down to 1/100 of a decibel (0.01 dB) difference in backscatter level. This specification must not be confused with level accuracy.
- Spatial resolution—Spatial resolution is how close the individual data points, which make up a trace, are spaced in time (and corresponding distance). The OTDR controller samples the sensor at regular time intervals to obtain data points closely spaced, enabling the OTDR to detect events closely spaced. The ability of the OTDR to locate the end of the optical fiber is affected by the spatial resolution; if it only takes data points every 8 m (26 ft), then it can only locate an optical fiber end within ± 8 m (26 ft). See Distance accuracy under Accuracy and Linearity below.

The operator is able to select and measure the distance and loss between any two data points. Those that are closely spaced will provide more detail. An OTDR displays the optical fiber trace as a line that connects the data points and allows the operator to place a cursor between points and on points. This interpolation of the information produces a better display resolution than the actual spatial (or data point) resolution.

Spatial resolution is reduced in certain areas by a dead zone. Valid measurements of optical fiber attenuation are only made from backscatter level to backscatter level. Data points that were taken while the sensor was in saturation because of a Fresnel reflection cannot be used to make loss measurements since the sensor was not able to make an accurate level measurement. Therefore, the spatial resolution around a Fresnel reflection is worse (lower resolution) because the only usable points occur before and after the dead zone.

Accuracy and Linearity

A number of factors contribute to accuracy and linearity:

- The level accuracy of the OTDR sensor is measured in the same way as optical power meters and photo detectors of any kind. The accuracy of any optical sensor depends on how closely the electrical current output corresponds to the input optical power. Most optical sensors convert incoming optical power to a corresponding electrical current level evenly across its operating range, but the electrical output is extremely low.

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Optical Time Domain Reflectometer (OTDR) Specifications, continued

- All sensors use electrical amplifiers to boost the very low electrical output level. All amplifiers introduce some amount of distortion to the signal. High-quality amplifiers boost both high and low levels by the same amount. In other words, they have a very linear response to an input over most of the operating range.
- Lower-quality amplifiers introduce significant distortion into the amplified signal at either high- or low-input levels—they become nonlinear at the extremes of operation. The linearity inherent in an optical sensor and its amplifier will determine how accurately the incoming optical power is converted to an amplified electrical event.
- Level accuracy for many optical sensors is stated as a flat plus or minus dB amount (if its measurement range is small), such as ± 0.10 dB, or a percentage of the power level such as two percent. For OTDRs, a better representation of the accuracy is the linearity, stated as a ± quantity of dB per dB of power measured over certain ranges of measurement such as ± 0.10 dB/dB in the 10 to 20 dB range.
- OTDRs are expected to maintain reasonable accuracy over very wide ranges of measurements (some spanning more than 35 dB of backscatter levels) and thus require good linearity over the entire optical input range of the sensor. Linearity problems in an OTDR are often revealed as rolling off or bumpy appearances of the displayed optical fiber trace.
- Fresnel reflections are generally outside the measurement range of the sensor and are not considered in the linearity specifications. However, the trace display during the recovery period after a reflection often exhibits characteristics of nonlinearity as the incoming power level transitions from extremely high to very low.

There are three components to distance accuracy of an OTDR:

- Clock stability
- Data point spacing
- IOR uncertainty

The accuracy of distance measurements depends on the stability and accuracy of the clock circuit, which times the pulses going out and the interval between sampling of the sensor output. Clock accuracy is stated as a percentage that relates to percentage of distance measured.

For instance, an accuracy of 0.01 percent of distance means that if the distance to the end of the optical fiber is measured as 6.1 km (20,013 ft), then the accuracy of this measurement is ± 2 ft (20,013 × 0.0001). If the clock runs too fast or too slow, then the time measurements will be shorter or longer than the actual value.

An OTDR can only make accurate distance measurements based on the actual data points it takes. The closer the data points are spaced, the more likely one of them will fall close to, or on, a fault in the optical fiber.

Optical Time Domain Reflectometer (OTDR) Specifications, continued

Distance using an OTDR is calculated from the speed of light in the optical fiber. The speed of light in optical fiber is calculated from the speed of light in free space (a constant value) divided by IOR. This means that IOR settable by the user is critical in accurate measurement of distance. If the IOR is wrong, then the distance will be wrong.

The characteristics of an optical fiber can change along its length, producing slight variations in its IOR, and therefore cause distance inaccuracies. Thus, an inaccurate optical fiber distance measurement is due to the variance of IOR within the same optical fiber and between two or more optical fibers spliced together.

In most cases, use the optical fiber manufacturer's recommended IOR setting for the optical fiber type and wavelength to be tested. These values were obtained from the optical fiber manufacturer and represent typical values, but they may change with new optical fiber types and processes. Check with the optical fiber manufacturer if there are any questions about the IOR.

Wavelength

Optical fiber is used and tested at the following wavelengths—850 nm, 1310 nm, and 1550 nm. Multimode optical fibers work in the 850 nm and 1300 nm bands. Singlemode optical fibers work in the 1310 nm and 1550 nm bands. OTDR measurements are made at the same wavelength at which the optical fiber system will be operated.

The measuring wavelength of an OTDR is listed as its central wavelength with a certain spectral width. Linewidth is the spread of wavelengths around the central wavelength of the laser source. For example, a laser with a central wavelength of 1300 nm and a linewidth of 20 nm will include wavelengths from 1290 nm (1300 – 10) to 1310 nm (1300 + 10). Lasers with narrow line widths are more expensive than those with wide line widths. Central wavelengths are normally specified as being within a certain tolerance (e.g., ± 30 nm).

Loss in optical fiber is wavelength dependent. It is important to test optical fiber at about the same wavelength at which it will be operated. Optical transmitters (lasers and LEDs) are generally specified by their wavelength band (e.g., 850, 1300, 1550 nm).

The specific central wavelength and linewidth is not always clearly listed. In some cases, if a test for attenuation is made at one end of a wavelength band (at 1320 nm, for instance), then the test signal will be attenuated at a slightly different amount than the operating signal. In long optical fiber runs, this could lead to unexpected problems at the receive end of the system.

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Operation

The following discussion will assist in understanding the operation of an OTDR.

Configuration

Choosing the configuration of an OTDR depends on the optical fiber to be tested. OTDRs can measure only one optical fiber type at a time—singlemode or multimode. Either a single or dual wavelength measuring capability for each type of optical fiber can be selected. OTDRs are capable of testing 850 nm and 1300 nm multimode and 1310 nm or 1550 nm singlemode cables.

Mainframe and Optical Card

In the modular design, the OTDR mainframe contains the controller, display, operator controls, and optional equipment (e.g., printers, plotters, external interfaces, modems). The optical card, consisting of the laser source and optical sensor sections, is plugged into the mainframe and can be changed to allow testing at various wavelength and optical fiber type combinations.

NOTE: All OTDRs are not set up as modular.

Optical Fiber Type

An optical network interface card (NIC) is limited to working with either singlemode or multimode optical fiber. The primary difference between these two optical fiber types is the diameter of the optical fiber core; multimode cores are at least five times larger than singlemode. Because an OTDR must both send and receive light, it cannot efficiently connect with both optical fiber types.

For example, a module designed for singlemode optical fiber will couple light into both singlemode and multimode optical fibers easily. When the light returns, most of the backscatter from the multimode optical fiber will be lost as it tries to couple into the smaller core of the singlemode optical fiber going to the detector.

Singlemode optical fiber cores are all about the same size—between 8 and 9 µm in diameter. A singlemode optical module is optimized for best light adapter in this diameter range. Multimode optical fiber core diameters are 50/125 µm and 62.5/125 µm. A multimode optical card is optimized at only one of these core sizes internally although it will be able to measure the two core sizes without difficulty.

Operation, continued

Wavelength

The test wavelength is one of the important specifications of an OTDR. It is critical to test an optical fiber system at the same wavelength at which it will operate. However, it may be useful to test the system at the other wavelength.

Shorter wavelengths of light exhibit greater amounts of attenuation in the same optical fiber because of their higher sensitivity to Rayleigh scattering. Longer wavelengths are more sensitive to bending loss and will allow light to exit out of the optical fiber core more than shorter wavelengths. This indicates that an optical fiber that has been stressed by bending will show a greater loss at the point of bending when tested at 1550 nm than it will at 1300 nm even though the overall end-to-end attenuation will be lower at 1550 nm than at 1300 nm.

The sensitivity of different wavelengths of light to different loss mechanisms in optical fiber can be a very important tool in troubleshooting optical fiber cabling.

Connector

Optical fiber systems are always connectorized before they are put into use. Either a connector is field installed on the optical fiber or a preconnectorized optical fiber pigtail cable is spliced onto the optical fiber end. The connector on the OTDR should match the connector of the optical fiber system for best results. Some OTDRs offer universal-type connectors that change in the field. Other OTDRs have fixed nonchangeable connectors.

When making a connection to a nonconnectorized, bare optical fiber, the use of a pigtail is recommended. This is the same as a jumper, but it has only one end connectorized. The other end is bare optical fiber, so a temporary splice to the bare optical fiber end to be tested can be made.

Measurement Parameters

Once an OTDR has been properly configured for the optical fiber system to be measured, the test can be made. There are few decisions that must be made in determining the instrument setup conditions to get the best results. Many of these measurement parameters only need to be set once and will remain in the instrument's memory. If trace data can be stored in the OTDR's memory or on a diskette, the setup information is normally recalled when the trace is recalled back to the screen.

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Operation, continued

Distance Range

Distance range also is known as display range. It limits the amount of optical fiber that will be displayed on the screen. The distance range must be longer than the optical fiber to be tested. The distance range affects test accuracy and the time required to complete a test.

Since an OTDR must send out one test pulse at a time and allow all returns from the pulse to get back to the detector before sending out another pulse, the distance range determines the rate at which test pulses are sent. This is known as the pulse repetition rate (PRR). The faster the rate, the quicker the averaging time for a given number of averages.

Because a longer optical fiber requires longer pulse transit times, the overall averaging is slower for longer distance ranges because the PRR is slower. If a long optical fiber is tested using a shorter distance range, there is a possibility that a new test pulse will be sent into the optical fiber before all the return signals from the previous pulse are received by the OTDR detector.

The resultant multiple received signal levels will produce unpredictable results on the OTDR display and will affect level measurements. It may produce ghosts in the optical fiber trace.

Resolution

Measurement resolution (spacing between data points) can be selected on some OTDR configurations. Higher resolutions (closer data points) will provide more detail about an optical fiber, but a test will usually take longer than one made at a lower resolution.

Higher resolution can provide more accurate location of an event. For instance, if an OTDR takes measurements every 8 m (26 ft) along an optical fiber, it is likely that a break could occur 7 m (23 ft) after a data point. The resulting Fresnel reflection would appear to start at the following point, with the last backscatter level occurring at the previous point.

Because distance to a break is always located at the last backscatter level prior to a Fresnel reflection, the actual location of the break (reflection) would be off by 7 m (23 ft). If the data point resolution were shortened to 0.5 m (1.6 ft), the reflection location would be more accurately located to within about 0.3 m (1 ft).

Resolution should not be confused with the horizontal display scale. The cursor resolution (how short a distance the cursor can be moved on the screen) has nothing to do with data point spacing. Most cursors can be placed between data points and thus appear to offer a better resolution.

Operation, continued

Pulse Width

The duration of the laser pulse can be changed by the operator. By selecting a long, medium, or short pulse width, the operator can control the amount of backscatter level coming back and the dead zone size.

A long pulse width will inject the highest amount of optical power into the optical fiber and will travel farther down the optical fiber and produce stronger backscatter levels. It will produce the longest dead zones. Conversely, a short pulse width will give the shortest dead zones, but it will send back weaker backscatter.

Long pulse widths give the maximum dynamic range for an OTDR and are used to quickly find defects and breaks in an optical fiber. Because the backscatter levels are higher, shorter averaging times are required to get a clean trace.

Short pulse widths are used to look at the part of the optical fiber that is closest to the OTDR. Because of the shorter dead zone, it can detect details in the optical fiber backscatter just past a Fresnel reflection. Because of the lower levels of backscatter, longer averaging times are needed.

The rule of thumb for setting the pulse width is long pulse to look long and short pulse to look short.

Averaging

The data points obtained from a single measurement pulse may vary in level from one to the next even though there is little change in the pulse they came from. The resulting trace looks noisy or fuzzy.

To obtain a more reliable and smoother looking trace, OTDRs send out thousands of measurement pulses every second. Every pulse provides a set of data points, which are then averaged together with the data from previous pulses to improve the signal-to-noise ratio (SNR) of the trace.

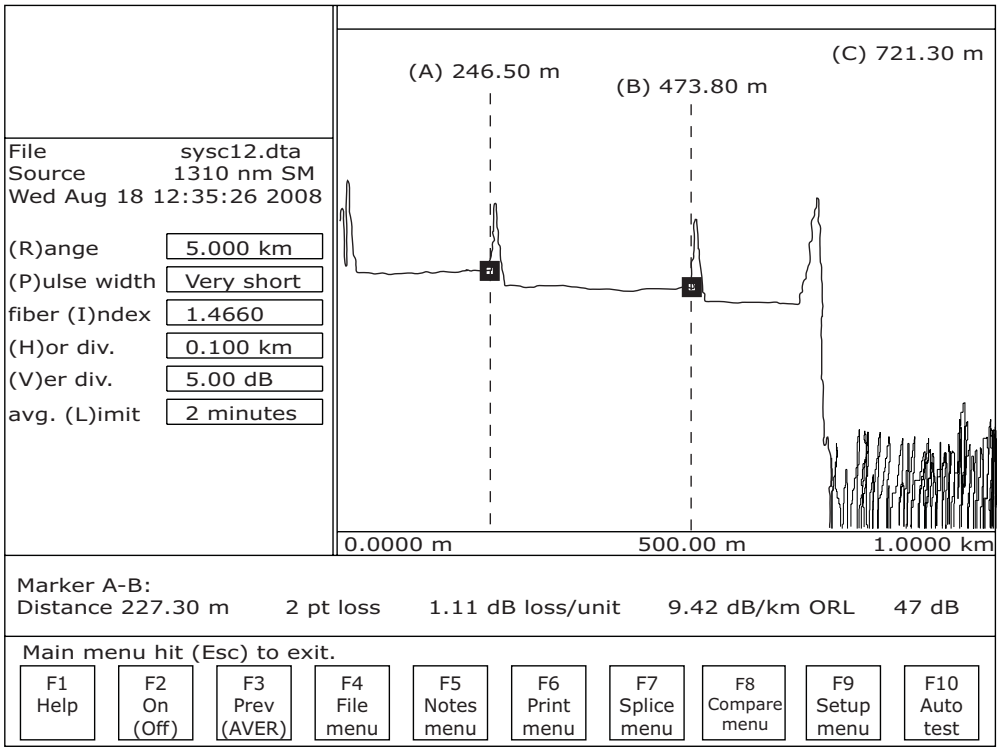
Averaging takes time. Usually, a lot of averaging is required when a long optical fiber is being tested or when a short pulse width is being used. The operator can preset the amount of averaging that occurs so that test results will be consistent.

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Operation, continued

After an optical fiber has been scanned and the resulting trace is displayed on the screen, the operator must interpret the trace. Cursors are used to select the end points of measurements. The numerical results are displayed on the screen (see Figure 6.53).

Figure 6.53
Interpret optical fiber trace



dB = Decibel
km = Kilometer
m = Meter
nm = Nanometer

Fault Location

The most critical measurement that is made with an OTDR is the location of a defect or break in the optical fiber. To repair a fault, the precise location must be located.

A Fresnel reflection occurs at all optical fiber faults. This appears as either a sudden spike or drop off of the optical fiber trace, indicating that the OTDR pulse has encountered a sudden change in the density of the glass; that is, it encountered air at the end of the optical fiber.

The distance to this reflection on an OTDR trace is the point at which the trace spikes up. If the trace recovers to the backscatter level after the reflection, then the optical fiber is not completely broken. The amount of shift in the backscatter level from before the reflection to after the reflection indicates how much light is lost at the fault.

Operation, continued

Some mechanical splices produce a Fresnel reflection. It is important to know where mechanical splices are located in an optical fiber to keep from mistaking them for faults.

Distance Measurements

The distance to a cursor is displayed on the screen. By simply moving a cursor to any point on the trace, the operator can read the distance to that point from the OTDR. Units of measurement can usually be selected to display distance in meters (feet) or kilometers (miles).

The measured distance to an event in an optical fiber (e.g., mechanical splice, fusion splice, optical fiber end) depends on where the cursor is placed. To obtain the most accurate distance measurements, always place the cursor on the last point of backscatter just prior to an event.

In other words, place the cursor at the point just before a reflection so that the cursor does not ride up on the spike. For a nonreflective event (e.g., fusion splice, optical fiber macrobend), place the cursor at the point just before the trace drops (or rises).

When two cursors are used, the OTDR will display the distance to each cursor from the OTDR as well as the distance between the two cursors. This feature is used to isolate sections of an optical fiber.

Loss Measurements

Loss measurements are indicated between two or more cursors. Loss can only be accurately measured from backscatter level to backscatter level. This means that both cursors must not be on a Fresnel reflection or in a dead zone.

- Overall loss—Estimate the end-to-end attenuation of an optical fiber by placing one cursor just to the right of the near-end dead zone and another cursor just to the left of the far-end Fresnel reflection. The loss from cursor to cursor is read on the screen.

NOTE: This means of measurement is not as accurate as an end-to-end attenuation measurement made with an OLTS because it does not count the connection.

- Section loss—Measure the loss in a section of optical fiber by placing two cursors on the ends of the section to be measured and reading the level difference between the two.
- Splice loss—A splice is identified as a shift in the backscatter level. It can appear as a drop off or even a rise or gain. There may be a Fresnel reflection if it is a mechanical splice. A splice loss occurs at a single point in the optical fiber. A bend or point of stress may show up as a point loss. The loss at a single point can be measured two ways:
  - Two-point method—The two-point method is identical to the way section loss is measured, except that the two cursors are placed as close together as possible, with the left cursor set just to the left of the point to be measured and the right cursor set as close as possible on the right side of the loss event but still on the backscatter. The backscatter level at a point loss does not shift directly down but has a slight roll-off to it. The length of the roll-off region is related to the pulse width (e.g., just like the distance taken up by a Fresnel reflection).

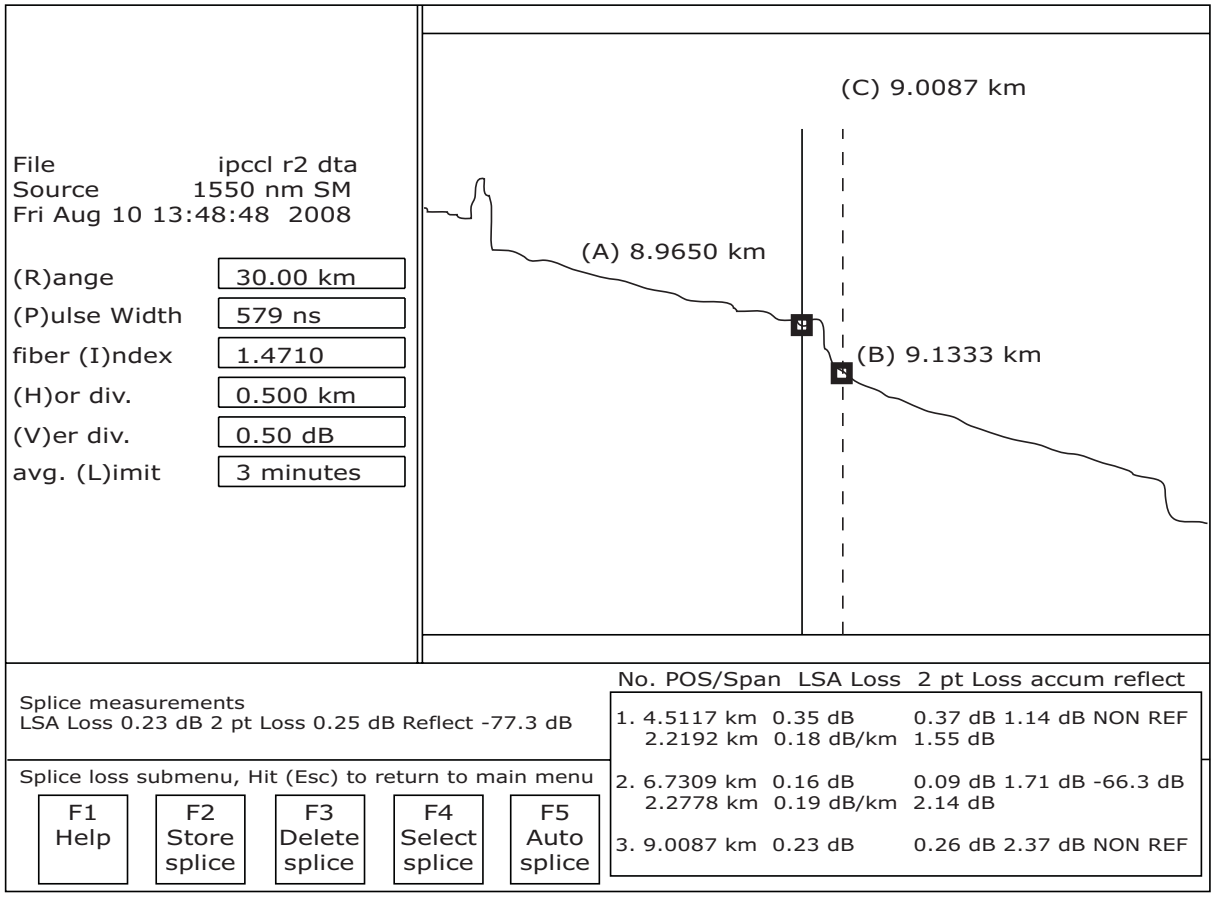
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Operation, continued

– Because valid loss measurements can only be taken from backscatter to backscatter, the right cursor cannot use any part of this roll-off portion. This forces the right cursor to be placed farther out on the optical fiber than the next data point after the loss occurs. Consequently, the level measurement between the two points includes the loss occurring at the point plus an amount of loss that would normally occur over such a distance although this is usually minimal.

– Least squares averaging (LSA) splice loss method—The LSA splice loss method uses a mathematical technique called least squares averaging to eliminate the distance induced loss found in the two-point method (see Figure 6.54). The operator places a cursor on the point to be measured and selects LSA splice loss from the control panel. The OTDR then determines what the loss would be if the drop in backscatter level display was straight down instead of rolling off.

Figure 6.54
Least squares averaging splice loss



dB = Decibel
km = Kilometer
nm = Nanometer
ns = Nanosecond

Operation, continued

Quality Factor

The measurement of loss per unit distance (db/km) is a common method for determining an optical fiber's quality. Less loss per unit length means a stronger signal at the receiver. Optical fiber cable is ordered based on its type (singlemode/multimode) and its loss per km at a specified wavelength. Typical values for singlemode optical fiber at 1310 nm are 0.3 to 1.0 dB/km. At 1550 nm, this drops to 0.2 to 0.50 dB/km. For multimode optical fiber, the values range from 1.0 to 3.5 dB/km.

The quality factor is automatically calculated for an optical fiber when two cursors are set on the trace and the dB/km measurement is selected from the control panel. The OTDR displays the distance and loss between the two cursors and calculates the dB/km value by dividing the distance into the loss. The quality factor will be skewed if there are any splices or connectors in the optical fiber section displayed between the cursors.

Reflectance

The amount of reflection at the location of a connector, optical fiber break, or mechanical splice depends on a connector's polish, the angle of cleave or break, and how much the IOR changes when the light leaves the optical fiber. Most mechanical splices use an index-matching gel or fluid to reduce the amount of change. Smaller changes in the IOR produce smaller reflections.

Some OTDRs can measure the amount of reflecting light automatically by placing one cursor just in front of the reflection and pressing the appropriate button on the control panel. Reflectance is measured in –dB (negative decibels) with a small negative value indicating a larger reflection than a large negative value. That is, a reflectance of –33 dB is larger than a reflectance of –60 dB. The larger reflectance will show up as a higher spike on the trace. This connector reflectance is known as return loss.

By knowing the level of reflectance at a connector, it is possible to determine whether a problem is occurring very close to the connector (e.g., pigtail splice, in the connector strain-relief part). If the OTDR measures the distance to the far connector to be the correct length but the reflectance is not as good as it was previously, the optical fiber might be fractured just millimeters (inches) short of the connector end face, causing a lower reflection because of the ragged edges of the shattered glass.

Since the connectors are the most frequently handled part of the optical fiber, it is easy to damage the optical fiber next to the connector and not realize it. An OTDR can be used to isolate this type of problem by utilizing its reflectance-measuring capabilities.

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Measurement Problems

A trained and experienced OTDR operator may have difficulty interpreting an optical fiber trace. There are a few cases where it is almost impossible to get an exact distance or loss determination based on one measurement. In some extraordinary circumstances, it may be necessary to test an optical fiber with different setup conditions or from both ends to get meaningful results.

Nonreflective Break

When an optical fiber is cut or broken, the end may shatter in such a way that the angle at which the light is hitting the end may not reflect at all. The end of the optical fiber may become immersed in a liquid, which may eliminate the Fresnel reflection. When this happens, the trace will suddenly fall into the noise level. There may be a rounding-off of the back-scatter where it falls off so that it may be difficult to judge where the fall-off point is. The best method to determine the break point is to use the two-point loss method to detect at which point the backscatter level drops off by 0.5 dB.

Place the left cursor as near to the end as possible but still on the backscatter. Move the right cursor in toward the left cursor until the loss between the two reads 0.5 dB. The actual end of the optical fiber should be very close to the point measured by the right cursor. To increase confidence in this location, take the OTDR to the other end of the optical fiber and test back to the break from the other side. It is possible that the other side of the break will reflect some light. (Keep in mind that the optical fiber could be broken at more than one point.)

Gain Splice

Sometimes, when two optical fibers are spliced together, the backscatter level at the splice point shifts up instead of down. At first glance, this would appear to be a gain in power at the splice. The OTDR may even indicate a negative splice loss. This means that the two optical fibers were mismatched; the second optical fiber has a higher backscattering coefficient than the first, and more light is scattered back by it. The OTDR sensor reads this as a higher level than the end of the first optical fiber and plots the corresponding data points higher up on the screen.

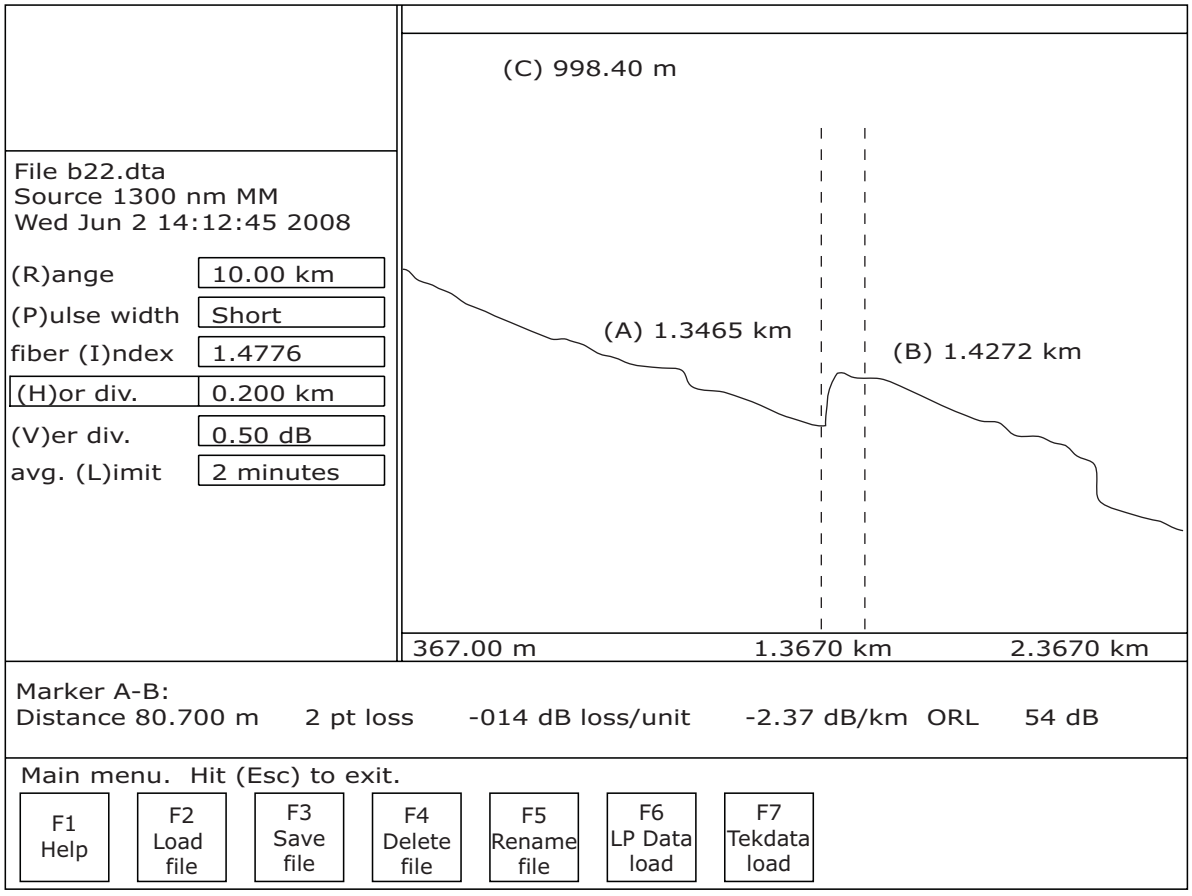
If the same splice were tested from the opposite direction, the OTDR would indicate a higher normal loss than the amount of the negative loss. In this case, the true splice loss value is the average of the difference between the two readings. That is, if the gainer reads 0.25 dB and the opposite direction reads 0.45 dB, then the actual splice loss is 0.1 dB ([0.45 – 0.25]/2).

Measurement Problems, continued

Figure 6.55 shows what a gain splice looks like on an OTDR display in comparison to a normal splice. Note that the slopes of the two optical fiber traces are different. The second optical fiber has a steeper slope than the first optical fiber, which indicates a higher back-scatter level throughout the optical fiber. It would normally appear higher on the screen than the first optical fiber because it returns more light to the OTDR.

A difference in IOR can produce different backscatter levels and thus different slopes of the trace. The other possible cause of gain is that the mode field diameter, which is related to the optical fiber's core size, is different for the two optical fibers. This causes more back-scattering to come back from the second optical fiber. When a gain splice occurs, it is because the two optical fibers being spliced together are mismatched in some way.

Figure 6.55
Gain splice



dB = Decibel
km = Kilometer
m = Meter
nm = Nanometer

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Measurement Problems, continued

The average of all splices in an optical fiber span (one or more optical fibers spliced together to make a continuous optical fiber link from one connector end to the other) is usually the benchmark used in construction of a system. If the average is equal to or better than the goal, the overall loss budget as planned will be met. Gain splices can be confusing in determining splice loss averages because they usually are displayed as a negative loss on the OTDR.

To determine the average splice loss value for a series of splices in an optical fiber span, include the gain splice values along with the normal loss values. In other words, use both the positive and negative values as displayed by the OTDR in summing the total of all splice loss values.

The most accurate method of determining the average splice loss values in an optical fiber span is to make a bidirectional measurement of each splice; that is, measure the splice of optical fiber A to optical fiber B, first from the end of optical fiber A and then from the end of optical fiber B. This method is time consuming and can usually only be done after the entire system has been spliced. The next best method is to take the one-direction average of all splices in a span using only the splice values measured from the same direction.

Normally, when a gain occurs, the next splice will be a higher-than-normal loss since the optical fiber with the higher backscatter level causing the gain will cause a higher measured loss going to the next optical fiber. The effects of the two splice measurements will cancel out. Avoid calculating splice loss averages using one-directional splice loss values when the individual splice values along the span were measured from different directions.

Ghost Reflection

Sometimes a Fresnel reflection can be seen where it is not expected—usually after the end of the optical fiber. This usually happens when a large reflection occurs in a short optical fiber. The reflected light actually bounces back and forth within the optical fiber, causing one or more false reflections to show up at multiple distances from the initial large (true) reflection.

That is, if a large reflection occurs at 400 m (1312 ft) and there is an unexpected reflection at 800 m (2625 ft), which is twice the distance to the first, and another at 1200 m (3937 ft), which is three times the distance to the first, then it is likely the second and third reflections are ghosts.

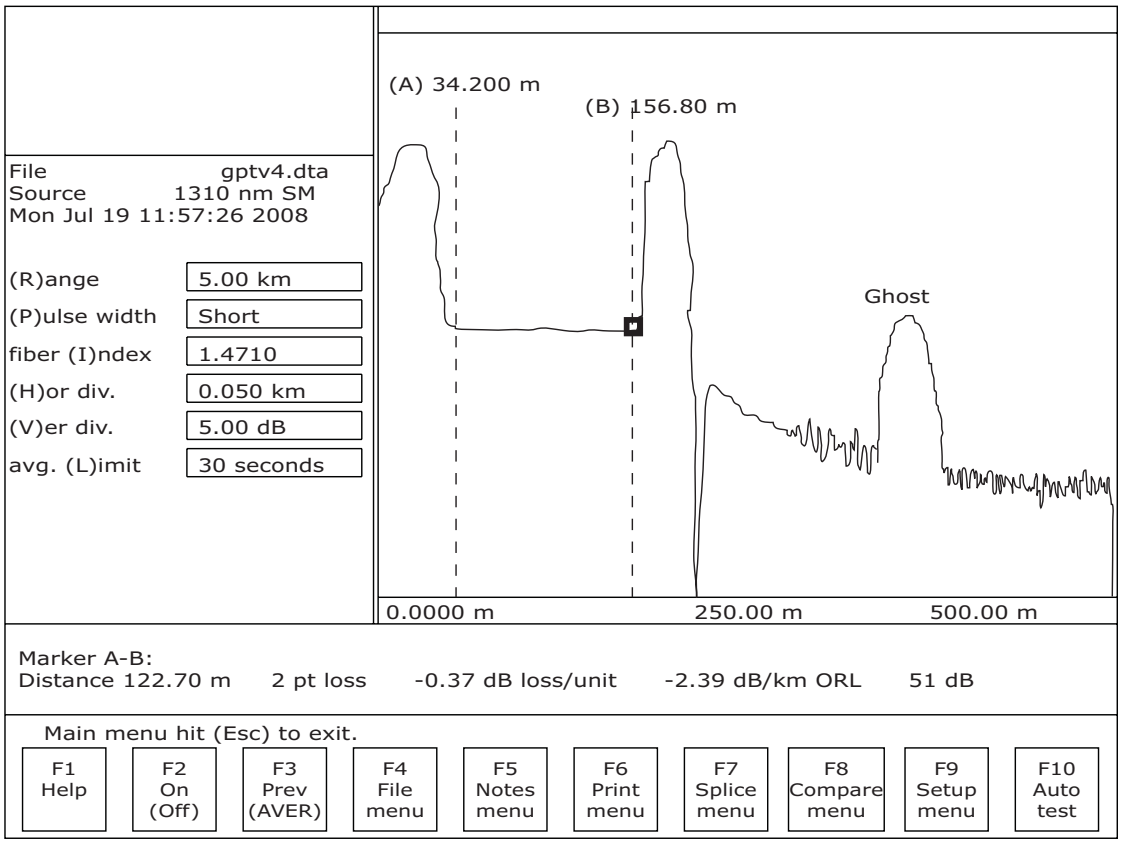
The cause of the ghost is a large reflective event at a point in the passive fiber link where there is a change in media (IOR). This occurs at the connector or the end of the fiber, the change from glass to air. The energy reflected back to the OTDR is of such intensity that the light pulse is reflected off of the connector at the OTDR and is again returned a second time. As the OTDR converts the travel time of the light pulse into distance, the reflective event is displayed on the screen for a second time.

Measurement Problems, continued

Here are a few techniques to use to determine whether ghosts are occurring and to eliminate them:

- Measure the distance to the suspect reflection. Place a cursor half this distance on the optical fiber. If an expected reflection is at the halfway mark, then the suspect is probably a ghost.
  - Change the distance range (display range) of the OTDR. In some OTDRs, a ghost is caused when the distance range is too short.
- Measure the loss across the suspected reflection if a ghost seems to occur in the optical fiber. A ghost will show no loss across it when doing a splice loss measurement (see Figure 6.56).

Figure 6.56
Ghost reflection



dB = Decibel
km = Kilometer
m = Meter

Remember that a ghost is a fault. It is normally caused by the end face of the connector being overpolished, creating an air gap between the two connector end faces.

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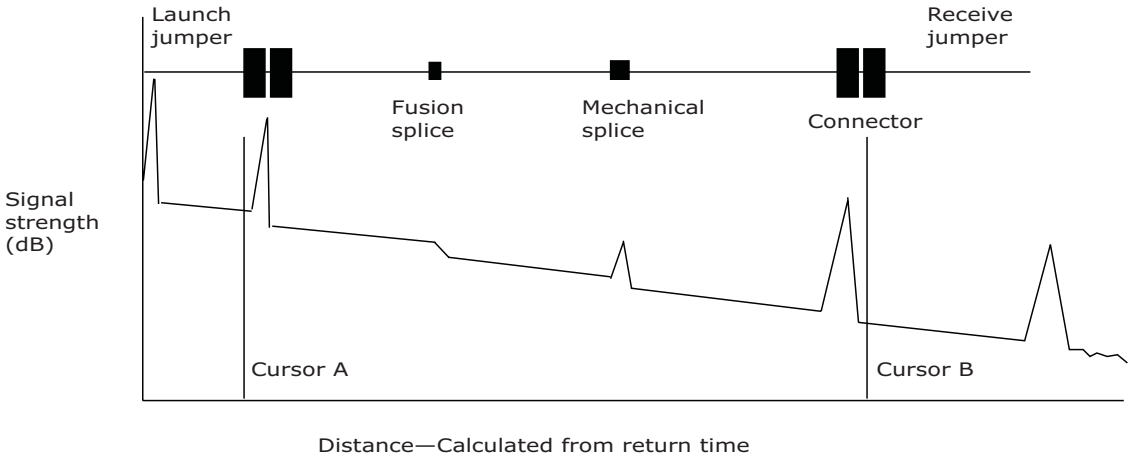
Testing Procedures

This section discusses the setup and testing procedure used with OTDR.

Considerations

The testing setup required is dependent on the optical fiber system under consideration. The first and probably the most frequently used OTDR test is the determination of the overall attenuation and characterization of the optical fiber link. Figure 6.57 shows the components to be tested and their relationship to the OTDR screen display. The cursors are positioned to measure the overall attenuation of the link under test.

Figure 6.57
Optical time domain reflectometer test configuration—end-to-end attenuation



dB = Decibel

The components required to complete this test are the OTDR, connecting jumpers, and the test link. To complete this test correctly, it is imperative that the correct launch and receive jumpers are used. As stated in the discussion of the dead zone, there are two points at which a measurement cannot be made. This is the beginning and end point of the optical fiber. One method of overcoming this limitation is the selection of the launch and receive jumpers.

To make any loss measurement in optical fiber, backscatter must be seen at both sides of the event. Since the dead zone at the OTDR may be from a few meters (feet) to more than a kilometer (mile) in length, select the launch jumper that has enough length to allow the system to recover prior to the first connector of the optical fiber to be measured.

As a rule of thumb, when testing multimode optical fiber in the LAN, the minimum length of the launch jumpers should be at least 100 m (328 ft). The jumper at the receive end must be of sufficient length to allow the system to recover and again show sufficient backscatter to allow a measurement. For singlemode, the launch jumper must be longer than the dead zone of the longest pulse width of the OTDR.

Testing Procedures, continued

Once this field test setup has been established, it is now possible to test all of the parameters necessary to completely characterize the optical fiber link. By positioning the cursors on each side of the event, determine the loss of each connector and splice as well as the loss per kilometer of each optical fiber segment within the link.

NOTE: Refer to the Measurement Parameters section in this chapter for additional details on interpreting the test results.

Accuracy is dependent on how well the cursors are positioned when the readings are taken. The view angle of the screen when placing the cursor makes a difference. The addition of more computing power built into today's field test sets provides some additional capability, which makes this difficult part of the ITS installer's job easier to accomplish accurately and quickly.

Automatic Measurements

The latest model OTDRs have the additional capability to automatically configure themselves and perform standard measurements. These autoranging and autoanalysis features allow each operator to make the same precise, consistent measurements on any optical fiber.

Autorange Feature

Autoranging, known as automode or autosetup, sets the variable distance range (display range) of the OTDR as well as the pulse width and resolution to the best settings for the optical fiber under test.

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Automatic Measurements, continued

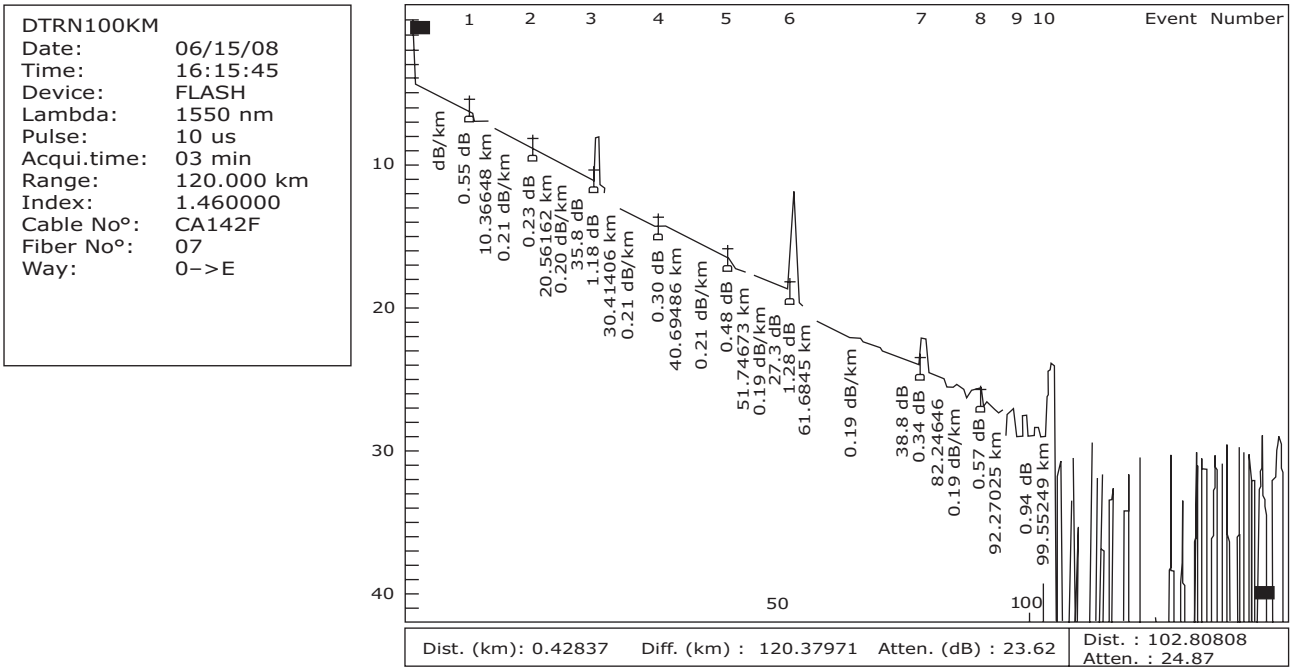
Optical Fiber Analysis Software

One of the most important tasks in using an OTDR is being able to interpret the optical fiber trace correctly (see Figure 6.58). The optical fiber analysis feature can perform this task by using the computer part of the OTDR to scan and analyze the digital test results obtained from the optical fiber. It will look for:

- Shifts in the backscatter level, which indicate splice losses or defects.
- Sudden spikes up from the backscatter, which indicate Fresnel reflections (e.g., usually mechanical splices, breaks, optical fiber terminations).

It will measure the loss in each of these events that it finds. The results are summarized in Table 6.13, which lists each event and its location, loss, and reflectance (if any).

Figure 6.58
Optical time domain reflectometer trace with automatic event selection



dB = Decibel
km = Kilometer
nm = Nanometer

Automatic Measurements, continued

Some OTDRs will link the event table to the actual trace so it can be seen where each event is situated in relation to the others (see Table 6.13). Events may be deleted and added. Text comments may be added for each event. This capability will allow complete documentation for each optical fiber for use in maintenance or for providing detailed records to customers.

Most OTDR manufacturers who use the autoanalysis feature have a similar stand-alone program available for use on a desktop or laptop computer. If the OTDR has the capacity for storing test data (e.g., universal serial bus [USB] port for storage device insertion), it can load a previous test either into the OTDR or into the computer and run the analysis software. This stand-alone software is a good choice if using an older OTDR that does not have built-in analysis but does have trace data storage.

Table 6.13
Event table linked to Figure 6.58

Event Number	Distance (km)	Attenuation	Reflectance	Relative Distance	Slope	Link Budget	Uncertainty
1	10.36648	0.55		10.36648	0.20	2.03	
2	20.56162	0.23		10.19531	0.21	4.22	
3	30.41406	1.18	–35.8	9.85244	0.20	6.21	
4	40.69486	–0.30		10.28081	0.21	8.32	
5	51.74673	0.48		11.05187	0.21	10.64	
6	61.68485	1.28	–27.3	9.93811	0.19	12.57	
7	82.24646	0.34	–38.8	20.56162	0.19	16.53	
8	92.27025	0.57		10.02379	0.19	18.46	
9	99.55249	0.94		7.28224	0.25	20.27	Two points
10	102.20836	25.96	> –32.2	2.65588			

km = Kilometer

Automatic optical fiber analysis routines do not always find all the events in an optical fiber and sometimes will find events that are not there. If splices are very good and it is difficult to find the splice on the trace, the software will probably have trouble finding and measuring them.

The ability of the software to locate an event depends on the thresholds setup, the length of the optical fiber, and the amount of averaging done on the trace. There is an option of setting the sensitivity of the analysis routine so that it will only find events that meet or exceed a certain threshold.

If the threshold is set to 0.2 dB, the software will not mark splices with lower losses. When measuring very long optical fibers, the far end of the trace may be very noisy with the individual data points fluctuating up and down from one to the next. This fluctuation may cause the software to find a false event that is not there. Decrease the noise in the trace by increasing the averaging time (scan time). Reduce the number of false events by keeping the loss threshold above 0.1 dB.

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Interferometer Inspection

Inspection of the end face of an optical fiber connector in the field is normally accomplished by using a microscope, generally 100× to 200×.

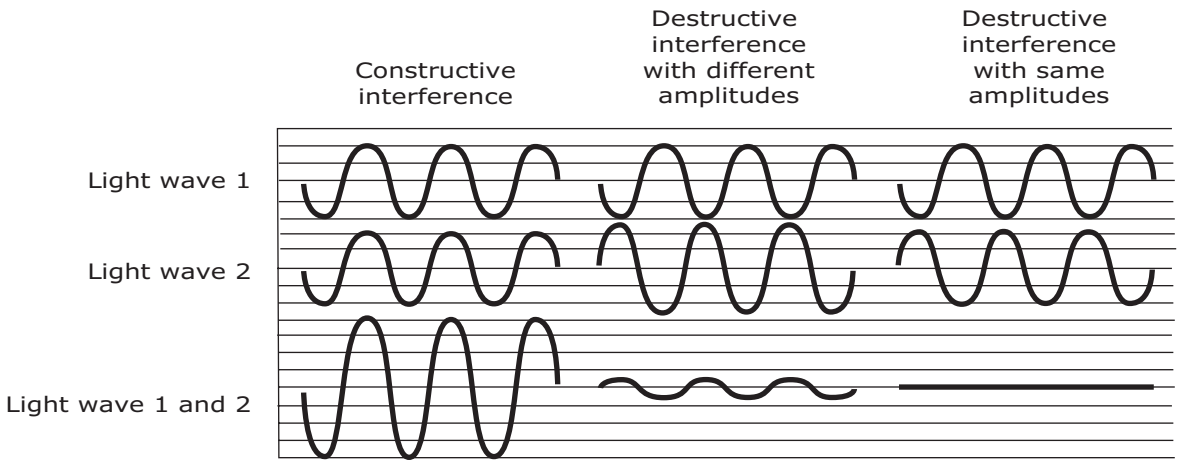
The optical fiber connector end face meets the cleanliness and damage criteria. An additional test set, called an interferometer, is required to view the end face in three dimensions.

Lightwave interference occurs when two or more waves of the same frequency or wavelength combine to form a single wave whose amplitude is the sum of the amplitudes of the combined waves. Constructive and destructive interference is the most striking examples of lightwave interference.

Constructive interference occurs when the lightwaves are completely in phase with each other (the peak of one wave coincides with the peak of the other wave).

Destructive interference occurs when the lightwaves are completely out of phase with each other (the peak of one wave coincides with the trough of the other wave). Refer to Figure 6.59 for an illustration of constructive and destructive interference.

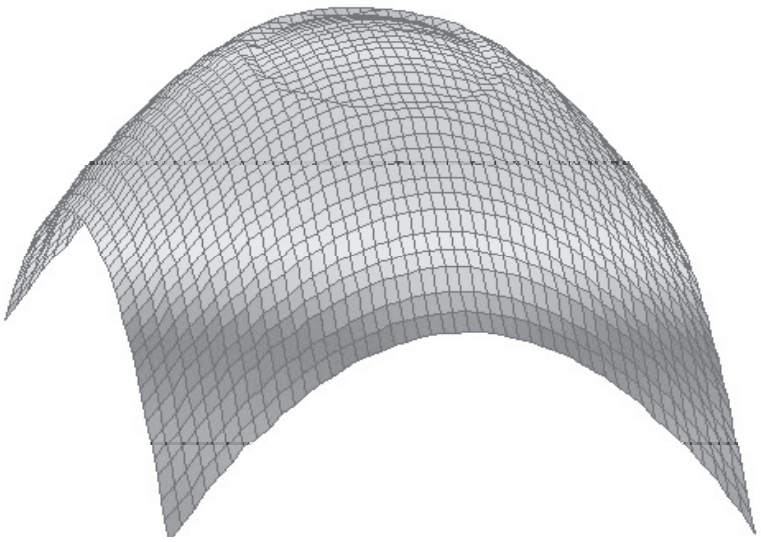
Figure 6.59
Constructive and destructive interference



Interferometer Inspection, continued

Based on the above, the interferometer provides three-dimensional information about the end face geometry of the optical fiber connector (see Figure 6.60).

Figure 6.60
Three-dimensional view of connector end face



The interferometer tests three specific components of the connector:

- Radius of curvature (RoC)
- Offset of polish
- Optical fiber height

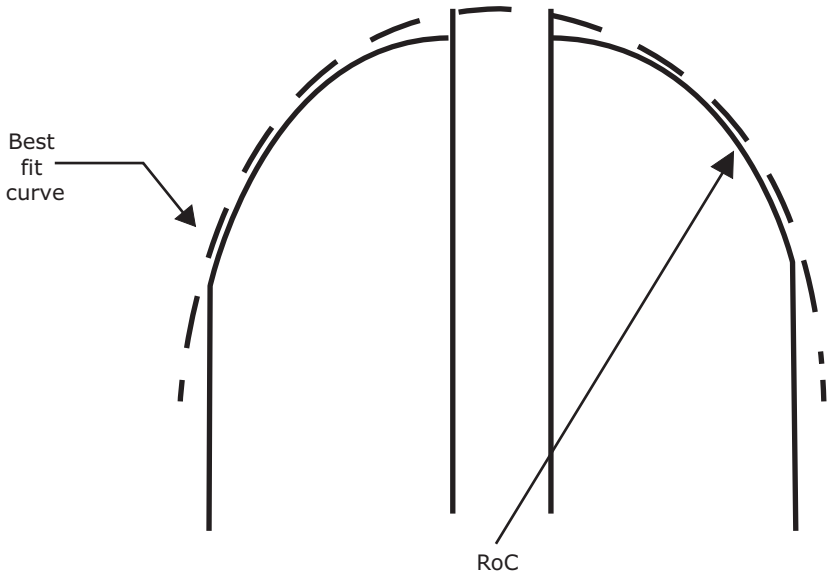
Radius of Curvature (RoC)

This portion of the test determines the overall diameter of the best fit sphere and its relationship to the actual end of the connector under test (see Figure 6.61).

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Interferometer Inspection, continued

Figure 6.61
Best fit sphere

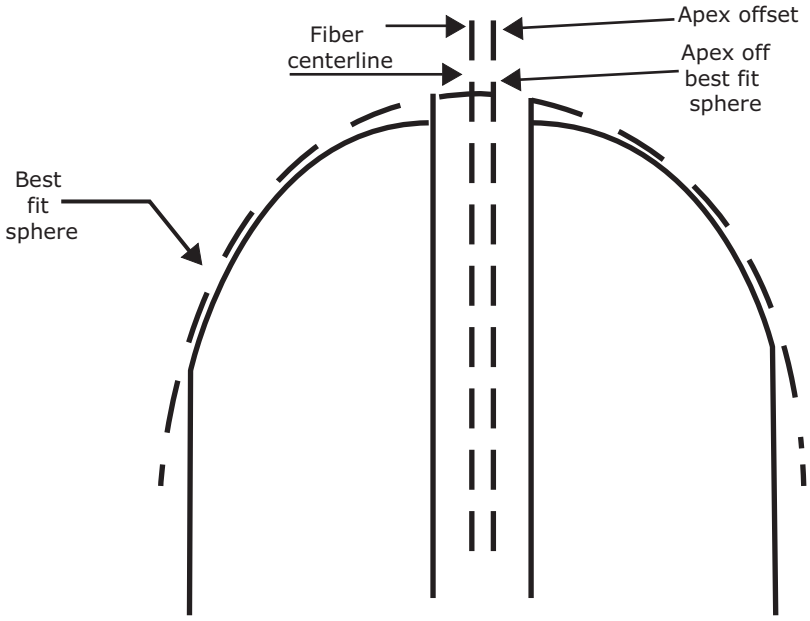


RoC = Radius of curvature

Offset of Polish

The offset of polish determines the actual centerline of the fiber and its relationship to the actual centerline of the best fit curve. With the ideal connector, both centerlines would be the same (see Figure 6.62).

Figure 6.62
Offset of polish

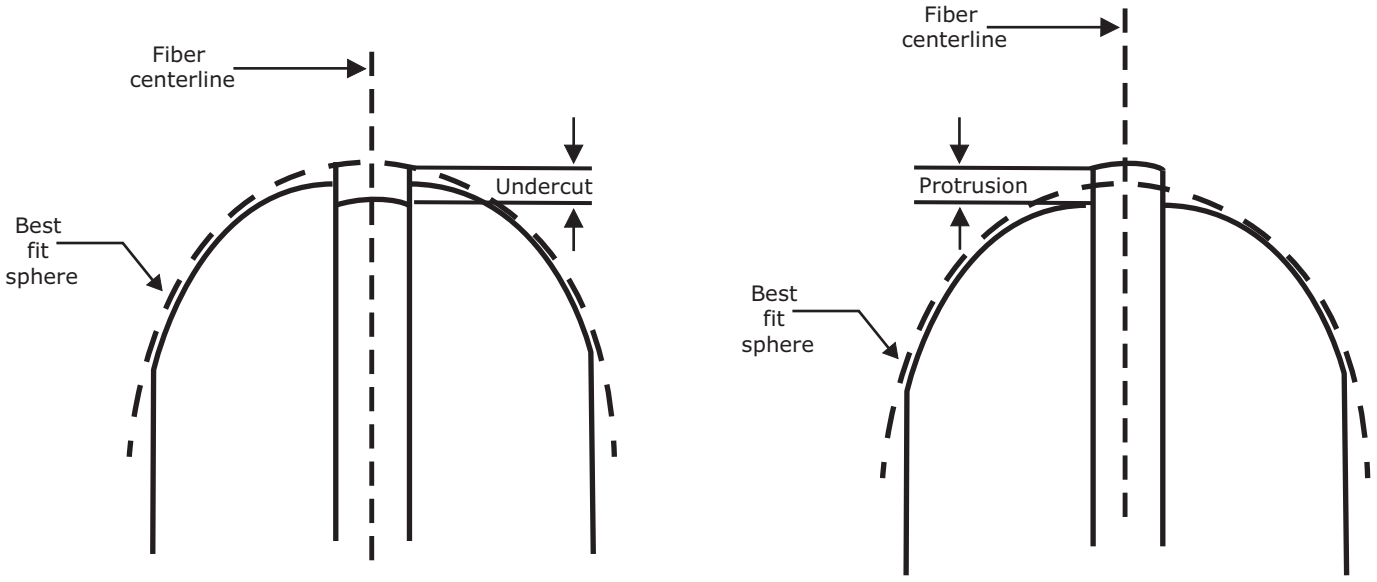


Interferometer Inspection, continued

Optical Fiber Height

The optical fiber height portion of the evaluation determines the amount of optical fiber that is above or below the end of the connector end face (see Figure 6.63).

Figure 6.63
Optical fiber height



The use of interferometry helps guarantee optical performance by providing consistent quality control of the polishing process. This quality control assures long-term stability when connectors are exposed over time to changes in temperature, pressure, and the affects of vibration.

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Field Test Equipment Selection

Overview

Some optical fiber analysis software will provide the ability to preset the location of the splice points into a template or master trace file. All the other optical fibers in the cable can be run against this master to obtain only the measurements on the splices known to be there. By measuring only specific known points, an overall cable loss table can be created by exporting the analysis results to a spreadsheet or database. This is an excellent way to manage optical fibers and to determine if the splices or other sections of the optical fiber are deteriorating over time.

The field test equipment represents a major investment. Several factors must be considered. Basic test equipment includes VFL and optical fiber flashlight, which involve a comparatively small investment.

Field test equipment (e.g., certification field test set, OLTS, interferometer, OTDR) involves high-cost items and requires more research prior to purchasing.

Some of the questions to ask before making a major purchase include:

- What type of media will be tested—copper or optical fiber?
- If copper, which of the several types will be primary?
- If optical fiber, is it multimode or singlemode?
- Is the primary usage for new installations or for troubleshooting?

Optical Fiber Media

There are three types of field test equipment for use with optical fiber media. The first is OLTS. This set is available in many different configurations and price ranges. If a great deal of optical fiber testing will be done, consider a stand-alone version.

Another option is a unit that connects directly to the certification test set. One advantage of this unit is that the tests may be saved the same as the copper tests and then downloaded with the other test results in the same format.

Optical Fiber Media, continued

Each optical fiber is tested at one wavelength (850 nm) in one direction and the other wavelength (1300 nm) from the other direction at the same time. This alleviates the need for multiple trips to each location to test both wavelengths and, in the case of bidirectional testing, each direction.

If testing beyond the capability of the OLTS, the next option is the OTDR. Of primary importance is the kind of measurements to be made—loss, distance, reflectance, and splice alignment. Be certain the selected OTDR can do all of these measurements easily, quickly, and accurately.

If live tests (hot cut or splicing of optical fibers in a working cable) are needed, an OTDR that can do an active splice loss measurement in real time will be required. Look for a simple front-panel control layout as well as a display that is easy to interpret. If the instrument will be used only when a problem occurs in the optical fiber or for semiannual maintenance evaluations, a simple unit with few front-panel controls that has a built-in help feature is adequate.

The third unit is the interferometer. The connector end faces should be tested as they are installed. This practice will ensure the lowest possible loss of the mated pair. However, as the interferometer is also an expensive instrument, its use may be limited to spot checking a representative sample of the installed connectors. First priority would be any circuit where low loss and reflectance are a priority, both data and video. Secondly, we have the backbone circuits that are designed for transmission at high data rates, 10 GB and above. This applies not only to the permanent part of the circuit but also to the patch cords. Short circuits such as fiber-to-the-desk-top, once they have passed the optical loss test, should not require any further testing. Its use in troubleshooting will be covered later in this section.

Training

Considerations for training curriculum can include:

- The number of operators required for each piece of equipment.
- The frequency of use by each operator.
- Information about whether the test result is open to the operator’s interpretation.
- How to make interpretations consistent.
- The current training level of the operator.

It may be that only supplemental training is required.

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Documentation

A permanent record of the test data is normally kept on file. The field test equipment selected should have the ability to store trace information on a disk, print it on an internal printer/plotter, or print/plot it from a computer program using the computer's printer.

Test Data Analysis

An efficient means of keeping trace data on file is to store the information in a computer. In the case of the certification test set, does it have the ability to store the trace data along with the pass/fail data? These traces can become a valuable troubleshooting aid as it has the ability to perform a direct comparison of an original test with a current test. This allows the traces to be recalled at any time for comparison and analysis.

Most OTDR manufacturers have programs that emulate an OTDR on a computer. The same loss and distance measurements can be made on a laptop computer or office computer just like on an OTDR. The software should be capable of analyzing the trace data to produce optical fiber event tables and cable loss tables for complete documentation. If this option seems beneficial, make certain the program will operate on the type of computer in use.

Manufacturer and Vendor Support

The type and amount of vendor support may be an important consideration when selecting a test set. Testing can be confusing at times, and an answer from someone who has seen the problem before may be needed. Check to see if the supplier has a help line or some way to provide technical information. Verify that the local representative is technically qualified and experienced enough to talk the user through problems. Confirm the warranty repair turnaround policy. How long will it take to have the field test equipment repaired? Does the manufacturer offer loaners or rentals? It is always good to know the manufacturer's reputation in the industry.

Another consideration is whether the field test equipment can be upgraded to add new features or improve operations. While some field test equipment must be taken out of service and sent to the factory for upgrades, most can be upgraded in the field by uploading the new software from a computer or placing a disk with the new operating software in the unit. Software upgrades can provide completely new features and improved performance without losing the use of the unit.

Compatibility

Will other field testers be purchased? If compatibility between models is important, then determine if the data from a manufacturer's previous models is compatible with the current (and future) models. Verify that it will be easy to compare traces with data taken years ago on a different model.

Some field test equipment manufacturers completely change their models and do not provide backward compatibility in features, operation, or data. If models are changed, it may be necessary to retrain the operators. However, most OTDR manufacturers have proprietary software programs that cannot be used with other OTDR software programs.

Example A: Optical Fiber Performance Calculations Worksheet

A. Calculating Passive Cable System Attenuation

1.	Calculate optical fiber loss at operating wavelength		Cable distance		1.5	km
		x	Individual optical fiber loss	x	1.5	dB/km (0.93 mi)
		=	Total optical fiber loss		2.25	dB
2.	Calculate connector loss (exclude Tx and Rx connectors)		Connector pair loss		0.75	dB
		x	Number of connector pairs	x	4	
		=	Total connector loss		3.0	dB
3.	Calculate splice loss		Individual splice loss		0.3	dB
		x	Number of splices	x	3	
		=	Total splice loss		0.9	dB
4.	Calculate other components loss		Total components (none)		0.0	dB
5.	Calculate total passive cable system attenuation		Total optical fiber loss		2.3	dB
		+	Total connector loss	+	3.0	dB
		+	Total splice loss	+	0.9	dB
		+	Total components	+	0.0	dB
		=	Total system attenuation		6.2	dB

B. Calculating Link Loss Budget

Example manufacturer's electronic specifications	System wavelength		1300 nm		
	Optical fiber type		62.5/125 µm multimode		
	Average transmitter output		–18.0 dBm		
	Receiver sensitivity (10^9 BER)		–31.0 dBm		
	Receiver dynamic range		11.0 dB		
6. Calculate system gain			Average transmitter power	– 18.0	dBm
		–	Receiver sensitivity	– (-31.0	dBm)
		=	System gain	13.0	dB
7. Determine power penalties			Operating margin (none stated)	2.0	dB
		+	Receiver power penalties (none stated)	+ 0.0	dB
		+	Repair margin (2 fusion splices at 0.3 dB each)	+ 0.6	dB
		=	Total power penalties	2.6	dB
8. Calculate link loss budget			System gain	13.0	dB
		–	Power penalties	– 2.6	dB
		=	Total link loss budget	10.4	dB

C. Verifying Performance

9. Calculate system performance margin to verify adequate power			Link loss budget	10.4	dB
		–	Passive cable system attenuation	– 6.2	dB
		=	System performance margin	4.2	dB

µm = Micrometer
BER = Bit error rate
dB = Decibel
dBm = Decibel milliwatt
km = Kilometer
mi = Mile
Rx = Receiver
Tx = Transmit

NOTE: 4.2 > 0. Therefore, the system will operate as installed.

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Example B: Optical Fiber Link Attenuation Record

Location: _____ Technicians: _____

_____ _____

_____ _____

_____ _____

Date: _____

Wavelength: 850 nm 1300 nm 1550 nm

Core size: 50/125 µm 62.5/125 µm 8-11 µm

Buffer Tube Color: _____

Reference Reading: _____

Optical Fiber Number	A to B Reading	A to B Attenuation	B to A Reading	B to A Attenuation	Loss Budget	Length Remarks
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

nm = Nanometer
µm = Micrometer

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Optical Fiber Troubleshooting

Overview

Optical fiber cable troubleshooting is a process used to eliminate faults and locate events or conditions causing decreased cabling performance. Restoration is the process of returning the circuit to an acceptable operational condition.

The following four steps are applicable regardless of the media:

- Verifying the problem
- Isolating the source of the problem
- Repairing the problem
- Testing the repaired system to ensure that it functions correctly

Verifying the Problem

Faults in a system occur during the initial installation and also during the useful life of the system. High loss because of macrobends and ghosts are examples of faults that would normally be seen during installation testing. For troubleshooting faults that occur during normal operation of the system, it may be helpful to take the user through a series of verification steps as performed for balanced twisted-pair cable.

- Contact the user by telephone to answer the following questions:
  - Who is affected by the condition?
  - What are the nature, scope, and severity of the condition?
  - Where are the possible areas that the condition could occur?
  - When did the condition occur? Does it correlate with any other activities (e.g., other works being undertaken) or abnormal conditions?
  - Why does this condition exist?
  - What provoked this condition (e.g., electrical outage, weather conditions, people working in the area)?
  - What test equipment is available?
  - What connector types and optical fiber types are involved throughout the optical fiber circuit where the problem exists?
  - What trained manpower is available?
  - What method or procedure will be used to identify, locate, and resolve the problem?

Verifying the Problem, continued

- Upon arrival at the site, assess the situation. Acknowledge arrival with the site's contact. Determine the priority of the condition and the resources available to correct the problem.

  Consider the following items:

  – What is the priority of the restoration? A circuit serving one computer may not be as critical as a backbone cable. Consider temporarily relocating jumpers to available working strands. Consider rerouting over a different cable or route to reinstate the service, albeit temporarily.

  – Has the customer done anything to identify the problem, fix it, or restore the circuit?

Isolating the Problem

There are two common approaches for isolating a problem:

- Start at one end of the circuit and work toward the other end.
- Start in the middle of the circuit (at a point of interconnection or cross-connection) and determine in which direction the problem lies. Move to the middle of the identified defective section and again determine which section is defective. Continue this process until the defective link is found, then work from one end of the link segment to the other end.

Swap the optical fibers over at one end of the circuit to check for an optical fiber transposition of transmit and receive optical fibers to verify polarity. Use a good light source to test for optical fiber continuity. Use an OTDR with launch and tail leads to pinpoint the location of the problem if polarity is not the issue.

For every cord removed, including the equipment ends, it is important that each connector be inspected and cleaned prior to making a connection. A dust particle on the end of a connector becomes an attenuator and can be transferred to the mating optical fiber connector.

NOTE: Refer to Section 5: Testing Cable in this chapter for detailed cleaning procedures.

Most problems in an existing circuit can be located in this manner, including a:

- Disconnected jumper.
- Jumper that has been incorrectly changed because of move, add, or change (MAC) activity.
- Hub or router that has been turned off. Look for the power-on indicator.
- Broken optical fiber inside a cord.
- Broken optical fiber inside an optical fiber distribution unit (enclosure).
- Damaged cable inside a TR, equipment room (ER), or entrance facility (EF).

NOTE: An MC (CD) may be found in an ER or EF.

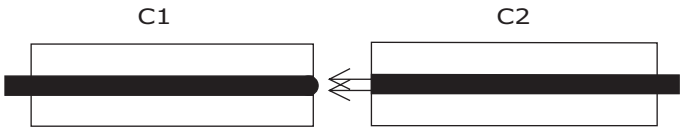
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Isolating the Problem, continued

There are other conditions, such as higher attenuation at the second window (e.g., 1300 nm on multimode) than at the first window (e.g., 850 nm on multimode) caused by macrobends or greater attenuation in one direction than in the other. If the system had been tested at one wavelength and in one direction, the conditions could have existed when the optical fiber cabling was installed but did not become evident until the optical fiber was activated. Ask for the original test results from the customer.

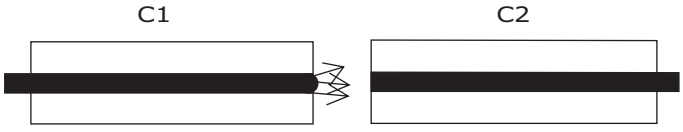
Unless otherwise specified, perform the measurements' bidirectionally. An example of when bidirectional testing will reveal the problem occurs when one end of a channel has a shattered end. Testing from the good connector (source end) to the shattered end (meter end) will likely show a higher than normal loss, but not as significant as that when testing from the bad connector to the good connector (see Figure 6.64).

Figure 6.64
Connector loss Connector 2 (C2) to Connector 1 (C1)



When the transmit and receive directions are reversed because of the dome-shaped polish on Connector 1, part of the light is allowed to escape, causing an increase in attenuation (see Figure 6.65). This may be corrected by repolishing the connector.

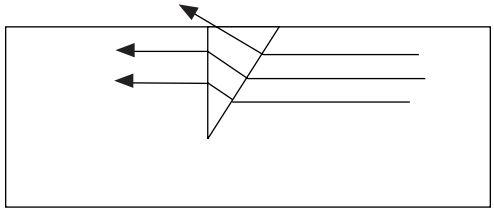
Figure 6.65
Connector loss Connector 1 (C1) to Connector 2 (C2)



Isolating the Problem, continued

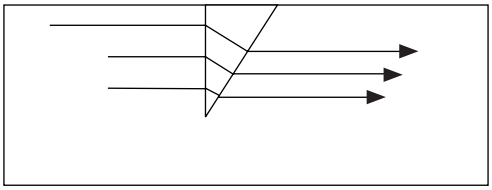
Another possible cause may be small asymmetrical nicks (microbends) in the optical fiber. This may have been caused by the optical fiber being bent tighter than the minimum radius bend or by compression (excess pressure on a tie wrap). When light is transmitted in one direction, the light is reflected into the optical fiber while transmission from the opposite direction causes the light to be reflected out of the optical fiber (see Figure 6.66).

Figure 6.66
Reflective loss



This condition causes some light to be reflected outside the optical fiber and lost. When the light is transmitted from the opposite end of the optical fiber, all light is reflected into the optical fiber (see Figure 6.67).

Figure 6.67
Nonreflective loss



For a circuit that shows a higher than expected loss or ghosts, in most cases, the fault is in the connector (undercut or overpolished). When the connector looks good in the optical fiber scope, which connector is defective? The OLTS will not give the answer, but the interferometer will; unlike the OTDR, it only takes one person (or a lot of walking) to run the test correctly. In addition, how is the coupling/adapter tested? With the interferometer, when both the connectors pass, the only remaining item is the coupling/adapter. This is the only method known that will pinpoint this defect. Even though this is now a field unit, it is still subject to vibration and must be set up on a stable platform.

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Repairing the Problem

Once the problem has been isolated, the next action is to correct the problem and restore the circuit to its intended condition. This may involve:

- Inspecting and cleaning a connector or connectors.
- Reseating a connector in the adapter.
- Replacing a connector.
- Installing a splice on a broken backbone optical fiber. Consider the link budget requirements when splicing an optical fiber.
- Replacing a broken splice.
- Replacing a broken jumper.
- Installing a replacement section of either horizontal or backbone cable.

Safety

NOTE: Refer to Chapter 2: Safety Procedures for further information.

Testing the System

Once repairs are finished, the final step is the testing and documentation of the repaired circuit.

Steps—Fault Isolation

Step	Isolating a Fault
1	Perform a visual inspection of the optical fiber and connectors. a. This may be accomplished using an optical fiber inspection microscope. b. In the case of high loss or high reflectance, test using an interferometer (see Section 5: Testing Cable in this chapter).
2	If physical damage is evident (e.g., chipped optical fiber at the connector, broken optical fiber at the panel or faceplate), make the necessary repair and proceed to Step 5. If physical damage is not evident, proceed to Step 3.
3	Clean the connectors by performing the optical fiber connector cleaning procedure detailed in Section 4: Cable Termination Practices in this chapter.
4	Check the optical fiber with the visible light source. If light is visible, proceed with Step 5. If light is not visible, proceed to Step 12.
5	Set up and calibrate the OLTS.
6	Test the optical fiber from the near end to the far end.
7	Document results.
8	Test the optical fiber from the far end to the near end.
9	Document the result.
10	Perform the mathematical averaging of the two readings (R1 + R2)/2.
11	If the results are within the standard values for the specific cabling under test, document the results and place the optical fiber back into service. If not, continue with Step 12. At this point of the fault isolation procedure, the fault is one of the following conditions: • A broken optical fiber, which was not evident during the initial visual inspection (Steps 12 through 15) • High attenuation from an unknown cause (Steps 16 through 20)
12	If looking for a no-light condition, connect the VFL to one end of the optical fiber.

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Steps—Fault Isolation, continued

Step	Isolating a Fault
13	Perform a visual inspection of the optical fiber path. A red glow should be evident at any point where light is escaping from the optical fiber if the cable sheath is opaque to the light. Mark each location on the sheath. Note that there may be more than one fault in the cable. If no light is detected, proceed to Step 16.
14	Repair the cable by the ITS designer's instructions.
15	Once the repair has been completed, complete Steps 5 through 11. At this point, there are two options—the fault locator or the OTDR. Each will find the cause of the no light or the high-attenuation condition. For the remainder of this checklist, the steps used will be those for the OTDR test set. Prior to setting up the OTDR, obtain a copy of the original OTDR tests for the optical fiber in question. These will be invaluable in the interpretation of the new test results.
16	Set up the OTDR. If the original traces are available, take special care to set the refractive index, pulse width, pulse duration, and sampling rate to that of the parameters for the original trace.
17	Connect the OTDR and perform the test. Reference Section 5: Testing Cable in this chapter. As our interest is in the total cable, it is imperative that both a launch and receive jumper of proper length be used for the test. NOTE: Representative samples of each type of optical fiber fault are contained in Appendix A: Typical Optical Time Domain Reflectometer (OTDR) Fault Presentations at the end of this chapter.
18	Compare the new test with the original. Most OTDRs allow the user to overlay the new test results onto the original test results. Note any point of difference between the two tests. These differences are the faults, either broken or partially broken locations.
19	Make repairs as necessary.
20	Once the repairs have been completed, complete Steps 5 through 11.

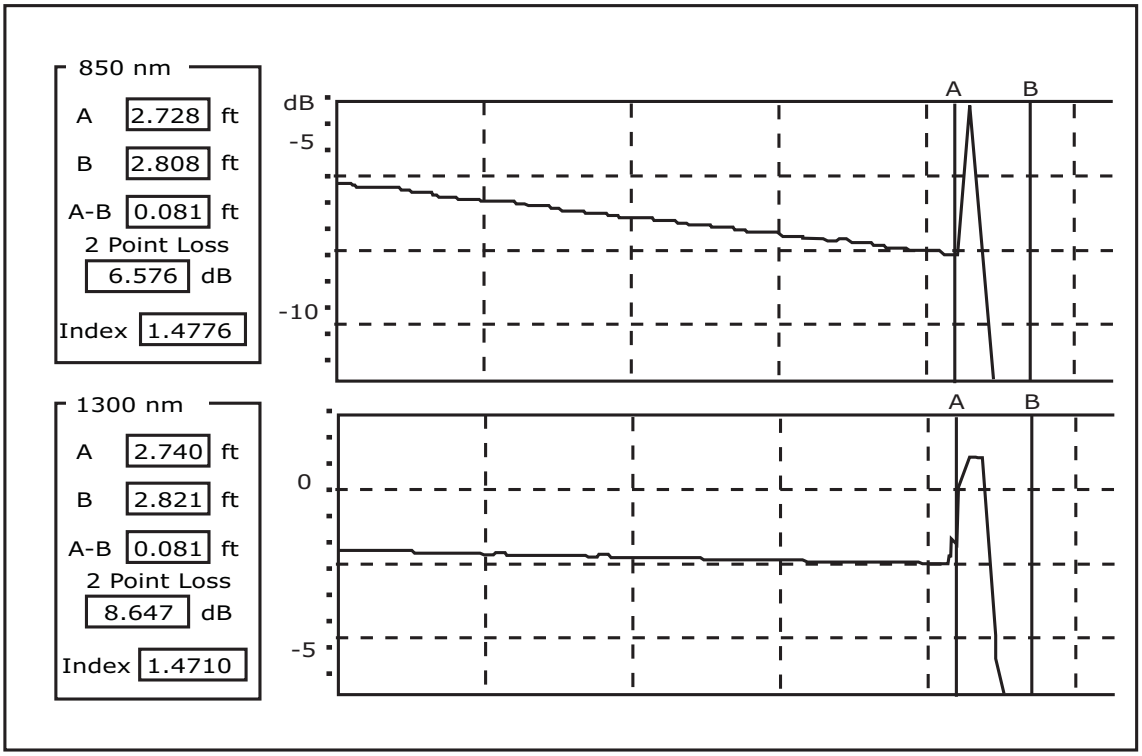
Appendix: Typical Optical Time Domain Reflectometer (OTDR) Fault Presentations

Reflective Break

A reflective break (see Figure 6.68) is most commonly observed under the following conditions:

- Unconnected optical fiber—As the loss is greater at 1300 nm than at 850 nm, this is an indication that the optical fiber is being influenced by macrobending. Therefore, the fault is with excessive bending in the cable prior to the connector and is not the connector.
- Broken or bad connector.
- Broken optical fiber.

Figure 6.68
Reflective break



dB = Decibel
ft = Foot
nm = Nanometer

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Nonreflective Break

When an optical fiber is cut or broken, the end may shatter in such a way that the angle at which the light hits the end may not reflect at all. The end of the optical fiber may become immersed in oil or grease, which may eliminate the Fresnel reflection (e.g., especially when the end is immersed in index-matching gel). When this happens, the trace will suddenly fall into the noise level.

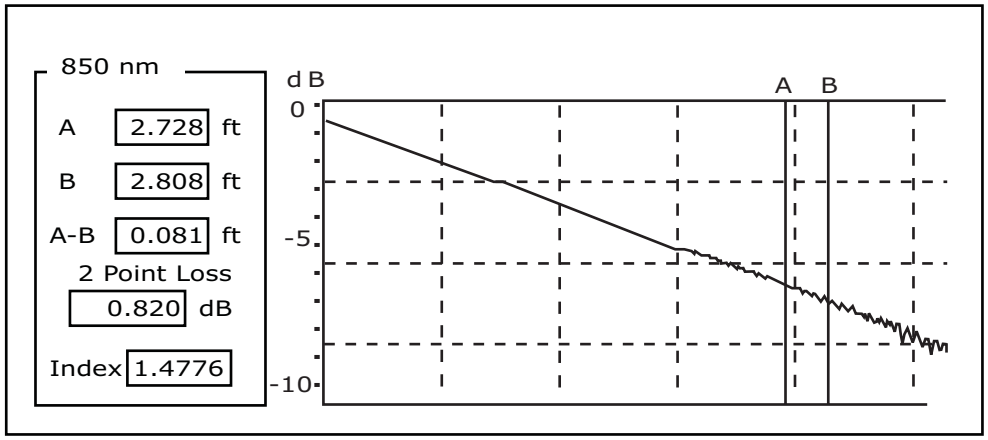
There may be a rounding of the backscatter where it falls so that it may be difficult to judge where the fall point is. The best method to determine the break point is to use the two-point loss method that indicates the point the backscatter level drops by 0.5 dB.

Place the left cursor as near as possible to the end but still on the backscatter. Then, move the right cursor toward the left cursor until the loss between the two reads 0.5 dB. The actual end of the optical fiber should be very close to the point measured by the right cursor.

To increase confidence in this location, take the OTDR to the other end of the optical fiber and test back to the break from the other side. It is possible that the other side of the break will reflect some light. Keep in mind that the optical fiber could be broken at more than one point.

This indication is most often seen when testing optical fiber on a reel. The optical fiber at the distant end has been cut; therefore, all of the light is escaping into the air with little or no reflection. It becomes imperative to terminate both ends of the optical fiber to achieve an accurate length measurement (see Figure 6.69).

Figure 6.69
Nonreflective break

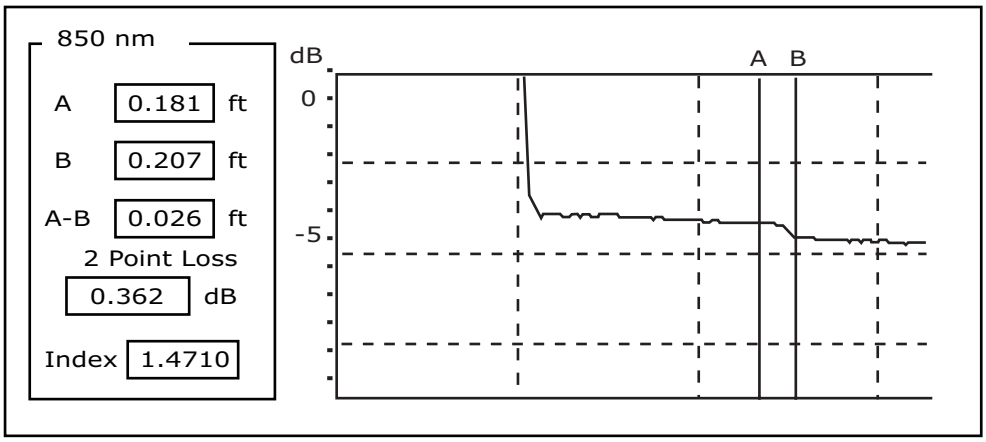


dB = Decibel
ft = Foot
nm = Nanometer

Defective Splices

In the case of a defective fusion splice, the defect is noted by the two-point loss method (see Figure 6.70). Measuring from the last flat spot on the trace before the splice (cursor A) to the first flat spot on the trace following the splice (cursor B), note that the loss is 0.362 dB. This loss is in excess of the 0.3 dB allowed by the standard.

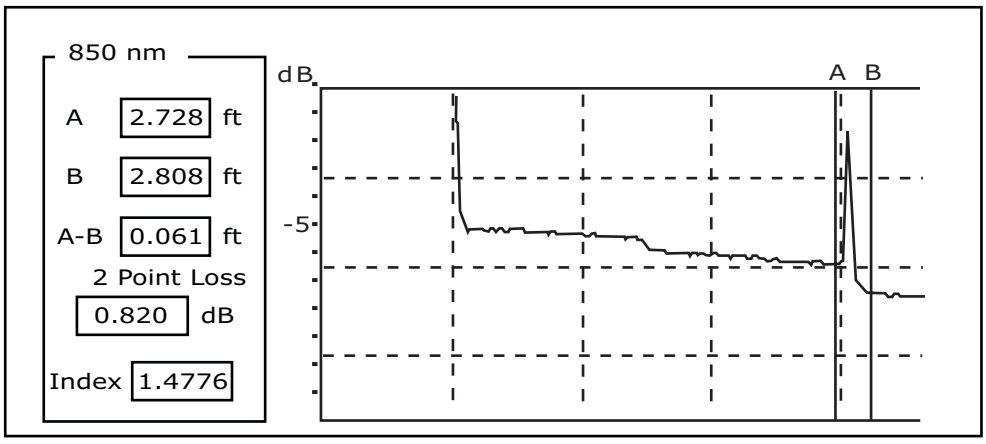
Figure 6.70
Defective fusion splice



dB = Decibel
ft = Foot
nm = Nanometer

As in the case of the fusion splice, the defect is determined by the two-point loss method (see Figure 6.71). As the indicated loss is in excess of the 0.3 dB allowed by the standard, the splice is considered defective.

Figure 6.71
Defective mechanical splice



dB = Decibel
ft = Foot
nm = Nanometer

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Chapter 7
Firestopping Practices

Chapter 7 discusses the regulations, testing, materials, methods, and guidelines for the installation of a firestopping system. This chapter provides the information technology systems (ITS) installer with the elements of a firestopping system as well as with ways to determine the best firestopping assembly.

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Firestopping Practices

Introduction

This chapter describes firestopping regulations, testing, materials and methods, and guidelines for selecting a firestopping system. For all firestopping issues, the information technology systems (ITS) cabling installer should consult the authority having jurisdiction (AHJ) for approved materials and practices.

Worldwide, fire kills thousands of people, injures hundreds of thousands more, and destroys billions of dollars in property value each year. In commercial and residential buildings, more deaths, injuries, and property damage result from smoke and toxic gases than from the fire itself. Building codes establish strict requirements and regulations designed to safeguard life and property from fire hazards. In every instance, the ITS distribution designers and contractors must adhere to local and national codes and standards for new construction and renovation projects.

The most common fire protection principle is compartmentation—construction of fire-resistant barriers to contain a fire to the area where it starts. Fire-resistant means that a material or structure can withstand fire and the passage of flame, smoke, or gases for a known period of time.

Fire-resistant barriers can be floors, floor/ceiling or roof/ceiling assemblies, and walls. These barriers include other components (e.g., fire doors, penetration seals, fire dampers) that help maintain the fire resistance of the floor, ceiling, roof, and wall assemblies.

Penetrations in fire and smoke barriers used or made by an ITS installer to place cable must be properly sealed or firestopped both at the end of the work day and at the end of the installation. Firestopping is the process of installing listed fire-rated materials into penetrations of fire-rated barriers to reestablish the barrier's fire-resistance rating.

A penetration that is left open or improperly sealed may allow lethal flames, toxic gases, and smoke to travel throughout a building and damage the areas that otherwise would not have been exposed to a fire.

Generally, construction drawings and specifications indicate the:

- Locations to be firestopped and the rating of the barrier to be penetrated.
- Required performance of firestopping systems to include ratings.
- Specified manufacturers.

For cabling installations, it is usually up to the ITS installer to determine the appropriate, code-compliant firestopping means and methods. This requires knowledge of local fire protection codes and the various manufacturers' systems, fire ratings, and installation procedures. The ITS installer plays a critical role in protecting people and structures from the devastation caused by fire.

NOTES: In new construction, appropriate firestopping means and methods are normally the responsibility of the ITS designer and general contractor.

Factory training is the best source for cabling installers to learn how to properly plan a firestop installation. All firestop manufacturers offer installation guidance, and many have certification training available for ITS installers.

Protection Codes and Ratings

Overview

Whether the cabling contractor is installing cable in a new building or as part of a renovation project, the ITS installer must know where firestopping is required and how to choose suitable materials. Government code regulations mandate locations that must be firestopped or smoke sealed. These regulations require the use of tested and certified firestop products. This section describes the codes and testing criteria for firestopping systems.

BICSI® recommends installing listed cables in all commercial buildings. BICSI requires that the installations in hollow spaces, vertical shafts, and ventilation or air-handling ducts are made in such a manner that the possible spread of fire or products of combustion is not substantially increased. Openings around penetrations through fire resistant-rated walls, partitions, floors, or ceilings shall be firestopped using approved methods to maintain the fire resistance rating.

Building Codes

The governments of most countries regulate the construction industry through building codes. These codes are intended to ensure the safety of building occupants by providing minimum standards for design, construction, materials, building use, location, and maintenance. Building codes include strict requirements for protecting occupants from fire, smoke, super-heated gases, and toxic fumes.

The first set of international, unified building codes was adopted in September 1999 at the Codes Forum Joint Annual Conference. The International Code Council (ICC) sponsored the conference. However, until the international building codes are globally accepted, firestopping systems must meet the requirements of existing local codes.

Qualification Testing

To qualify, a firestop product must be tested as an assembly by a nationally recognized testing laboratory (NRTL).

An assembly is made up of a type of:

- Fire barrier (e.g., floor, wall, combination floor/wall).
- Construction (e.g., concrete, framed wall).
- Penetration (e.g., cables, conduit, cable tray).
- Firestop material (e.g., putty, caulk).

For example, the laboratory could test the fire resistance of a manufacturer's firestop putty placed in a metal conduit installed through a concrete floor. Testing is then conducted using specific parameters (e.g., thickness of the floor, size of the opening, type of conduit).

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Qualification Testing, continued

Depending on the laboratory, a firestop assembly that meets the testing requirements is labeled as qualified, tested, listed, classified, or approved. For simplicity, this chapter uses the term "qualified" to represent all of these terms.

Some of the NRTLs that conduct tests to evaluate firestop materials and methods include:

- Factory Mutual (FM) Systems.
- Inchcape Warnock Hersey (W-H).
- Omega Point Laboratory (OPL).
- Southwest Research, Inc. (SWRi).
- Underwriters Laboratories Inc.® (UL®).
- Underwriters Laboratories of Canada (ULC).

These laboratories test the fire resistance of through-penetration firestops by exposing the product to a controlled fire and measuring performance on a time/temperature curve. Immediately after burn, the firestop is subjected to a hose stream of up to 310 kilopascals (kPa [45 pounds per square inch (psi)]).

Many firestop assemblies combine several materials, each offering specific physical properties that contribute to the success of the overall design.

Surviving the dynamics of a fire test depends on the interrelationship between:

- Component products and dimensions.
- Anchoring and installation techniques.

Additional testing may be required to confirm that the firestop assembly can perform other functions, including:

- Accommodating pipe movement without violating the integrity of the seal.
- Providing protection against pressure or flooding.
- Providing environmental protection.
- Meeting requirements (e.g., electromagnetic interference [EMI]/electromagnetic pulse [EMP] barrier).
- Resisting the effects of explosion.

The testing laboratories issue system numbers to each firestop manufacturer for each combination of items tested and certified. No two manufacturers will have the same system numbers unless one of the parties is a private-label manufacturer for the other.

UL® has the greatest number of tested firestopping systems.

NOTE: The UL® product numbering system is described in Appendix A: Underwriters Laboratories Inc.® (UL®) Numbering System at the end of this chapter.

Qualification Testing, continued

Firestop products must always be installed according to the manufacturer's instructions based on the independent testing. The ITS installer and the contracted company may be legally, criminally, and financially responsible if the manufacturer's instructions are not followed.

This means the ITS installer:

- Cannot substitute products that are not part of the qualified assembly.
- Cannot add more of a product to get a higher rating.
- Cannot add or change the type or location of penetrations.
- May be deemed personally responsible for improperly firestopping or not firestopping.
- Can contact the manufacturers to obtain written assistance for situations that are not covered in their installation practices for the qualified assemblies. These are considered engineering judgments, and preapproval by the AHJ shall be obtained.

It is not possible to test every firestopping arrangement. Many test assemblies are based on testing the worst case in a number of variables. The ITS installer must contact qualified manufacturers with questions regarding engineering judgments to select a suitable firestopping system for a particular application.

Rated Devices

A fire-rated device is an assembly that is specifically designed for use within or through a fire-rated structure or barrier. For example, a raceway installed through a firewall is not a rated device until the approved firestop seal has been applied and accepted by the AHJ.

One rated assembly used by ITS installers is the poke-thru style floor outlet that must be installed according to the approval sheet from an NRTL. This assembly consists of an outlet box, conduit, and premade firestop materials designed to fit snugly within the core opening in the floor. Unless linked by conduit, the cables within the poke-thru must be rated for the structure in which the cables are placed (e.g., ceiling plenum of the floor below).

ITS installers must be aware of their responsibilities for maintaining fire safety standards when undertaking many aspects of the job, not just when placing cable or a conduit through a fire-rated wall. Cutting in an outlet or opening a wall to fish a cable may cause the failure of a rated barrier. If there is any doubt, seek preapproval from the AHJ.

Plastic outlet boxes may not be suitable in some installations. Plastic faceplates and low-voltage mounting brackets are not suitable for use in fire or smoke barriers. The ITS installer must be aware of the local codes and should not rely solely on usual practices or even the job specifications. If there is any doubt, seek preapproval from the AHJ.

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Fire Rating Classifications

UL®'s *Fire Resistance Directory* rates successfully tested firestopping systems with F, T, and L ratings, as follows:

- An F rating provides the amount of time (in hours) the firestopping system can prevent flames from passing through the system.
- A T rating provides the amount of time (in hours) the firestopping system can keep the temperature from rising above a specified point.
- An L rating indicates a firestop's ability to provide an effective smoke seal.

NOTE: In many cases, cold smoke will kill more people and damage more property than the fire.

Both F and T ratings require the firestopping system to withstand a specified level of pressure from a hose stream that simulates fire-fighting activities.

Table 7.1 explains these fire-rating classifications.

Table 7.1
Fire rating classifications

Rating	Description
F (Required number of hours)	The firestop withstands the test fire (direct flame) for the rating period without: • Permitting flames to: – Pass through the firestop. – Occur on any element of the unexposed side of the firestop (i.e., autoignition). • Developing any opening in the firestop during the hose stream test that permits a projection of water beyond the unexposed side.
T (Required number of hours)	The firestop: • Meets the criteria for an F rating. • Limits temperature rise during the rating period. The temperature on any unexposed surface can increase no more than 163 degrees Celsius (°C [325 degrees Fahrenheit (°F)]) plus ambient (room) temperature.
L (Air leakage)	The firestop: • Indicates a firestop's ability to provide an effective smokestop by reporting a number value. • Measurements are made at ambient and 204 °C (400 °F). • A lower number is a better L rating. The minimum reportable value is <1.0 in cubic meters (m^3) per minute per square meter (m^2) or cubic feet (ft^3) per minute per square meter (m^2 [square foot (ft^2)]) of opening. NOTE: This rating is an optional part of UL 1479 and is not included in ASTM E814.

Firestopping Systems

Overview

Firestopping systems are a specific combination of materials installed within a defined structure (e.g., fire-rated wall, partition, floor, ceiling) using identified methods, all of which have been tested as an assembly by an independent laboratory. This combination of materials and methods is approved for use in the specific situations outlined for the purpose and time qualified by the testing agency.

Because the systems are rated only for specific uses, there is no single firestopping solution to all situations. It is important for the ITS installer to identify the fire barrier requirements (type of structure and F, T, and L ratings needed) before looking for a firestop system.

These requirements will drive the selection of materials, thereby preventing the installation of an inadequate or homemade, untested system.

Firestopping systems include the following four components:

- Barrier being penetrated (floor, floor/ceiling or roof/ceiling assembly, wall)
- Construction and thickness of the barrier being penetrated (e.g., concrete, framed wall, masonry)
- Item penetrating the barrier (e.g., cable, conduit, cable tray)
- Materials and methods used for sealing the penetration

Firestopping systems can be divided into two broad categories—mechanical and nonmechanical. These systems are described in the following sections.

Mechanical Firestopping Systems

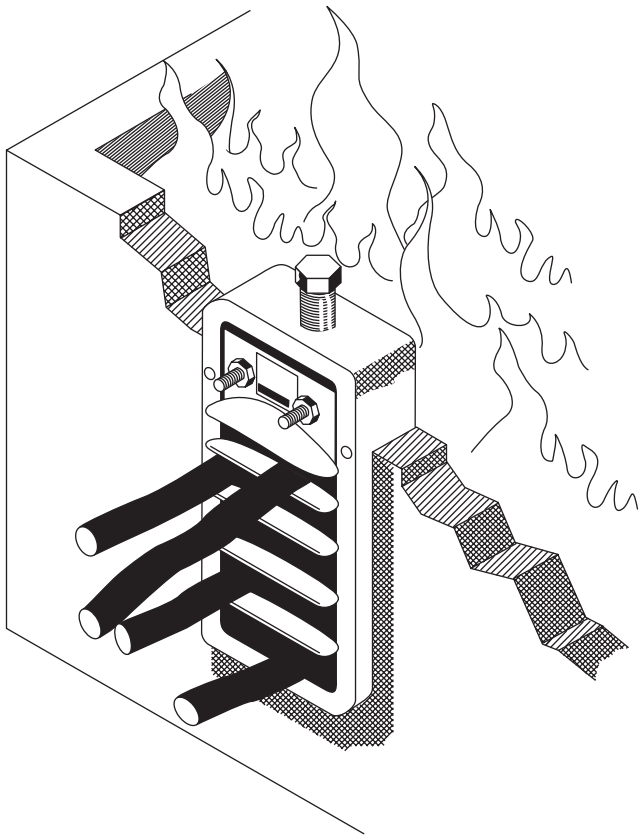
Mechanical firestopping systems use elastomeric firestop materials, which are flexible and resemble rubber. Manufactured elastomeric components are presized and shaped to fit around standard cables, tubes, and conduits. Mechanical pressure holds the elastomeric components in place and provides a tight seal around the penetrating devices. Sometimes, a frame is required to apply compression to the modules. The elastomer is mainly designed to withstand the fire and hose stream test for the rated time.

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Mechanical Firestopping Systems, continued

Figure 7.1 illustrates elastomeric modules with compression applied by a frame.

Figure 7.1
Elastomeric modules (within frames)



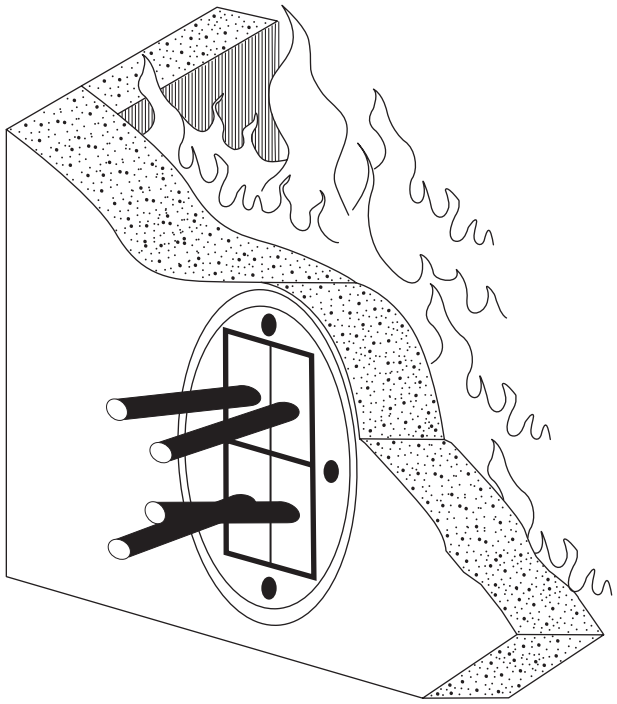
Mechanical firestopping systems are considered highly durable while providing:

- Reliable pressure and environmental sealing.
- Excellent resistance to shock and seismic vibration.
- Support for penetrating elements.
- The opportunity to reconfigure the penetrating elements as required.
- The ability to withstand an explosion.
- Waterproofing.

Mechanical Firestopping Systems, continued

The most useful systems are highly modular to ensure maximum flexibility in accepting multiple elements with different diameters (see Figure 7.2).

Figure 7.2
Mechanical firestopping systems



Nonmechanical Firestopping Systems

Nonmechanical firestopping systems use materials that are generally pliable. These materials include items such as putties, caulks, blankets, pads, foams, pillows, and other types of materials that can be molded or sized to fit into an opening to seal it.

Nonmechanical firestop materials are available in two general categories, based on their reaction to heat, flame, or leakage:

- Intumescent materials expand when exposed to fire or heat. The material swells around and within the penetration to provide a tight seal. In some applications, it is designed to crush the penetration (with combustible conduits).
- Passive firestop materials, which either absorb heat or insulate, include:
  - A firestop that is endothermic—It has the ability to absorb heat, which prevents the temperature from rising on the other side of the fire barrier.
  - A firestop that is ablative—It develops a hard char that resists erosion from fire and flames. This hard char allows a soft firestop to become rigid to help it withstand high-pressure gases and the force from a hose stream.

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Nonmechanical Firestopping Systems, continued

Intumescent Firestop Materials

When cable is exposed to fire, the cable jacket burns, the conductors collapse, and the size of the cable bundle shrinks. If intumescent firestop materials are used, the materials expand and fill the space left by the shrinking cables. It is important to install intumescent firestopping so that it can compress the cable bundle.

Forms of intumescent materials include:

- Sheets—Intumescent sheets with a sheet metal backing can be used to seal large openings. Use sheets without metal backing with caulk or putty to fabricate a honeycomb-like partitioned opening for cable, conduit, metal, or nonmetallic pipe.

  When using intumescent sheets, always follow the manufacturer's instructions for:

  – Layering.

  – Spacing/size.

  – Anchoring.

  – Sealing.

- Pads—Firestop putty is available in the form of a presized pad. The pad is used to seal the back of outlet boxes or other electrical fixtures installed in a membrane penetration. Testing indicates that the putty pad prevents flame-through and undesirable heat buildup on the nonfire side of the wall. The pad:

  – Seals knockouts and openings in the fixture.

  – Prevents smoke and fire from entering hollow wall cavities.

- Wrap strips—Intumescent wrap strips are normally used for firestopping plastic piping, insulated metal piping, cable/cable bundles, plastic conduit, innerduct, or any other material that may burn away in a fire and leave a significant void.

- Firestop putty—Firestop putties are common because of their wide range of applications, ease of installation, and long shelf life. They may be intumescent, and most are endothermic (heat absorbent). These putties:

  – Have the consistency of glazing putty.

  – Remain permanently soft and pliable until exposed to heat.

  – Allow easy firestop reentry.

  – Are available in bulk, bars, or sticks.

  – May be installed in conjunction with ceramic fiber, rock wool filler, or other approved fill material.

  – Provide a consistent smoke seal when used correctly.

  Systems that allow complete installation of a putty seal from one side of a penetration are available. The consistency of some putty allows it to be installed from the underside of an opening.

Nonmechanical Firestopping Systems, continued

- Caulk—Several firestop materials are available in caulk form. The materials may be intumescent, endothermic, or ablative (able to resist the erosion of fire and flames). Caulks are dispensed either from standard caulk tubes or large pails. The caulk quickly skins over to form a tight seal, but it may require up to two weeks to fully cure.

  Firestopping caulks may be latex, water, or solvent based, 100 percent solid, or self-leveling.

  The types of caulk vary somewhat in:

  – Their ability to adhere to various surfaces.

  – Their flexibility and moisture resistance.

  – The quantity required to achieve a rated firestopping seal.

  Caulks are for permanent installations that are not intended to be reentered.

  Some caulking materials can be installed from the underside of an opening without dripping or slumping. A self-leveling type is available for application as the topside of a firestop.

  Some caulking materials may require the removal of the existing caulking firestop and the installation of all new materials when the seal is penetrated to add or remove cables.

  When using these products, the following considerations are very important:

  – Some products are flammable until cured.

  – Some solvent-based caulk seals may give off toxic or noxious fumes. Do not use this type of product in poorly ventilated areas.

  – Material safety data sheets (MSDSs) of the manufacturers are usually required for submission to the building owner, general contractor, and end user.

- Pillows—Firestop pillows are a recent development in firestop sealing. Unlike earlier pillows, which contained noncombustible fibers, contemporary pillows contain a specially treated, compressible fiber matrix.

  When exposed to fire, the matrix:

  – Swells to provide further sealing.

  – Becomes rigid, allowing the pillow seal to withstand the force of a hose stream as required by fire test standards.

  This approach to firestop sealing is particularly attractive where frequent cable changes are anticipated or a live fire watch would otherwise be required during construction.

  Pillows are often regarded as temporary firestops because of their convenience. However, pillow fire test qualification standards are the same as for any other sealing system.

  NOTE: In some applications, pillows may require wire restraints to pass the hose stream test.

- Flexible blocks—Intumescent blocks are ready-to-use, standard-size blocks that are stacked in an opening. The blocks accept single or multiple penetrants.

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Nonmechanical Firestopping Systems, continued

- Collars—Some firestopping systems incorporate firestop putty within a metallic collar, sometimes referred to as a pipe choke system. When the collar is exposed to heat, it forces the putty inward to seal and crush the penetrating item. Collars are typically used for firestopping plastic piping, insulated metal piping, cable/cable bundles, plastic conduit, innerduct, or any other material that may burn away in a fire and leave a significant void.
- Foams—Several firestop materials are available in foam form. The materials may be intumescent, endothermic, or ablative.

  Foams are dispensed from a two-part mixing tube and quickly cure to form a tight seal (about one minute). Foam:

  – Can be used on concrete floors, framed walls, and masonry walls.

  – Is flexible and moisture resistant.

  – Forms an excellent smoke barrier and flows between cables during installation.

  – Is excellent in applications that are difficult to reach.

  – Is reenterable.

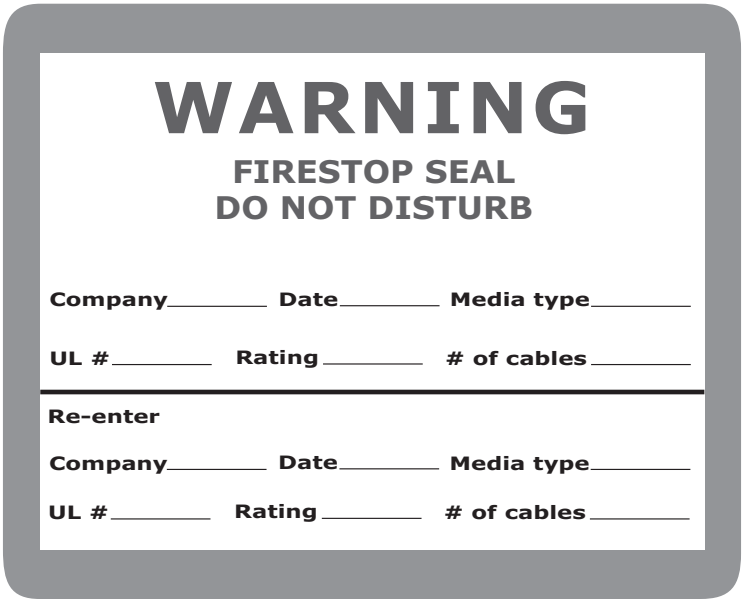
  – Expands during installation and is intumescent.
- Sleeve systems—Sleeve systems are commercially available and should include the sleeve, wall flanges, couplings, rated bushings, documentation labels (see Figure 7.3), and firestop material to seal the system. Sleeve systems:

  – Offer robust smoke seals.

  – Provide for proper fit and function.

  – Are tested for multiple applications with the same device.

Figure 7.3
Labeled firestop graphic



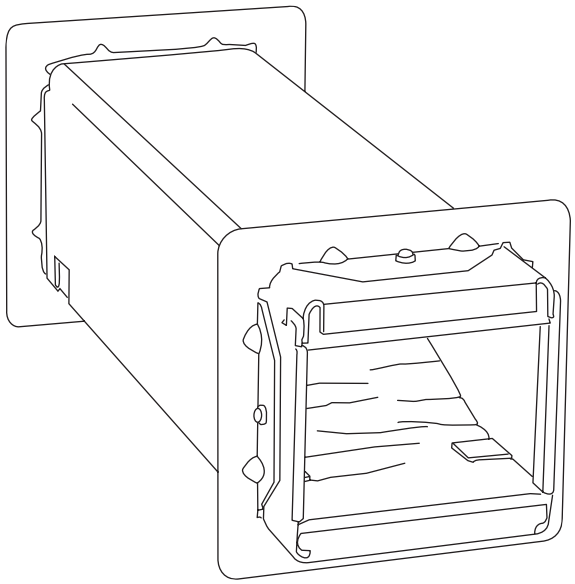
Passive Firestop Materials

Passive firestop materials either draw heat away or insulate items. These materials include:

- Cable pathways—One of the newest technologies for the penetration of cable and wires through fire-rated walls and floors is the fire-rated pathway. It is a self-enclosed fire-stopping system/pathway that automatically adjusts to cable load.

  Empty or full, the pathway is always fire and leakage compliant. Moves, adds, and changes (MACs) are easily accomplished without the removal or installation of additional firestop materials (see Figure 7.4).

Figure 7.4
Passive firestop assembly



- Cementitious materials—Some firestop materials are available in a cementitious (cement-like) form. These materials are:
  - Premixed or a dry powder to be mixed with water.
  - More adaptable to large openings than putty or caulk.
  - Easily applied by trowel or pump for larger installations.
  - Easily bored through to add additional penetrations.
  - Lighter and more cohesive than cement.
  - The best means to reseal concrete barriers (floors and walls) for unused pathways.

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Passive Firestop Materials, continued

When using cementitious materials, ensure that the installation allows for thermal expansion or motion of the penetrating item. This may require a mixture of materials. However, the manufacturer must specifically permit the use of multiple materials.

Do not substitute ordinary grout, plaster, or cement for a cementitious firestop. Although this substitution is often tried, it is not acceptable.

According to tests and field observations, seals made of these materials may:

- Crack.
- Fracture or fall out.
- Be extremely difficult to penetrate again.

- Sprays—Spraying an insulating firestop over critical cables provides additional time to utilize the cable in the event of a fire. When a fire occurs, containment may not be enough. Power, control, and telecommunications cables that contribute to critical functions may need to be protected to avoid or delay losing the services needed in emergency conditions.

  The spray covers the cables and can make future cable identification difficult unless documentation is well maintained.

- Firestop blankets—Firestop blankets are used primarily for large air handling and exhaust vents. The blankets are wrapped around the vents to contain the fire (e.g., fire in a grease duct system from a commercial kitchen).

  The blankets may be used in situations where a cable tray containing critical power or data cables must remain in operation during a fire. The blanket also allows access for future cable plant modifications and inspections.

  NOTE: Pillows, flexible blocks, putties, and caulks are described in the section on Intumescent Firestop Materials in this chapter.

Firestopping Methods

Overview

One of the more difficult tasks for ITS installers is to properly define the best method of firestopping in the various situations they face each day. There is no single solution or best product to be used in all cases. It is necessary for the ITS installer to be aware of local codes and practices as well as the capabilities and limitations of the products available at the job site.

The first issue the ITS installer must address is the identification of structures that are fire-rated barriers and the determination of the F, T, and L values of the barriers.

In a new construction, this is a matter of reading the construction prints and discussing the issue with the general contractor. In retrofit projects, the customer's drawings may not always indicate existing fire-rated barriers. It is a good practice for the ITS installer to note on the floor plans the fire ratings of barriers that may be impacted by the ITS installer's work. The AHJ will require the hourly rating of the barrier to be restored with an approved (tested) system.

Once the barriers have been identified, any existing or planned pathways (e.g., sleeves, cable trays, conduits) must be located and analyzed to determine whether they are adequate for the services to be installed. If additional pathways are required, negotiate this need with the general contractor.

Any penetration made in a rated barrier (e.g., installation of a conduit or sleeve) may require different firestop materials than those used to firestop the cables it will carry. Generally, placement of such pathways must be coordinated with other trades, anchored to an appropriate support, and installed in accordance with methods for electrical support system installation.

The prime components involved in a successful installation of a firestopping system are the ITS installer's understanding of the construction issues and the use of the manufacturer's products exactly as outlined. By understanding the construction and usage issues, the ITS installer can select from systems offered by various manufacturers or, if there is a question, discuss the situation with the manufacturer's representative in sufficient detail to obtain an approved engineering judgment. The engineering judgment should be approved by the AHJ prior to the installation to ensure acceptance.

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Selection Criteria

Starting with the type of structure (e.g., wall, ceiling, combination) and the type of material to be penetrated (e.g., concrete, framed wall, wood), the ITS installer must develop a complete report of the situation to determine the specific firestop assembly.

The ITS installer must then consider the following:

- The number, size, and types of cables to be placed will roughly define the size of the opening.
- The size of the opening and the item(s) penetrating the opening will define the annular measurement or space.
- The construction and location of the fire-rated barrier will influence the methods for creating the opening, the pathway system (conduit/tray), and firestop assembly.

Other issues that impact the specific selection are:

- The F, T, or L rating to be supported.
- Reuse of the pathway.
- Method of placement.

The existing conditions on the work site (e.g., other penetrations, construction methods, aesthetic issues) must be taken into consideration. Try to match the existing conditions, whenever possible, by using the same materials and procedures.

There is the potential for movement of the pathways and cables within a barrier opening. Normal daily operations, seismic events, or subsequent installations may cause movement that could loosen firestop material, causing a reduction or even the elimination of the fire or L rating.

NOTE: Cable trays routed rigidly through firewalls offer many obstacles to proper sealing. The best practice in earthquake zones is to stop the tray short of the firewall and install an independent approved system.

Cautions

Based on the previous information, the ITS installer must determine the materials and methods that match exactly the installation situation at hand.

The best way to accomplish this is through training from the manufacturer. Manufacturers can support the customer with product data sheets, MSDSs, AHJ preapproval forms, and drawings that match the planned situation. Install the product following the details outlined below:

- Never substitute materials from one manufacturer's product assembly with materials from another. All components used to make up a rated assembly are designed and tested as a unit, and the parts are not necessarily interchangeable.

Cautions, continued

- Follow the manufacturer's data installation sheet for the penetration. No one has the authority to ignore fire safety. The owner, general contractor, ITS installer, or the installation company may be held responsible for improper firestopping. The individual ITS installer is at the center of the installation process and must be aware of the ramifications of doing the job incorrectly.
- Never use materials in an environment or in an amount not specified by the manufacturer. More is not always better—simply adding more caulking material will not bring a one-hour firestopping solution to two hours. Pay attention to the minimums and maximums.
- Never firestop only one side of an opening unless the assembly is designed specifically for such an installation.
- Never use support materials that are not called for by the manufacturer. If a rated assembly calls for mineral wool, do not substitute caulking compound, blocks of wood, foam insulation, or other materials.
- Check local codes with the AHJ and contract requirements when working in occupied buildings. It may be necessary to completely firestop some or all openings (e.g., even pre-existing openings) at the end of each shift. If this is not possible, it may be necessary to arrange for the establishment of a live fire watch.

IMPORTANT: Firestopping is a situation in which the manufacturer's directions are not simply the better way of doing something. It is the only way to properly install an assembly that will result in a fully rated solution.

Sleeves and Cable Trays

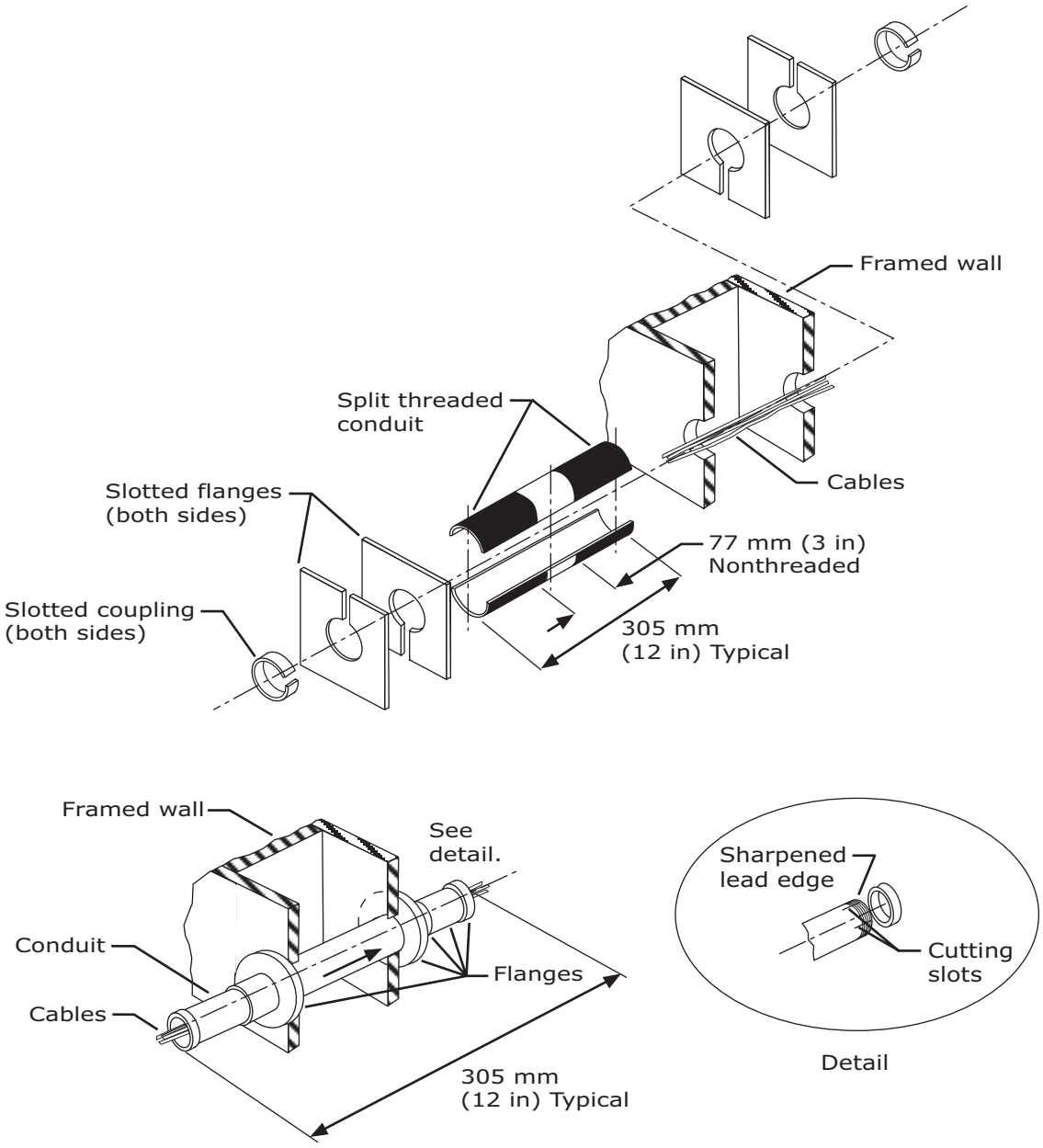
Five situations in which the method can limit the potential for problems and provide a better long-term solution to firestopping are the use of:

- Retrofit split sleeves (see Figure 7.5).
- Pathway barrier penetration plates (PBPPs).
- Core bore seals (CBSs).
- Sleeve systems to firestop and smoke seal cables through a wall or floor penetration.
- Cable trays.

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Sleeves and Cable Trays, continued

Figure 7.5
Retrofit split sleeve system



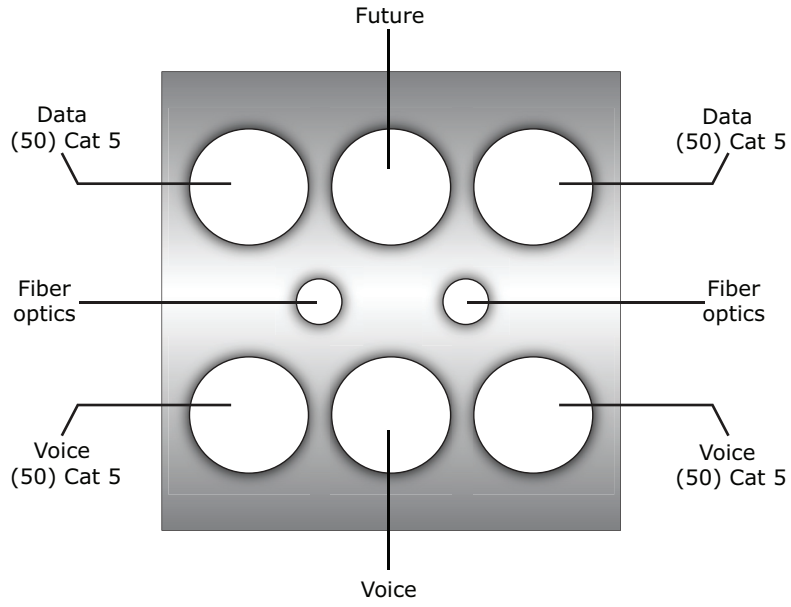
in = Inch
mm = Millimeter

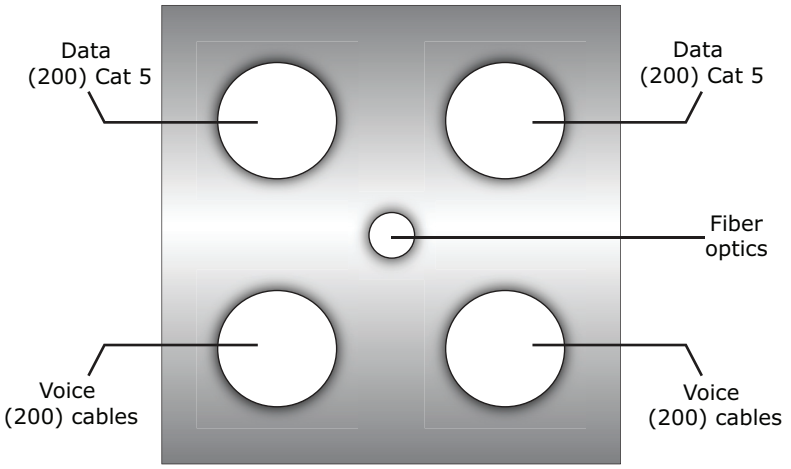
Sleeves and Cable Trays, continued

Pathway Barrier Penetration Plates (PBPPs)

The PBPP is a firestop tool designed for architects, designers, and engineers to enable centralized installation, administration, and maintenance of current and future firewall penetrations made by ITS installers for the life of the building (see Figure 7.6).

Figure 7.6
Pathway barrier penetration plate





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Sleeves and Cable Trays, continued

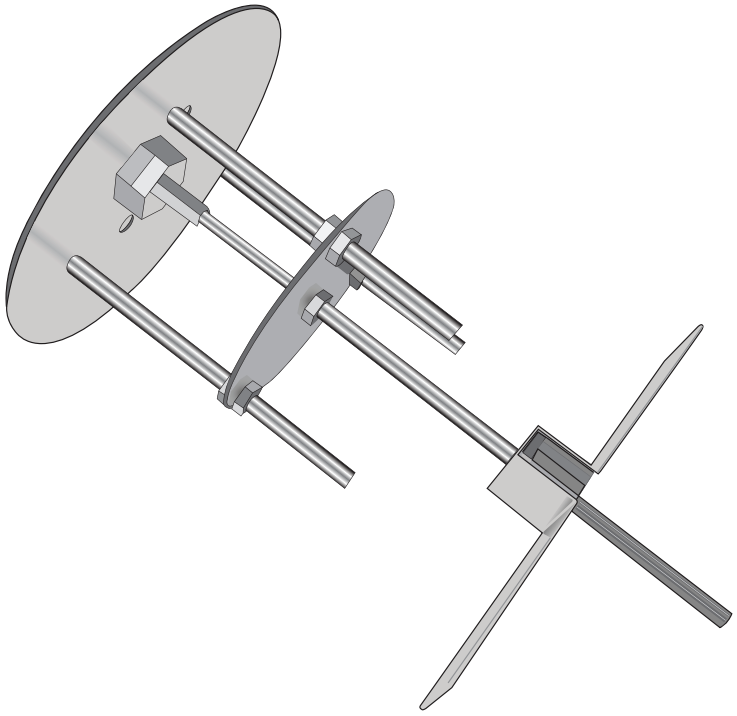
PBPPs can be designed with multiple holes for different types of cabling to be installed, smoke sealed, and firestopped. They are sealed with firestop caulk behind the pair of plates with a bead of caulk around each of the holes on both sides of the firewall. Use the PBPP as a template to ensure that only the necessary penetrations of the correct size will be made for that particular installation. The design should be made with enough holes for future cabling; install the PBPPs by screwing them to the wall studs or anchoring them in block walls.

PBPPs are unique in that they can be used with any type of mechanical sleeve system. PBPPs are normally powder-coated red. They are available in any number of configurations and are able to group different cable media as well as ensure AHJ acceptance.

Core Bore Seals (CBSs)

CBSs are designed to seal core holes during construction and postconstruction, thereby reducing installation time and reducing costs while meeting all building codes (see Figure 7.7).

Figure 7.7
Core bore seal



The CBS is inserted into an abandoned core hole, pulled tight, and tightened with an Allen socket on a cordless drill or with a wrench.

After placement of the CBS, fill the core with fire-rated foam supplied with the system. Made of high-grade plate steel, the unit is available with everything required and can be used with slabs between 77 millimeters (mm [3 inches (in)]) and 305 mm (12 in) thick in sizes ranging from 77 mm (3 in) to 147 mm (5.8 in) in diameter.

Sleeves and Cable Trays, continued

Sleeves Versus Direct Cable Placement

The issue of when to use sleeves may not be clearly defined within the code other than the need to provide an approved firestop assembly.

The construction documents often are not clear about the requirement to place sleeves or any specific type of cable support systems in new or retrofit construction projects.

Sleeves are a better long-term solution to passing through a rated barrier and:

- Allow a proper firestop and smoke seal.
- Provide a pathway through hollow wall construction.
- Allow easy placement of additional cables.
- Act as a tool (roller) to freely pull cable through a firewall without attendance.

Unfortunately, sleeve systems are often overlooked in the design process. It is critical that the ITS installer notify the owner or general contractor when it is not possible to properly firestop a cabling installation without the installation of a sleeve.

It may be necessary to submit a change order for the installation of sleeves or to contact a firestop manufacturer to determine if an alternative solution is offered for the specific installation problem.

Cable Trays

Installing a cable tray through a rated barrier may not be the best long-term solution to meeting fire safety codes, and it is often prohibited. Trays can be difficult to properly fire seal during the initial installation, and firestop materials may not be properly replaced if untrained staff undertake future installation work.

Designers often specify the use of sleeves to penetrate a rated barrier between two sections of cable tray. This specification allows the ITS installer to use common materials to seal the cables within a sleeve. If the designer does not call for the use of sleeves, the ITS installer may wish to submit a change order request for the placement of sleeves rather than spend the time and effort necessary to properly seal a tray opening. Many tray seal solutions are expensive and offer little flexibility.

If it becomes necessary to utilize a tray through a barrier, the ITS installer must obtain a specific firestop product design and approval for its use from the local fire inspection authority. Because the assembly must stop the spread of flame and resist the force of a fire hose spray, the large cable tray opening may require blocking with some form of mechanical structure in addition to nonmechanical expanding bricks, pillows, or other materials. The mechanical systems may consist of a wire mesh system, blocks and compression assemblies, metal-backed sheets, or blocked out framed walls.

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Appendix A: Underwriters Laboratories Inc.® (UL®) Numbering System

UL® assigns a unique number to each tested and qualified firestopping system. This numbering convention contains a series of letters and numbers that identify the system's components and appropriate use. Table 7.2 shows how to interpret the system number.

Table 7.2
Underwriters Laboratories Inc.® numbering system

Position	Designator	System Component
1	Letter indicating the type of barrier in which the firestop system was tested	F = Floors W = Walls C = Combination floors/walls
2	Letter indicating the type of floor or wall construction (Letter designators in the second and third positions indicate a combination of two construction material types tested in one qualified system.)	A = Concrete floors < 125 mm (5 in) B = Concrete floors > 125 mm (5 in) C = Framed floors D = Deck construction J = Concrete or masonry walls < 200 mm (8 in) K = Concrete or masonry walls > 200 mm (8 in) L = Framed walls (drywall) M = Bulkheads
3	Number indicating the type of penetrating item that was tested	0000–0999 = No penetrating item (blank openings) 1000–1999 = Metallic pipe, conduit, or tube 2000–2999 = Nonmetallic pipe, conduit, or tube 3000–3999 = Cables 4000–4999 = Cables in cable tray 5000–5999 = Insulated pipes 6000–6999 = Miscellaneous electrical penetrants (bus duct) 7000–7999 = Miscellaneous mechanical penetrants (heating, ventilating, and air conditioning [HVAC]) 8000–8999 = Mixed multiple penetrants 9000–9999 = Reserved for future use

in = Inch
mm = Millimeter

Using this table, System CAJ-8049 means:

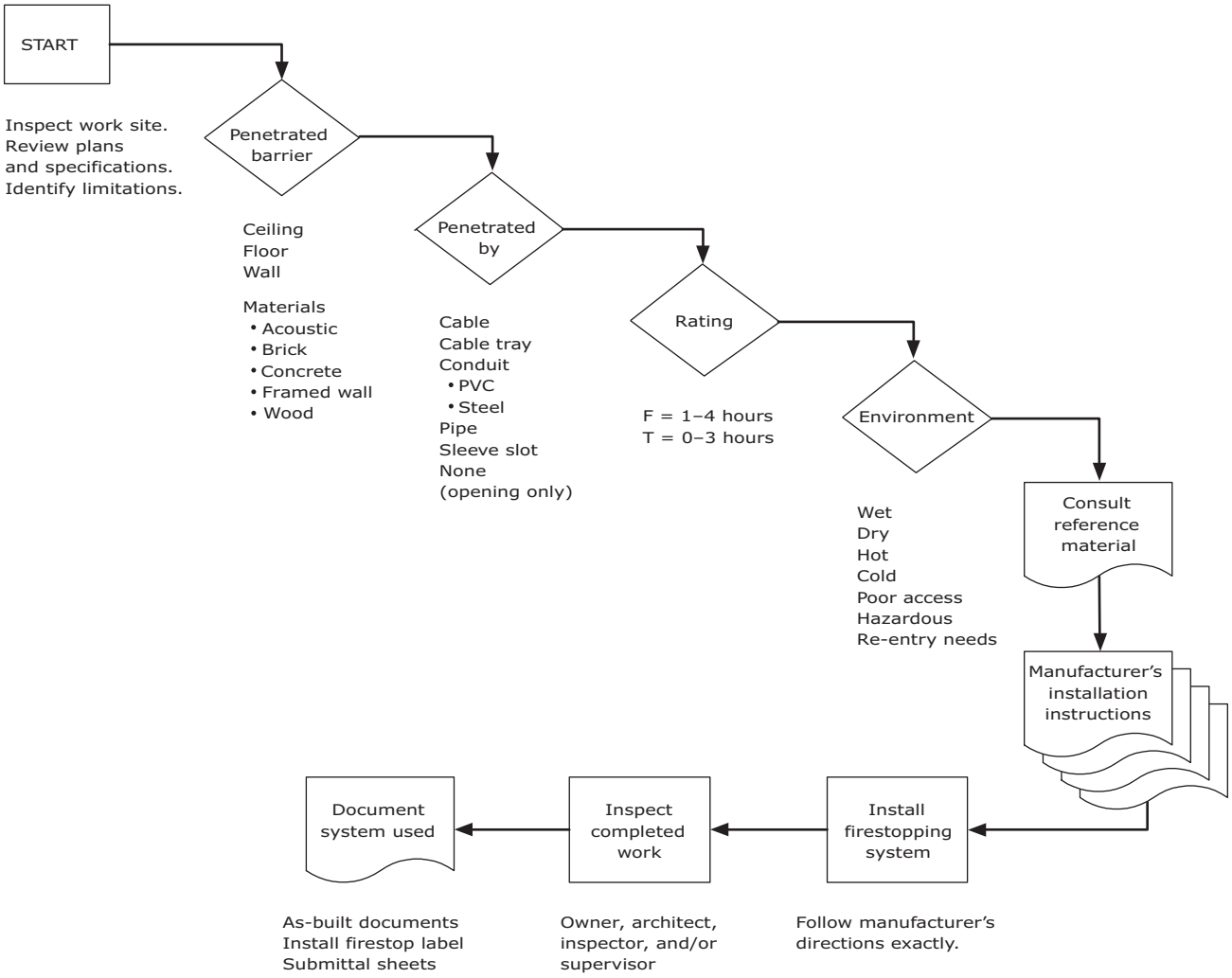
- C is either a floor or wall.
- AJ is a concrete floor with a maximum thickness of 125 mm (5 in) or concrete wall with a maximum thickness of 200 mm (8 in).
- 8049 is the 49th system in the 8000 series of mixed multiple penetrants.

In this example, System CAJ-8049 can be used for multiple penetrants (e.g., metallic pipe with specific outside dimensions, copper cable) and installed through concrete floors up to 125 mm (5 in) thick or walls up to 200 mm (8 in) thick.

Appendix B: Firestopping Decision Methods

The types of firestop systems illustrated in these diagrams are examples only. Most manufacturers of firestop materials provide catalogs, software, or Web-based services, allowing the ITS installer to identify one or more solutions for a specific need. The ITS installer must consult the manufacturer's specifications to properly identify the assembly. See Figure 7.8 for an example of firestopping decision methods.

Figure 7.8
Firestopping decision methods



PVC = Polyvinyl chloride

NOTE: Sample diagrams are provided in Appendix C: Approved Firestopping Methods.

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Appendix C: Approved Firestopping Methods

Firestopping for Brick, Concrete Block, and Concrete Walls

Pipes, Cables, Conduits, Cable Trays, and Innerducts

Use qualified firestopping systems to seal penetrations in brick, concrete block, or concrete walls for pipes, rigid electrical conduits, cable trays, and innerducts.

Verify that penetration conditions fall within the following firestopping system parameters:

- Wall thickness
- Hourly rating required
- Opening size
- Annular space (e.g., ring outside of the pipe or cable being protected and inside the hole or sleeve)
- Sleeves (present/required/optional)
- Material selection (if subject to movement)

Install the materials according to manufacturer-tested methods.

Pipes, Cables, Conduits, and Innerducts in Cored or Sleeved Openings

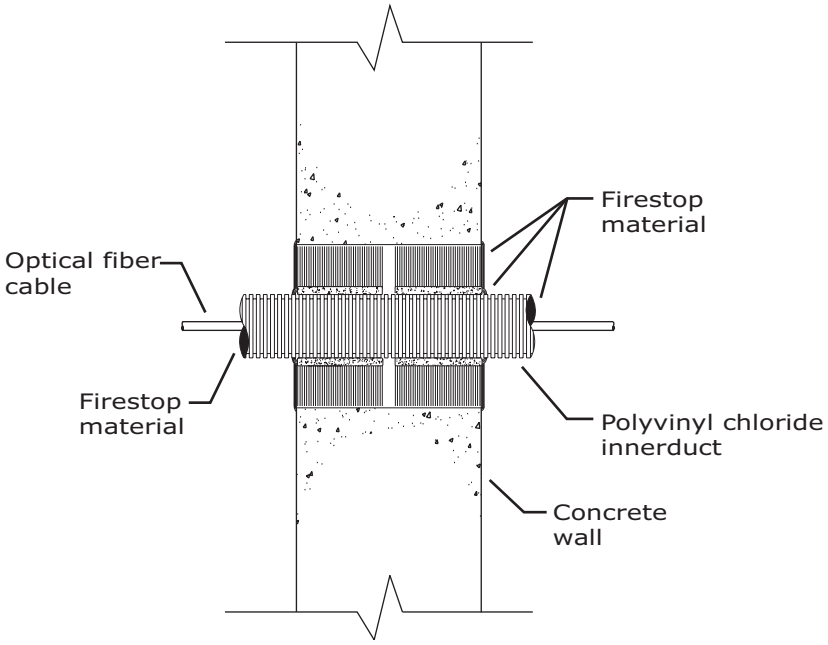
Use qualified materials when firestopping sleeved penetrations. Install the materials according to manufacturer-tested methods. If necessary, have the seal design evaluated for its ability to tolerate movement.

Secure sleeve systems in place according to the manufacturer's instructions.

Firestopping for Brick, Concrete Block, and Concrete Walls, continued

Figure 7.9 shows a penetration firestop for a single optical fiber cable with a polyvinyl chloride (PVC) innerduct through a concrete wall.

Figure 7.9
Polyvinyl chloride innerduct penetration in concrete wall



NOTE: Before installing innerduct, ensure that it has an appropriate fire rating (e.g., riser, plenum rated).

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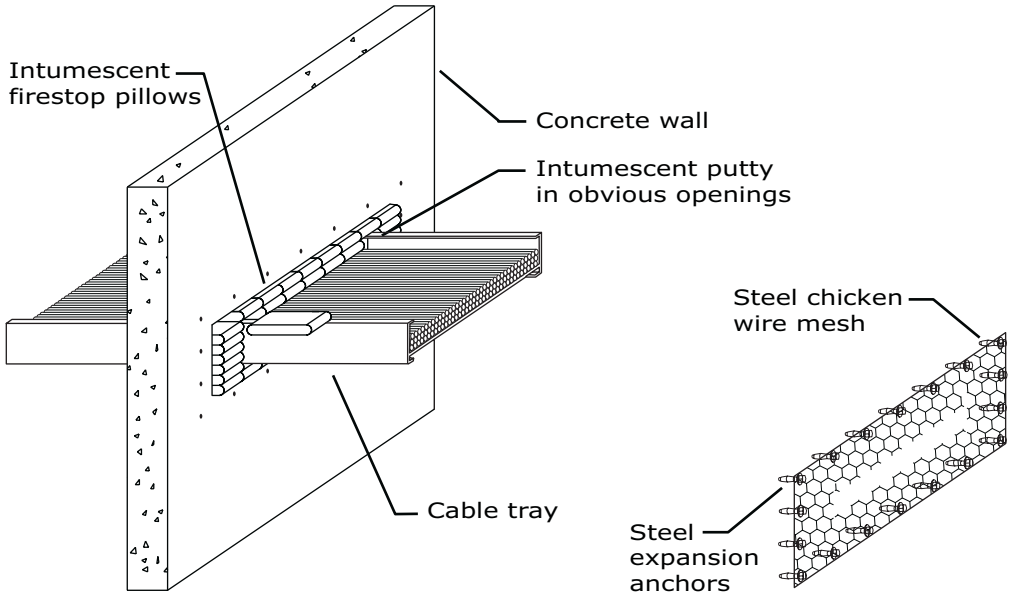
Firestopping for Brick, Concrete Block, and Concrete Walls, continued

Cable Trays

Close cable tray penetrations with a qualified firestopping system. Install the system according to the manufacturer's instructions.

A qualified seal system is shown in Figure 7.10.

Figure 7.10
Qualified cable tray seal system in concrete wall



Firestopping for Floor Assemblies

Making Penetrations

Never make penetrations in either new or existing concrete floor systems without the approval of a structural engineer. Penetrations can damage the structural load-bearing capacity of the floor.

Pipes, Cables, Conduits, Ducts, Innerduct, and Cable Trays

Use qualified systems to firestop through penetrations in concrete floor systems for pipes, cables, conduits, ducts, innerducts, and cable trays. The thickness (or depth) of firestop materials must:

- Match the thickness recommended by the manufacturer.
- Be established by formal testing.

Firestopping for Floor/Ceiling Assemblies

Introduction

Independent penetrations are the major firestopping concerns when dealing with floor/ceiling assemblies.

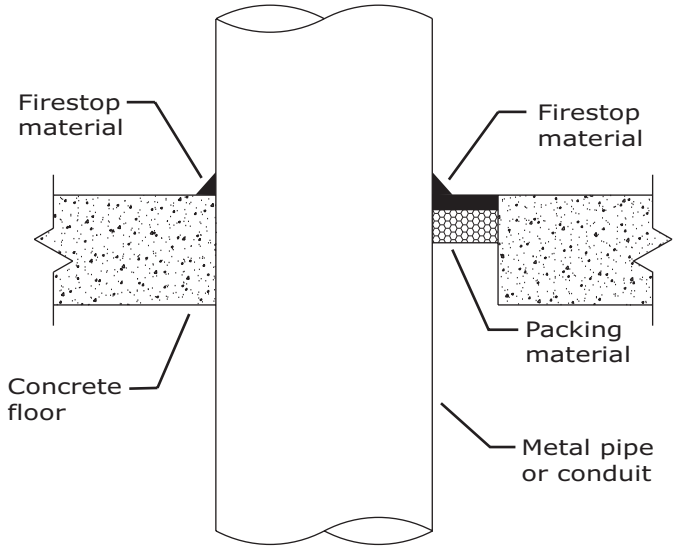
Effects of Fire on Ceilings

WARNING: Firestopping of ceiling penetrations is particularly critical. Once a ceiling is violated by fire, the increase in temperature reduces the load-bearing capacity of the structural support members in the assembly.

Always follow listed assembly installation instructions.

Figure 7.11 shows conduit penetration through concrete or masonry wall or floor.

Figure 7.11
Conduit penetration on concrete floor



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Firestopping for Framed Wall Assemblies

Pipes, Conduits, and Innerducts

Use qualified firestopping systems to seal penetrations in framed wall assemblies. Verify that penetration conditions fall within the following firestopping system parameters:

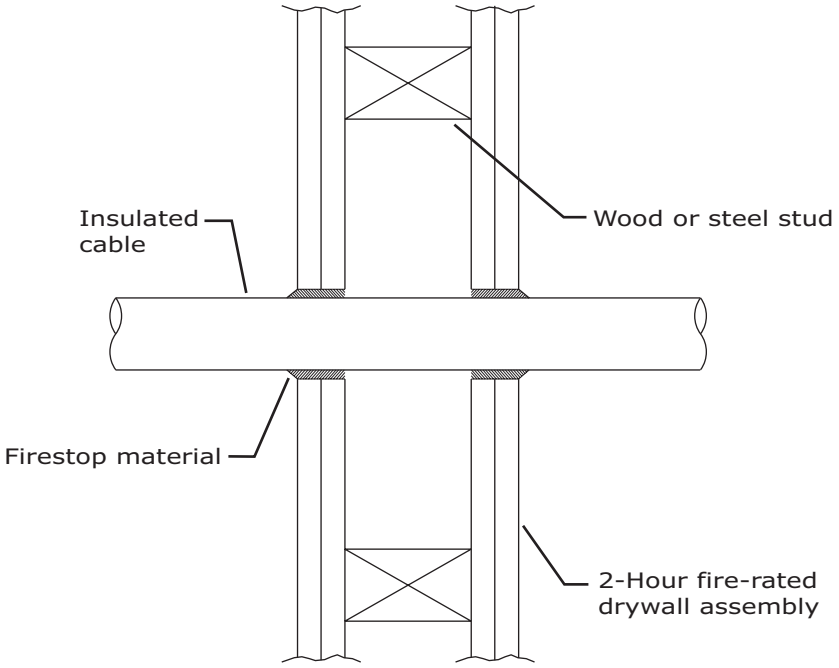
- Hourly rating
- Opening size
- Annular space
- Sleeves (present/required/optional)

The firestopping system is typically required to be installed symmetrically on both sides of the wall. Install the materials according to manufacturer-tested methods.

Telecommunications Cable

Telecommunications cable that is not enclosed in conduit may penetrate framed walls if a qualified firestopping system is used (see Figure 7.12). Always check with the local code authority to determine if conduit or sleeves are required.

Figure 7.12
Telecommunications cable seal system for framed wall



Firestopping for Framed Wall Assemblies, continued

Firestopping a Shaft

A penetrating electrical apparatus that is connected to a conduit that penetrates one or more floor/ceiling assemblies may create a shaft condition.

In this situation, use an appropriate firestop method inside the conduit.

Firestopping Considerations (General)

Match Existing Conditions

Select a qualified firestopping system that matches the actual conditions that exist (e.g., penetrating item(s), material, wall/floor/ceiling configuration).

NOTE: See Fire Rating Classifications in this chapter.

If an exact match cannot be made between firestopping systems listed and actual conditions, select a system that is close and seek an engineering judgment from the firestop manufacturer's technical support/engineering department for submittal to the local AHJ.

Selection Criteria

When selecting a qualified system, take into account the following:

- Consider the actual conditions tested and covered by the system.
- Never substitute products of a qualified firestopping system with another manufacturer's products. Products from one manufacturer's system are not interchangeable with products from another manufacturer's system.
- The difference between the actual floor/ceiling/wall thickness and conditions tested during qualification may affect listed F, T, and L ratings.
- A firestop material capable of sealing against the passage of smoke and toxic gases through the penetration is highly desirable.

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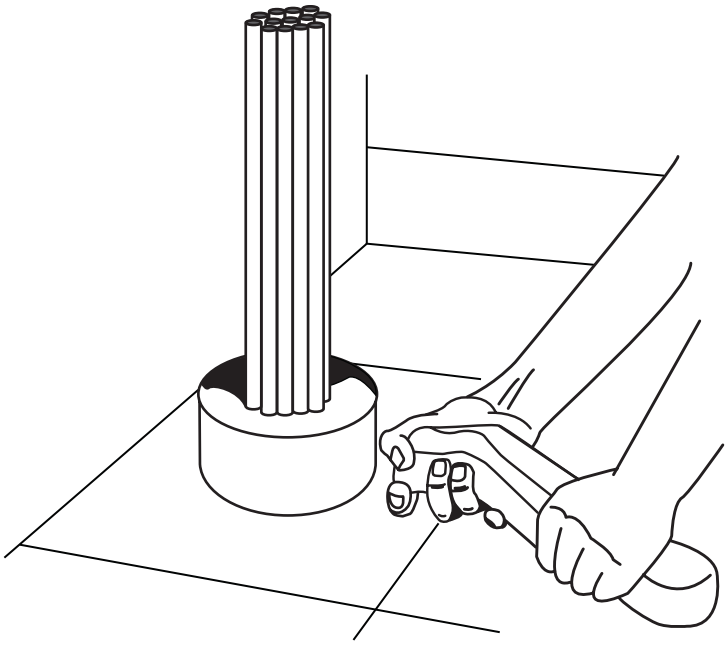
Typical Installations

Steps—Sealing a Floor Penetration with Putty

The following illustrations show an example of installing a putty seal from one side of a floor penetration.

Step	Installing a Putty Seal
1	Tear off a small portion of the putty (see Figure 7.13).
	NOTE: Use a drop cloth or other cover to protect the floor surface from the putty and insulation material.

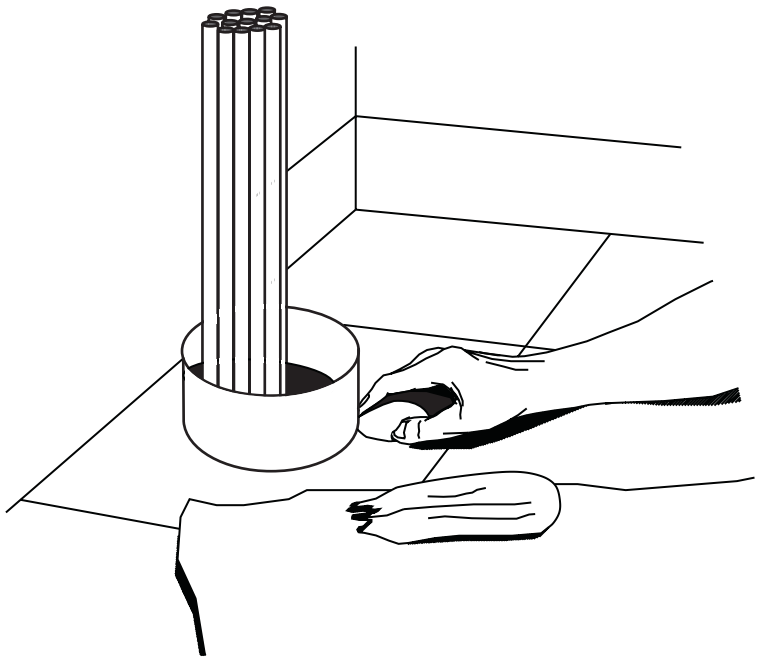
Figure 7.13
Tear off putty



Typical Installations, continued

Step	Installing a Putty Seal
2	Use the putty to build a bottom in the penetration according to the manufacturer's instructions (see Figure 7.14).

Figure 7.14
Building bottom of penetration seal

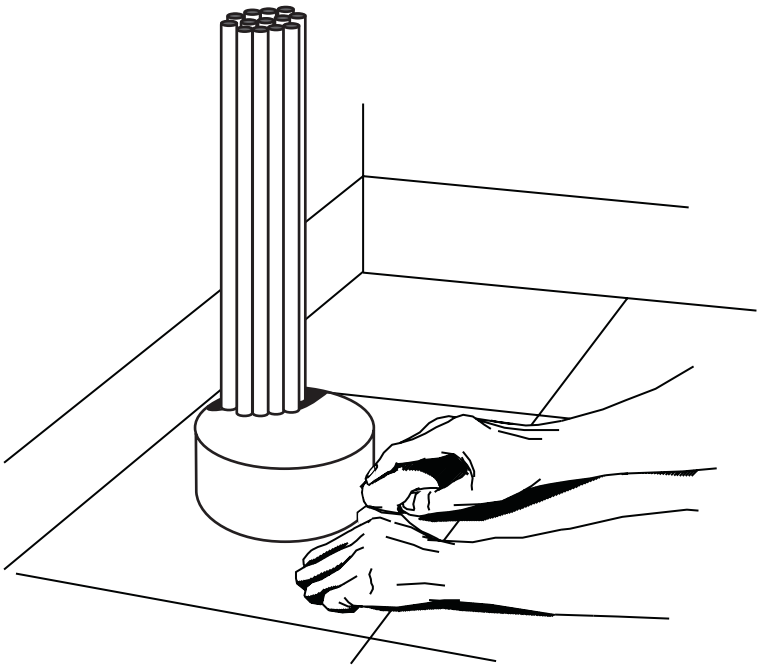


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Typical Installations, continued

Step	Installing a Putty Seal
3	Fill the penetration with ceramic fiber or rock wool fill, stopping far enough from the upper rim to allow for a top layer of putty at the manufacturer's recommended thickness (see Figure 7.15).

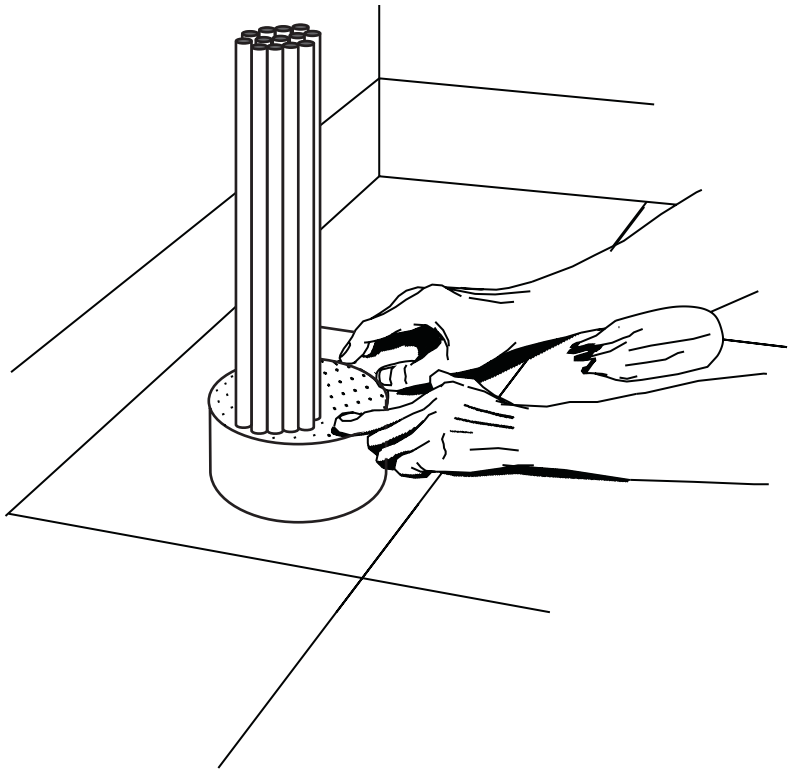
Figure 7.15
Filling the penetration



Typical Installations, continued

Step	Installing a Putty Seal
4	Use the putty to build a top on the penetration according to the manufacturer's instructions (see Figure 7.16).

Figure 7.16
Building top on penetration



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Typical Installations, continued

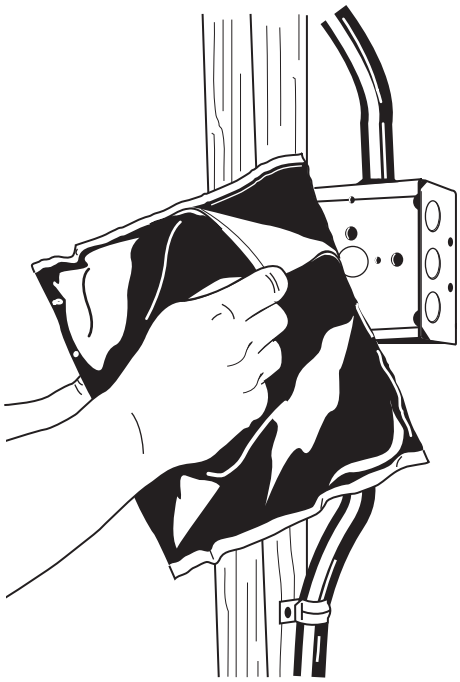
Steps—Sealing an Outlet Box with Putty (Membrane Penetration)

To seal an outlet box, follow the steps below.

NOTE: New types of putty pads are available to seal the outlet box from the inside. Follow the manufacturer's instructions.

Step	Sealing an Outlet Box with Putty (Membrane Penetration)
1	Remove poly liner from one side of pad (see Figure 7.17).

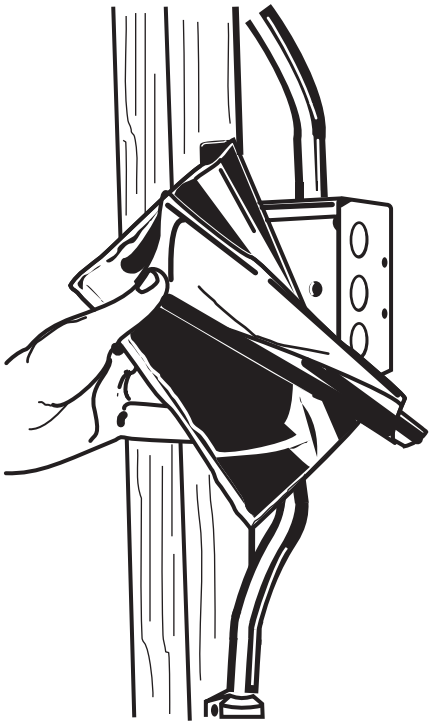
Figure 7.17
Poly liner removal



Typical Installations, continued

Step	Sealing an Outlet Box with Putty (Membrane Penetration)
2	Align pad to the side of the box, partially overlapping the stud and adhere. Work to the opposite side of the box to the edges (see Figure 7.18).

Figure 7.18
Align pad to one side of box



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Typical Installations, continued

Step	Sealing an Outlet Box with Putty (Membrane Penetration)
3	If wall membrane is in place, pack putty into the gaps between the box and the framed wall, slightly overlapping the inner framed wall surface. If the membrane is to be installed after pad installation, overlap the front edge of the box so that the putty will be compressed around the edges of the box as framed wall is installed. Cut slits in the pad to fit around conduits or cables (see Figure 7.19).

Figure 7.19
Cut slits into the pad



Typical Installations, continued

Step	Sealing an Outlet Box with Putty (Membrane Penetration)
4	Press pad to the surface of the top, bottom, and sides of the box (see Figure 7.20).

Figure 7.20
Press pad to surface



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ASTM. ASTM E814. *Standard Test Method for Fire Tests of Penetration Firestop Systems*. West Conshohocken, PA: ASTM, 2010.

Underwriters Laboratories Inc.®. UL 1479. *Standard for Fire Tests of Through-Penetration Firestops*. Northbrook, IL: Underwriters Laboratories Inc., 2010.

Acknowledgments

Steps 1-4 on pages and Figures 7.29- 7.36 are provided by Specified Technologies Inc. (STI), 210 Evans Way, Somerville, NJ 08876. 800-992-1180.

Figures 7.8 and 7.9 are provided by Unique Firestop, 21303 County Rd 68, Robertsdale, AL 36567. 251-960-5018.



Chapter 8
Data Centers

Chapter 8 describes the installation methods involved in data centers, including their security, equipment, and spaces.

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Introduction

This chapter describes and provides guidance regarding installation practices in data centers. The data center represents the pinnacle of design and integration for telecommunications cabling and information technology (IT). The impact of implementation decisions made for one component has a more significant effect on others in a data center because all components are critically linked to each other.

Data centers typically have high densities of IT and telecommunications equipment, which are commonly mounted in cabinets and racks. Such high equipment densities also result in high densities of cabling, power, and cooling.

Data centers also support functions that are critical to the operation of the organization. This means that data centers have higher security and change control requirements than general office spaces.

Working in Data Centers

Overview

Because of the critical functions typically performed in data centers, they have special security, safety, and change control procedures. Check with the data center owner or operator to determine the requirements for the data center before planning the work because the requirements may affect the schedule, the persons who can perform the work, and the type of work that can be performed.

Security

The data center owner or operator may have special security requirements for all persons who perform work in the data center. The extra security provisions vary, depending on the policies of the data center owner or operator. Examples of such provisions include:

- Criminal or other background checks, which may take several days or weeks.
- Security badges and biometric system access, which may be good for one day or a longer duration.
- Identification (e.g., driver's license, other government-issued identification) for each person requiring access to the data center to obtain a temporary badge.
- Escort by a security officer or other representative of the data center owner or operator.
- Special tools to lift access floor tiles or cable tray covers.
- Special tools, keys, badges, or codes required to access computer room cabinets.
- Prohibition of the following activities:
  - Taking photographs or videos
  - Eating, drinking, or smoking except in designated areas
  - Using radio transmitters in the computer room
  - Using mobile phones in the computer room
  - Cutting or welding metal in the computer room
  - Unpacking equipment in computer room spaces (e.g., to minimize or avoid airborne debris)
  - Using the computer room for storage
  - Leaving doors propped open

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Safety

The data center owner or operator may have special safety requirements for all persons who perform work in the data center. For example, all persons working in the data center may be required to take a safety training class before performing any work.

Access floor systems are rated for maximum static loads and dynamic (rolling) loads. The stability of the access floor system can be compromised if any access floor stringers or if too many access floor tiles are removed. Perform the following:

- Confirm the static and dynamic load specifications of the access floor system before bringing heavy equipment into a computer room with access floor.
- Avoid removing any stringers in computer room access floor systems. If stringers must be removed, obtain permission from the data center owner or operator first and determine the maximum number of stringers that may be removed at any one time.
- Obtain permission from the data center owner or operator before removing any access floor tiles. Determine the maximum number of access floor tiles that may be removed at any one time.

Data centers typically have fire detection and suppression systems. Hot work permits may be required. Ensure that installation activities do not disable or cause activation of an alarm. Check with the data center owner or operator regarding the protection system and if the activity being performed can cause an alarm (e.g., dust created during installation/removal of cable, smoke created during welding of bonding conductors). Do not disable any alarm systems without the approval of the data center owner or operator.

Change Control

The data center owner or operator may have change control requirements for any activity performed in the data centers. The change request typically requires a description of the:

- Proposed time and date of the activity.
- Activity to be performed.
- Impact of the change or activity (e.g., systems or applications that may be down while the activity is being performed).
- Dependencies and related change requests or projects.

Depending on the organization, change requests may require days or even weeks to process. Check with the data center owner or operator or the project manager to determine the change control requirements, expected lead time for approvals, and person who will be responsible for submitting and confirming the approval of change requests.

If the data center has a change control process, confirm that the change request covering each activity is approved before starting work on that activity.

Do not perform activities not specifically covered in the change request, including opening of cabinets not covered by the change request.

Some data centers only permit work to be performed during specific times of the week, month, or year.

Consider lead times for the change control process and permitted data center change windows when planning installations in data centers.

Data Center Spaces

Relationship of Spaces within a Building and Data Center

See Figure 8.1 for an example of various spaces within a building housing a data center, spaces within the data center that are exterior to the computer room, and the computer room.

Computer Room

A computer room is the portion of the data center that actually houses the IT equipment and is defined as a room whose primary purpose is to accommodate data processing equipment.

Data Center

A data center is a building or portion of a building whose primary function is to house a computer room and its associated support spaces. Thus, the data center includes the data center electrical rooms, mechanical rooms, storage rooms, staging rooms, operations/command center, and other spaces whose primary function is to support the computer room.

Entrance Room (ER)

The entrance room (ER) may be a space within the computer room or exterior to the computer room that supports the interface between the data center cabling system and external cabling (e.g., campus cabling or entrance cables for access providers [APs (telecommunications carriers)]).

Security and change control procedures for data center ERs are typically the same as those for computer rooms.

Telecommunications Room (TR)

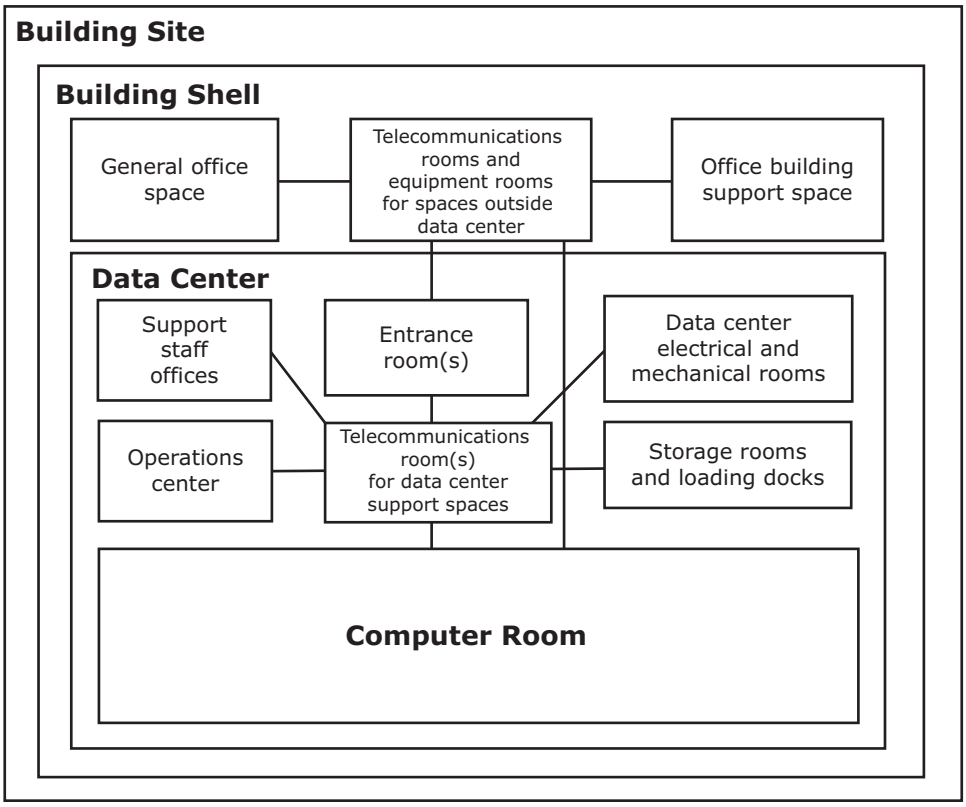
Telecommunications rooms (TRs) support termination of horizontal cabling to the spaces outside the computer room. TRs outside the computer room but within the data center may support horizontal cabling for data center support spaces (e.g., electrical rooms, mechanical rooms, operations/command centers).

TRs outside the data center may support general office spaces and other spaces in the building that are not associated with the data center.

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Relationship of Spaces within a Building and Data Center, continued

Figure 8.1
Relationship of data center spaces



Computer Room Spaces and Distributors

The names for the spaces and termination points vary between organizations and standards. The ones used in Figure 8.2 and described in this chapter are from the published BICSI Data Center Standard 002 and the draft of ANSI/TIA-942-A. The corresponding terms used in European (CENELEC EN 50173-5) and international (ISO/IEC 24764) data center telecommunications standards are provided in Table 8.1.

Table 8.1
TIA, CENELEC, and ISO data center distributors/termination points

TIA Term	CENELEC and ISO/IEC Term
External network interface	External network interface
Main distributor	Main distributor
Intermediate cross-connect	Not currently defined
Horizontal cross-connect in HDA	Zone distributor
Horizontal cross-connect in TR	Floor distributor
Consolidation point in ZDA	Local distribution point
Equipment outlet	Equipment outlet

CENELEC = Comité Européen de Normalisation Electrotechnique
HDA = Horizontal distribution area
IEC = International Electrotechnical Commission
ISO = International Organization for Standardization
TIA = Telecommunications Industry Association
TR = Telecommunications room
ZDA = Zone distribution area

No specific terms are defined in the European Committee for Electrotechnical Standardization (Comité Européen de Normalisation Electrotechnique [CENELEC]) and International Organization for Standardization/International Electrotechnical Commission (ISO/IEC) data center standards for the rooms or spaces containing distributors (e.g., main distribution area [MDA], intermediate distribution area [IDA], horizontal distribution area [HDA], zone distribution area [ZDA], equipment distribution area [EDA]).

All spaces other than the MDA and EDA are optional. A data center must have at least one of each.

All distributors other than the main distributor (MD) and horizontal cross-connect (HC [floor distributor (FD)]) are optional. A data center must have at least one of each.

Active equipment (e.g., LAN and storage area network [SAN] switches) are often located in MDAs, IDAs, and HDAs. For top-of-rack switch configurations, switches may also be located in EDAs.

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Computer Room Spaces and Distributors, continued

Telecommunications Entrance Room (ER) and External Network Interface (ENI)

The telecommunications entrance room (ER) is the room or space that contains the external network interface (ENI), the distributor that contains the interface between computer room cabling and external cabling (e.g., campus cabling, AP cabling). Thus, AP/carrier demarcation is typically located in the ER.

The ER may be located inside or outside the computer room. Additionally, the ENI may be located in the MDA in data centers that do not require separate ER spaces.

Data centers may have multiple ERs for redundancy to avoid exceeding maximum circuit distance limitations for circuits provisioned by APs (e.g., T1s, E1s, T3s, E3s).

Main Distribution Area (MDA) and Main Cross-Connect (MC [Campus Distributor (CD)])

The MDA is the room or space in the computer room that contains the main cross-connect (MC [campus distributor (CD)]) for computer room cabling. It also commonly contains core LAN and SAN switches.

The term main distribution frame (MDF) is sometimes used for this space. Although used in the industry, the term is not recognized in data center standards.

Every data center must have at least one MDA and MC (CD). The MDA also may contain ENI if there is no separate ER in the computer room and may contain an HC (FD) for horizontal cabling to nearby equipment cabinets and racks (EDAs).

A data center may have more than one MDA for redundancy and may have separate MDAs for LAN and SAN cabling to keep the size of the MDAs manageable.

Intermediate Distribution Area (IDA) and Intermediate Cross-Connect (IC [Building Distributor (BD)])

The IDA is the room or space in the computer room that contains the intermediate cross-connect (IC [building distributor (BD)]), a second layer backbone distributor that may be present in large data centers.

Horizontal Distribution Area (HDA) and Horizontal Cross-Connect (HC [Floor Distributor (FD)])

The HDA is the room or space in the computer room that contains the HC (FD). The HC (FD) is the distributer for horizontal cabling to equipment cabinets and racks (EDAs). The HC (FD) may be located in the MDA or IDA to support horizontal cabling to cabinets/racks located near MDAs or IDAs.

The term intermediate distribution frame (IDF) is sometimes used for this space. Although used in the industry, the term is not recognized in data center standards.

Computer Room Spaces and Distributors, continued

Zone Distribution Area (ZDA)

The ZDA is an optional interconnection where an equipment outlet or consolidation point (CP) may be located.

If equipment outlets are located in the ZDA, the ZDA is performing a function similar to a multiuser telecommunications outlet assembly (MUTOA) in a commercial office building. In this case, the ZDA might be used to terminate cabling for cabinets in which it is not possible or desirable to install a patch panel (e.g., mainframe, storage system).

The ZDA also may contain a CP to support cabling to an area of the data center where cabinet locations change frequently or are not yet known.

The ZDA only includes passive termination hardware (e.g., patch panels). It does not support active equipment (e.g., LAN switches).

The ZDA may be located within a cabinet, rack, or overhead space or under the access floor.

Equipment Distribution Area (EDA)

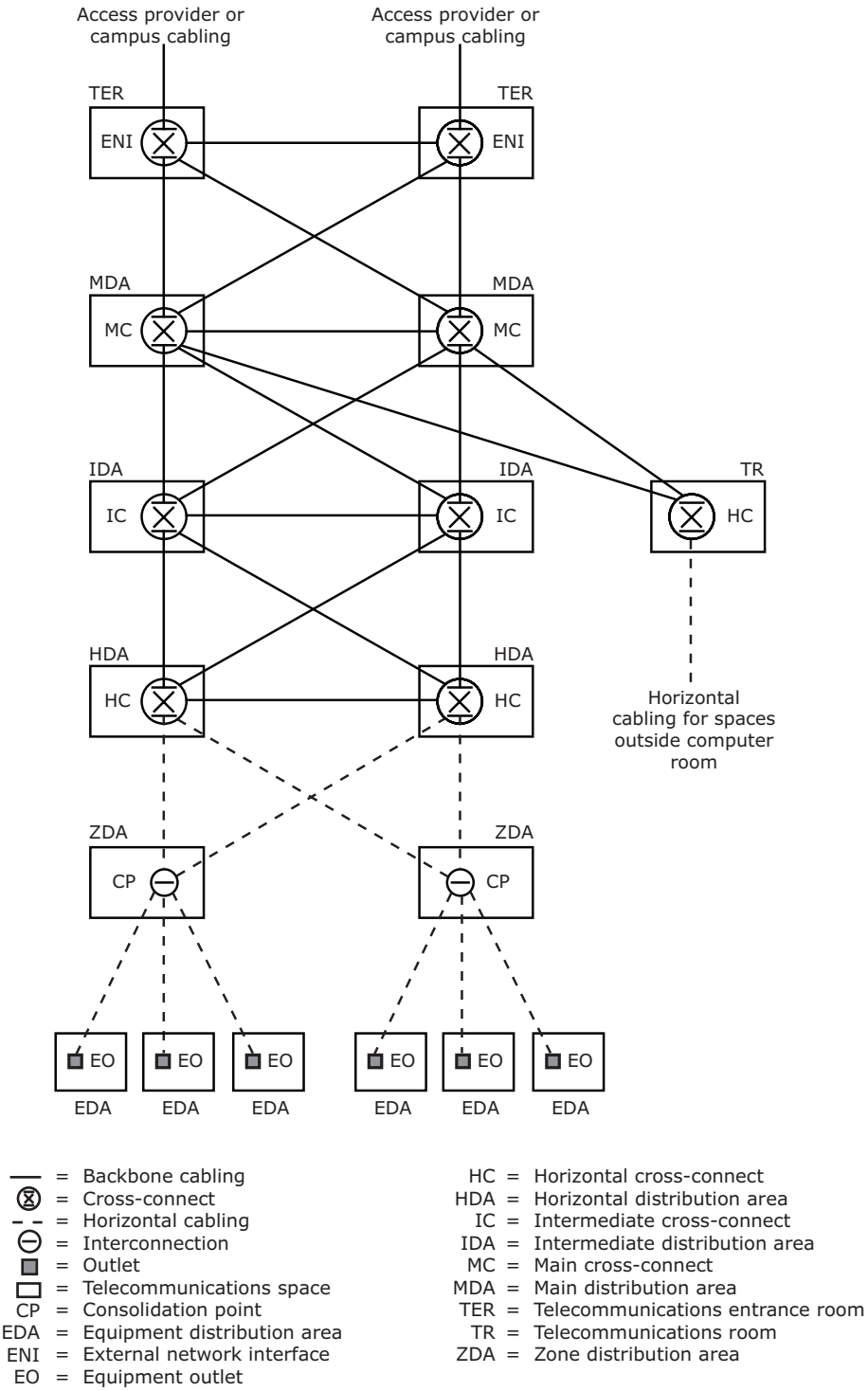
The EDA is the computer room space occupied by equipment cabinets or racks. Horizontal cabling terminates in the EDA in an equipment outlet (EO), which is typically mounted in a patch panel.

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Computer Room Spaces and Distributors, continued

See Figure 8.2 for an example of a data center that illustrates the spaces and cabling termination points commonly found in a computer room.

Figure 8.2
Example of computer room spaces and distributors

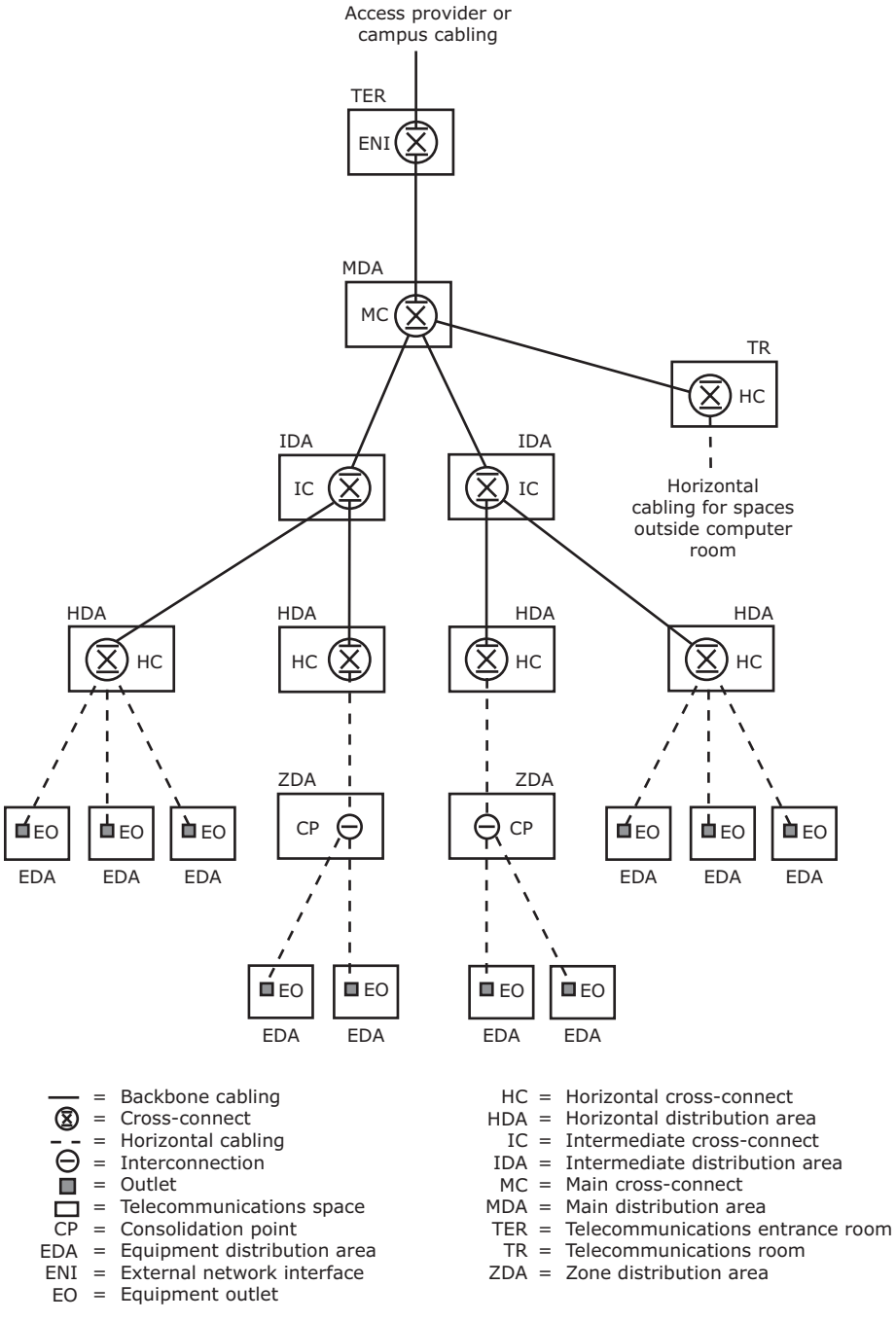


Data Center Cabling

Topology

The data center cabling requirements are described in the applicable standard (e.g., ANSI/TIA-942, CENELEC 50173-5, ISO/IEC 24764). The basic topology is a hierarchical star topology (see Figure 8.3). Additional distributors and cabling may be added to provide additional redundancy (see Figure 8.2).

Figure 8.3
Example of hierarchical star topology



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Topology, continued

Additionally, direct cabling from the ER to an IDA or HDA is permitted to avoid exceeding maximum circuit distance restrictions for circuits provisioned by APs (e.g., T1s, E1s, T3s, E3s).

Backbone cabling includes cabling between distributors located in the ER, MDA, IDA, HDA, or TR.

Horizontal cabling includes the cabling from the HC (FD), which may be located in the MDA, IDA, or HDA, to equipment outlets in the EDA or ZDA.

Cable and Connector Types

Overview

Data center equipment and technologies change rapidly. Thus, data center cabling should be provisioned to provide flexibility to accommodate anticipated variations and changes in configurations and technologies with minimum change. For example, it may be desirable to install enough cabling to each cabinet to handle 90 percent or more of the typical configurations. Additionally, the performance of this cabling should be high enough to handle anticipated future LAN and SAN technologies.

Cabling Types

The following types of cables are recognized in data center telecommunications cabling standards:

- 100 ohm balanced twisted-pair cables
- Multimode optical fiber cable
- Singlemode optical fiber cable
- 50/75 ohm coaxial cable

Cable and Connector Types, continued

Balanced Twisted-Pair Cabling

Balanced twisted-pair cabling performance is described using a scale based on classes or categories as defined by ISO/IEC and TIA, respectively (see Table 8.2).

Table 8.2
Balanced twisted-pair cabling channel performance

TIA Categories	ISO Categories/Classes	Frequency Characterization
Category 3	Category 3/class C	16 MHz
Category 5e	Category 5e/class D	100 MHz
Category 6	Category 6/class E	250 MHz
Category 6A	Category 6_A/class E_A	500 MHz
N/A	Category 7/class F	600 MHz
N/A	Category 7_A /class F_A	1000 MHz

MHz = Megahertz

NOTE: TIA does not define cabling above category 6A. Category 7/class F and higher cabling are defined by CENELEC and ISO/IEC. Each of these standards writing organizations defines component performance by the term category while ISO/IEC and CENELEC define system performance by the term class.

The draft ANSI/TIA-942-A recommends category 6A/class E cabling for horizontal and backbone cabling and specifies a minimum of category 6/class E for balanced twisted-pair horizontal cabling. Category 3 is the minimum specification for backbone cabling.

CENELEC EN 50173-5 specifies a minimum of category 6/class E for balanced twisted-pair cabling in all but network access cabling (cabling extending from the ER to the rest of the data center).

ISO/IEC 24764 specifies a minimum of category 6_A/class E_A for balanced twisted-pair cabling except for public network access cabling.

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Cable and Connector Types, continued

Optical Fiber Cabling Types

There are four classes of multimode optical fiber cabling (OM1, OM2, OM3, and OM4) and two classes of singlemode optical fiber cabling (OS1 and OS2). Table 8.3 shows the minimum bandwidth or optical performance for each cabled optical fiber cable by type.

Table 8.3
Optical fiber cable performance by type

Cabled Optical Fiber Type	Description	Performance
OM1	62.5/125 µm multimode	Minimum overfilled launch bandwidth of 200 and 500 MHz•km at 850 and 1300 nm, respectively.
OM2	50/125 µm multimode 62.5/125 µm multimode	Minimum overfilled launch bandwidth of 500 and 500 MHz•km at 850 and 1300 nm, respectively.
OM3	50/125 µm 850 nm laser optimized	Minimum overfilled launch bandwidth of 1500 and 500 MHz•km at 850 and 1300 nm and an effective modal bandwidth of 2000 MHz•km at 850 nm.
OM4	50/125 µm 850 nm laser optimized	Minimum overfilled launch bandwidth of 3500 and 500 MHz•km at 850 and 1300 nm and an effective modal bandwidth of 4700 MHz•km at 850 nm.
OS1	Singlemode	Minimum bandwidth of singlemode optical fiber cable is not characterized in the same manner as multimode. Loss characterization is 1.0 dB per km at 1310 nm and 1550 nm for indoor and 0.5 db per km at 1310 nm and 1550 nm for outdoor.
OS2	Singlemode	Minimum bandwidth of singlemode optical fiber cable is not characterized in the same manner as multimode. Loss characterization is 0.4 db per km at 1310 nm, 1383 nm, and 1550 nm for both indoor and outdoor.

dB = Decibel
km = Kilometer
MHz•km = Megahertz kilometer
µm = Micrometer
nm = Nanometer

Cable and Connector Types, continued

Multimode Optical Fiber Requirements and Recommendations in Standards

ANSI/TIA-942 specifies a minimum of OM1 and recommends a minimum of OM3 for multimode optical fiber cabling. The draft ANSI/TIA-942-A specifies a minimum of OM2 and further recommends the use of LC connector and multifiber push on (MPO) connectors.

CENELEC EN 50173-5 specifies a minimum of OM2 for multimode optical fiber cabling except for public network access cabling. Additionally, this standard specifies the following connectors for termination of multimode optical fibers at the EO and ENI:

- LC connectors for termination of one or two multimode fibers
- MPO connectors for termination of more than two multimode fibers

ISO/IEC 24764 specifies a minimum of OM3 for multimode optical fiber cabling except for public network access cabling. It also specifies the LC and MPO connectors for termination of multimode optical fibers at the EO and ENI.

Singlemode Optical Fiber Requirements and Recommendations in Standards

ANSI/TIA-942, CENELEC EN 50173-5, and ISO/IEC 24764 permit both OS1 and OS2 singlemode optical fiber cables.

The draft ANSI/TIA-942-A recommends the use of LC and MPO connectors.

CENELEC EN 50173-5 specifies the following connectors for termination of singlemode optical fibers:

- LC-PC connectors for termination of one or two singlemode fibers at the EO
- Angled LC connectors for termination of one or two singlemode fibers at the ENI
- MPO connectors for termination of more than two singlemode fibers at the EO or ENI

ISO/IEC 24764 specifies the following connectors for termination of singlemode optical fibers:

- LC connectors for termination of one or two singlemode fibers at the EO
- Angled LC connectors for termination of one or two singlemode fibers at the ENI
- MPO connectors for termination of more than two singlemode fibers at the EO or ENI

75 Ohm Coaxial Cabling

ANSI/TIA-942 recognizes 734-type and 735-type coaxial cable for E1, E3, and T3 circuits. Such cables are terminated on BNC or TNC connectors. This type of cable is not recognized in CENELEC EN 50173-5 and ISO/IEC 24764.

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Cable and Connector Types, continued

Testing

Cabling shall be tested as specified in the installation specification and the applicable standard (e.g., ANSI/TIA-942, CENELEC EN 50173-5, ISO/IEC 24764).

Test results should be saved in electronic format, preferably both in the format of the test equipment manufacturer's software and in another format that does not require the use of the vendor software (e.g., .xls, .csv).

Administration

The cabling system shall be labeled and documented as specified in the installation specification and the applicable standard. Each cabinet and rack shall be labeled on the front and back with its identifier. Power strips should be labeled with the power distribution unit or panelboard identifier and circuit breaker number.

Good documentation and labeling significantly reduce troubleshooting time and planning for moves, adds, and changes (MACs).

Data Center Pathways

Overview

Telecommunications cables should be installed in cable pathway systems to manage routing of cabling and to ensure that telecommunications cabling is adequately separated from lighting, electrical power, and moisture, which can impair the performance of the cabling.

Pathway Sizing and Installation

Cable pathway systems typically used in data centers include cable trays, cable matting, conduits, and noncontinuous supports (e.g., hooks, cable ties, other cable supports).

Cable pathways should be sized to permit growth. Cable trays should be planned for an initial maximum calculated fill ratio of 25 percent (ratio of cable area to ratio of tray area). At 50 percent fill ratio, cables completely fill the cable tray.

The depth of cables in pathways shall not exceed 152 millimeters (mm [6 inches (in)]).

Optical fiber patch cords should not be placed in pathways with solid bottoms rather than wire basket trays, cable ladders, and noncontinuous supports to avoid an increase in fiber attenuation for cables because of localized areas being exposed to higher compressive loads. It is recommended that optical fiber patch cords use separate pathways from other cables.

The cable trays, cable runways, and cable tray support system shall be free of burrs, sharp edges, or projections that can damage cable insulation. Threaded rods installed within the area where cables are placed shall have a smooth, nonscratching covering to prevent damage to cables.

At least 305 mm (12 in) clearance should be provided above the top of cable trays and cable runways to provide adequate space for the installation and removal of cables. The top of cable trays installed directly below access floor tiles should be at least 51 mm (2 in) below the bottom of the access floor tile to permit cables to be routed out of the cable tray without incurring damage from floor tiles installed above them.

Do not use cable trays and cable runways as walkways or ladders. See National Electrical Manufacturers Association® (NEMA®) VE2 for additional information regarding cable tray installation and support.

Abandoned cables shall be removed.

Pathway Segregation and Coordination

Cable pathway routing shall be coordinated with other trades to ensure that adequate clearances are provided and that adequate segregation from lighting and electrical power is provided. See local regulations and the applicable standard (e.g., ANSI/TIA-942, CENELEC EN 50173-5, ISO/IEC 24764) regarding segregation requirements.

Overhead cable trays are less disruptive to efficient cooling than underfloor cable trays.

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Pathway Segregation and Coordination, continued

If cable trays are installed under the access floor, they should be installed in the hot aisles (aisles facing the rear of the cabinets) so as to not interfere with airflow in cold aisles. Additionally, cable trays should be placed so as to minimize disruption of airflow into or out of air conditioning equipment.

Consider using computational fluid dynamics (CFD) models to optimize the location of telecommunications pathways, air conditioning equipment, equipment enclosures, air return, air vents, and ventilated tiles.

If cable trays are installed overhead, they should generally be installed above cabinets and racks rather than above the aisles so as not to block lights and sprinklers, which should be placed above the aisles between cabinets.

Cable tray placement should avoid interfering with sprinkler spray patterns and other fire suppression and detection systems.

Data Center Cabinets and Racks

Overview

IT and telecommunications equipment should be placed in equipment cabinets and racks instead of being placed on shelving systems because cabinets and racks:

- Securely mount the equipment.
- Permit higher equipment density.
- Assist in managing cabling.
- Assist in managing air flow.
- Are typically more stable.

Cabinet and Rack Installation

Cabinet and Rack Placement

Cabinets should be placed so as to permit floor tiles in front and behind to be lifted. It is generally a good idea for cabinets to be placed with one edge flush with the floor tile to ensure that no more floor tiles than necessary get captured and to minimize the distance required to reach under cabinets. Additionally, rows of cabinets and racks should be placed parallel (rather than at an angle) to the rows of floor tiles.

Given a choice, where placing one edge of the cabinet creates unequal aisle sizes, the front aisle should be the larger one as it provides more working space for the installation of equipment into cabinets and a greater area for providing cool air to cabinets.

Cabinets and racks should be placed so that hardware used to secure racks and cabinets to the underfloor slab (e.g., threaded rods) does not penetrate access floor stringers.

Sharp edges at the top of the threaded rods should be capped using plastic covers, domed nuts, or other means. The exposed threads under the access floor should be covered using split tubing or other methods to avoid abrading cable.

In seismic zones, it is recommended that the design of the attachment methods and the installation be reviewed by a licensed structural engineer. Many jurisdictions will require a seismic certification report signed by a professional engineer.

The mounting surface should be prepared for the specific anchors required for the application. Refer to the recommended practices of the manufacturer and structural engineers, and verify that those practices are acceptable to the authority having jurisdiction (AHJ). Racks and cabinets in a lineup where they are properly attached together may require fewer anchors per unit than those installed as stand-alone units. When drilling into the mounting surface, use proper techniques to ensure that dust or particles do not become airborne. Vacuuming with a high-efficiency particulate air (HEPA)-filtered vacuum is effective in containing dust or particles while drilling in floors or walls.

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Cabinet and Rack Installation, continued

Racks or cabinets should be set in place and leveled throughout the lineup. Shimming of any anchoring point should not exceed 12.7 mm (0.50 in) unless specified by the project engineer. If racks or cabinets require more than 12.7 mm (0.50 in) of shimming, use an engineered solution to ensure that rack or cabinet lineups are properly supported. Connect adjacent racks or cabinets together in the lineup before anchors or bracing is installed. Install anchors or bracing per the manufacturer's specifications, making sure all shims are properly located.

Some lineups require additional bracing to meet the customer's specifications or local codes. Required bracing may be based on rack style, equipment, and location. Bracing should be installed as a system to ensure proper fit and support. Install all parts hand tight, and then tighten fasteners in a series to prevent stress on rack lineup. All bracing should be installed before racks are populated.

Doors and panels that may interfere with leveling feet or anchor installation should be removed during installation.

On solid or slab floors, set cabinets in place and level throughout the lineup. Most cabinets are equipped with leveling feet. If leveling feet are not provided, consult the manufacturer for proper shimming hardware.

On access floors, if cabinets in the lineup are to be connected, install attachment hardware before anchors are installed. Install anchors per the manufacturer's specifications, making sure all shimming hardware is properly located.

Floor Tile Cuts

Where underfloor cooling is utilized, limit floor tile cuts both in size and quantity to minimize loss of underfloor air pressure.

Employ brushes, grommets, or other methods to minimize the loss of air through cable openings in floor tiles.

Hot and Cold Aisle Configuration

Install equipment cabinets and racks with rows oriented in a hot aisle/cold aisle configuration with the rears of cabinets/racks facing each other and fronts of cabinets/racks facing each other. Such a configuration avoids hot air from equipment mixing with cold air being directed into equipment intakes.

Avoid empty cabinet or rack positions in equipment rows. Replace removed cabinets or frames, and fill any gaps in a row of cabinets with a substitute blanking panel of the same height as the cabinet or frames to either side to avoid recirculation of air between hot and cold aisles. For the same reason, install cabinets and racks with no blank spaces between them. In the case of vacant cabinets and racks and where blank spaces exist in populated cabinets and racks, install blanking panels. Vertical cable managers can provide cable management and block recirculation of air between racks. Cabinets should be butted up against each other. Where possible, cabinets should share a side panel or include other means to seal the rear-to-front airflow path along the side of rack-mounted equipment.

Cabinet and Rack Installation, continued

Grounding (Earthing) of Cabinets and Equipment

Computer rooms typically have a telecommunications grounding infrastructure (e.g., telecommunications grounding busbar [TGB], mesh bonding network [BN], often called a signal reference grid).

ANSI/NECA/BICSI-607 specifies that non-current-carrying metallic portions of telecommunications cabinets, telecommunications racks, and telecommunications pathways be bonded to the computer room grounding infrastructure. IT and telecommunications equipment and cable shields shall be bonded to the computer room grounding infrastructure per the manufacturer's instructions.

See ANSI/NECA/BICSI-607 for additional information regarding computer room bonding and grounding (earthing).

Installation of Equipment in Cabinets and Racks

Equipment should be installed in cabinets with the air intake oriented toward the front of the rack or cabinet and the air exhaust oriented toward the rear of the rack or cabinet. Pay careful attention to airflow for networking equipment, which often uses a side-to-side rather than front- to-back cooling scheme. For such equipment, consider cabinets that duct air into the hot aisle and in from the cold aisle. If ducting is not installed, ensure that the side clearances specified by the manufacturer are provided to ensure adequate airflow.

Ensure that equipment placed in a rack or cabinet does not exceed power circuit capacity. Power strips supporting only single-corded equipment should be loaded to no more than 80 percent of circuit capacity. A power strip supporting dual-corded equipment should be loaded to no more than 40 percent of circuit capacity so that the remaining circuit is at no more than 80 percent load if the redundant circuit has a failure. Load on circuits can be either calculated or preferably monitored (e.g., using power strips or power distribution units that permit monitoring of power levels).

Anticipate the weight of the equipment in the racks and cabinets. Ensure that the cabinets, racks, and floors (both access floors and slabs) are rated to handle the expected mechanical loads.

Equipment in the computer room should be mounted to cabinet or rack rails and should not be placed on shelves because equipment on shelves provides a return path for air between the rear and front of the cabinet or rack.

Blank panels should be installed in unused rack positions to maintain separation between hot aisles and colds aisles and prevent hot exhaust air from recirculating and mixing with chilled air at equipment intakes. Blank panels also improve rigidity of racks.

In active data centers, institute a process to identify and remove equipment that is no longer needed or to identify and consolidate underutilized equipment.

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Cable Management for Cabinets and Racks

Routing of telecommunications cabling within cabinets, racks, and other enclosure systems should not hamper the proper cooling of the equipment within the enclosures (e.g., avoid routing of cabling in front of equipment and enclosure vents).

Shorter power, data, and keyboard/video/mouse (KVM) cables should be specified to reduce the cable management density in the back of the cabinet.

With nonangled balanced twisted-pair or coaxial cable patch panels, one rack unit of horizontal cable management should be provided for each rack unit of patch panel.

Each rack should have vertical cable managers sized for maximum rack capacity attached on both sides. Vertical cable managers between two racks should be sized to serve both racks simultaneously.

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Chapter 9
Health Care

Chapter 9 introduces the specialized systems and specific installation requirements associated with acute care hospital settings. This chapter focuses on the working conditions in medical facilities, nurse call systems installation, and infection control risk assessment (ICRA).

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Introduction

Information technology systems (ITS) are expanding into every segment of health care in medical facilities. Health care facilities need specialized systems and specific installation requirements. ITS professionals often specialize in a specific technology applicable in several different areas, including health and safety technologies.

This chapter focuses on some of the most critical considerations related to:

- Working conditions in medical facilities.
- Health care facility systems.
- Installing nurse call systems.
- Infection control risk assessment (ICRA).

Working Conditions in Medical Facilities

Overview

The health care industry is constantly changing its methods of service delivery. Because of these changes, technology is forced to maintain a level of service just beyond the facility needs. Several factors are driving these changes:

- Regulatory bodies
- Continual modernization of health care equipment and technologies
- Facility upgrades of aging buildings or the expansion of existing buildings
- Competition among health care providers

In recent years, health care industry regulations have driven several new requirements that have had a significant impact on how owners, ITS distribution designers, and ITS cabling installers plan and conduct business in the health care industry. Two issues having the most impact are the privacy of patients' records and infection control.

This chapter addresses the specific aspects of an ITS within an acute care hospital. Throughout the chapter, the use of the term "health care facility" is in reference to the acute care hospital setting. However, many of the requirements and recommendations listed within this chapter can be applied to other types of medical facilities, such as:

- Skilled nursing facilities (nursing homes).
- Rehabilitation centers.
- Psychiatric facilities.
- Ambulatory clinics and surgical centers.
- Outpatient clinics.

A hospital's main function is to save lives, and its infrastructure must be capable of supporting that mission.

Overview, continued

All ITS found throughout this manual are currently being deployed in health care facilities.

Integrating these systems and providing a more efficient work flow will translate into better patient care. Facilities that are truly committed to this idea will be able to deliver safer, more accurate care at the patient's bedside. Doctors will be able to retrieve lifesaving information at the touch of a button and see it instantly instead of spending the hours or days that this process used to take.

Additionally, the teaching environment has improved greatly. Medical students are no longer required to be physically present to study procedures. The advances in voice systems and surgical video and signal transmission (telemedicine) have expanded opportunities to the world. For example, with the use of high-speed transmission, doctors located in Africa can connect to a facility in the United States and establish an audio and video link to transmit vital information for review. This technology allows faster care results and real-time solutions.

With wireless technology, more portable medical devices operating on facility wireless networks will develop, achieving a health care environment that is both paperless and wireless. In the quest for a paperless facility, the IEEE® wireless standard 802.11 has begun to provide the pathway for the paperless transition.

Health care initiatives that are driving ITS include:

- Electronic health records (EHRs).
- Patient portable (personal) health records.
- Electronic security.
- Clinical and information technology (IT) convergence.

This chapter will outline the types of systems typically installed in a health care facility and those special working conditions that can affect the ITS installer.

A health care facility is an institution with one primary purpose: to deliver health care. As such, health care facilities have very unique requirements for their:

- Operations.
- Architecture.
- Support systems.
- Users/occupants.

In a health care facility, the ITS installer will install systems that transport biological vital signs of patients, EHRs, emergency (code) calls, real-time surgical video, and billing and financial information, as well as voice, data, and security.

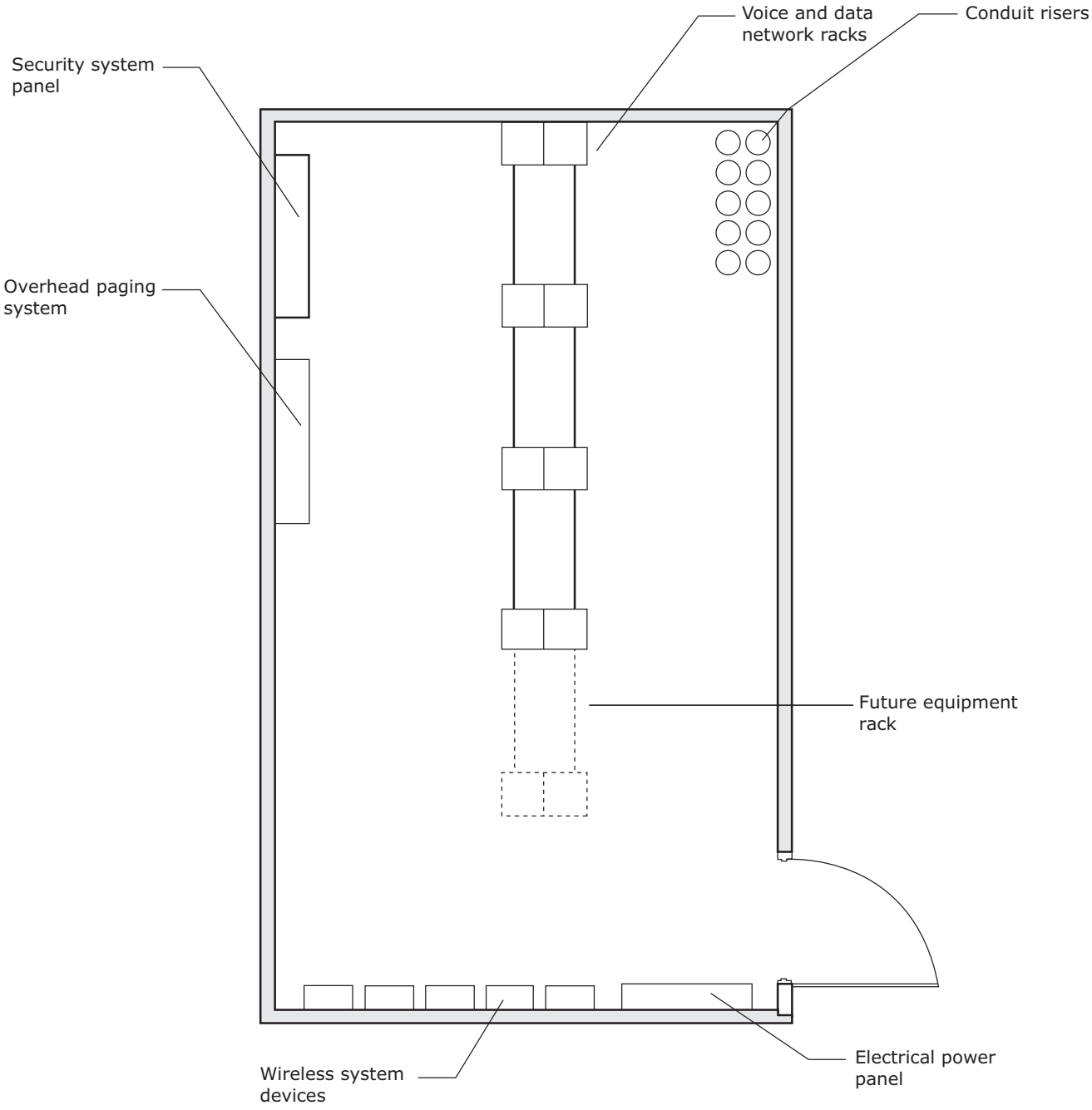
Many health care facilities operate around the clock. Stringent work environments as well as scheduling issues are some of the factors that will have to be considered by the ITS installer.

Figure 9.1 displays a typical telecommunications room (TR), whereas Figure 9.2 indicates the additional requirements in a typical health care facility for the ITS systems necessary to meet the requirements for the various services discussed in this chapter.

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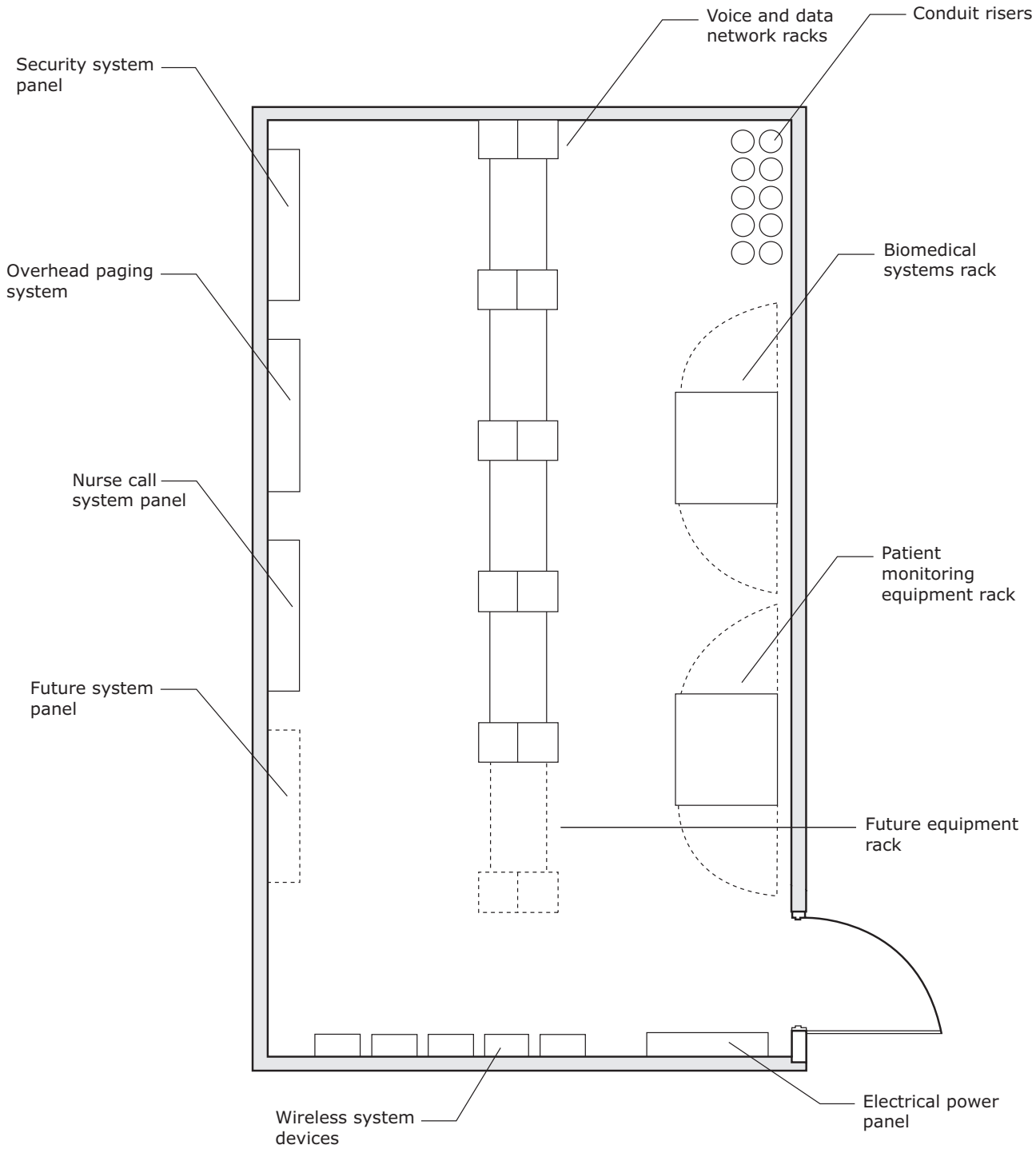
Overview, continued

Figure 9.1
Typical telecommunications room layout



Overview, continued

Figure 9.2
Typical health care telecommunications room



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Health Care Facility Systems

Overview

Many of the systems found in acute care hospitals will be described in this section. When interfacing with hospital staff, the installer should understand the terms medical professionals commonly use. Where systems in health care differ from other facilities, those requirements will be explained.

Voice

Voice includes the private branch exchange (PBX) switch, voice over Internet protocol (VoIP), voice mail system, operator's console, call center, and interactive voice response (IVR). In certain jurisdictions, it is required that the PBX equipment resides within the health care facility envelope. This will require the health care facility to have its own dedicated switching equipment. Serving other buildings from the health care facility is acceptable, but not vice versa.

Overhead Paging

Also known as the public address (PA) system, overhead paging consists of ceiling speakers, amplifiers, and headend equipment that allows overhead announcements to be made from a central station (e.g., typically the telephone operator's console) or from any telephone handset if integrated with the PBX switch. Health care facilities may require an enhanced integration into other systems, including:

- Fire alarm override.
- Priority volume controls.
- Ambient level controls.
- Conference room audio controls.
- Mass notification.
- Specific zoning requirements.

Wireless Networks

The active wireless spectrum found in a modern hospital is broad and diverse. Typically, wireless systems supporting a hospital must accommodate many users and much greater densities and be more robust.

Wireless Networks, continued

Wireless networks in a health care facility can include:

- Regulated and licensed wireless networks, including wireless medical telemetry.
- Medical grade applications of typical business wireless systems, including electronic medical equipment networks:
  - Pumps
  - Transport monitors
  - Patient beds

Other systems found in hospitals can include:

- Real-time location:
  - Equipment
  - Patients
  - Staff
- Safety and security:
  - Infant protection
  - Wandering patient
  - Psychiatric monitoring
- Timekeeping
- Patient queuing/waiting
- Special design considerations:
  - Spurious noise generation (cauterization)
  - Imaging systems
  - Specialty shielding

Patient TV

TV displays can be controlled from the nurse call system's patient interface device (e.g., pillow speaker) for basic functions (e.g., volume control, on and off switching).

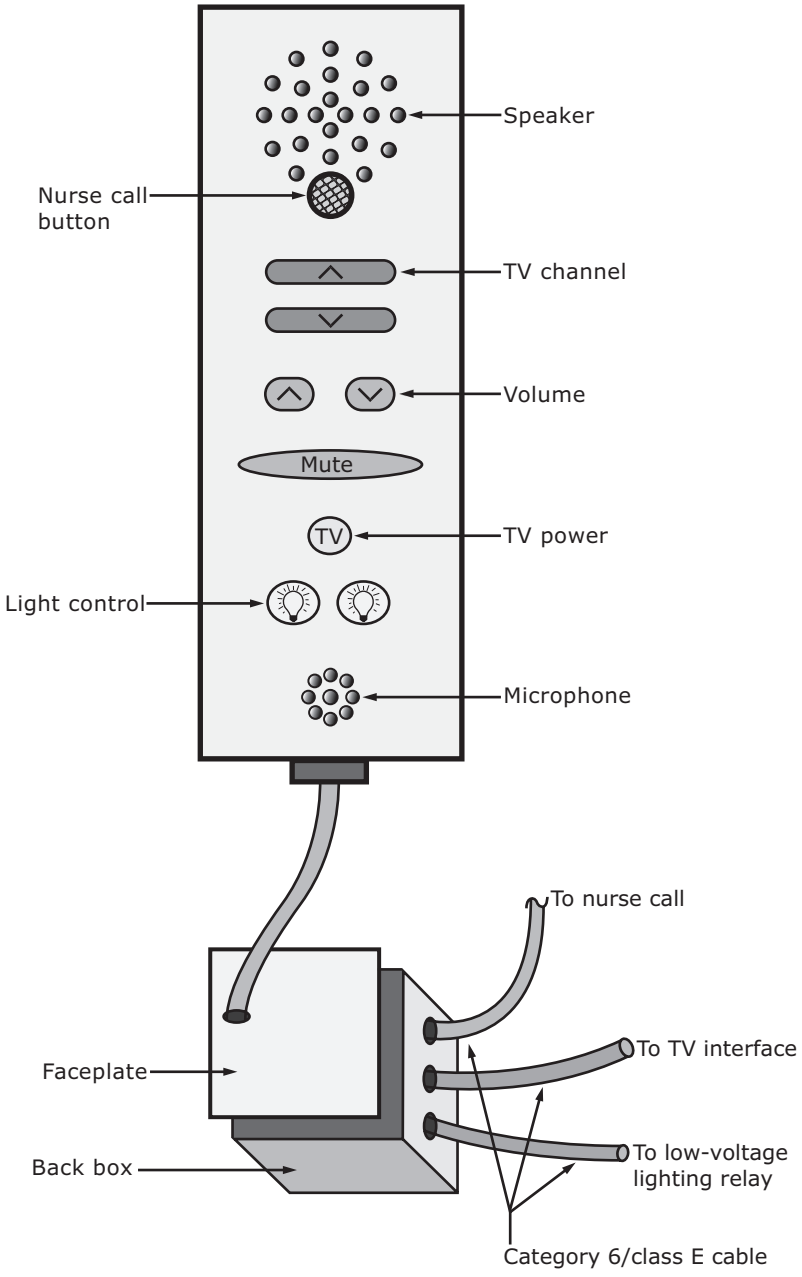
See Figure 9.3 for a sample layout of basic infrastructure to support the system. The following materials may be installed for this system:

- Backbone riser cable:
  - Optical fiber cable
  - Series-11 coaxial cable
  - Hard line 12.7 millimeter (mm [1/2 inch (in)]) coaxial cable
- Distribution amplifiers
- Miscellaneous splitters and taps

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Patient TV, continued

Figure 9.3
Typical pillow speaker



Access Control

The access control system in a health care facility has many challenges based on the need to secure several areas for patient privacy and safety. However, a health care facility operates 24 hours, requiring access to those areas most of the time.

Advanced access control systems can integrate with the health care facility's data network backbone to allow for remote access and control of the system. Some unique aspects of health care regarding access control are:

- Elevator controls (cab calls and override).
- Integration with infant protection, wandering patient, and elopement systems.
- Card readers not always being located at the door.
- Multiple levels of access control for care providers, visitors, and security.

Special Systems

Patient and Asset Tracking

Patient and asset tracking is typically achieved through sensors that transmit infrared (IR) pulses or ultrasonic or radio signals by receivers mounted in the ceilings.

Health care quality may be enhanced through the use of tracking systems since many delays in service are caused by the time required to find staff or equipment. Reducing these delays is akin to improving quality.

Patient tracking is used most often in geriatric or psychiatric units where patients are likely to become lost or disoriented. A tracking system can notify staff of unexpected patient movement.

Note that the patient and asset tracking system often may be an integrated nurse call, closed-circuit TV (CCTV), or other communications system.

Infant and Child Protection

An infant and child protection system is usually found in the maternity unit, the nurseries of a hospital, and pediatric units.

These systems typically are combined with a badge system where mother and baby are matched for ID and security purposes. A tag is affixed to the child or infant that is not easily removed without specialized tools. Sensors are located at all unit exits to prevent the unwanted exit of babies from the maternity department. In more encompassing deployments, the sensors cover all the units completely and detect and alarm if a tag is removed without the system being properly informed, identifying for security the child and where the tag was cut.

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Special Systems, continued

Radio frequency is the most popular technology for tracking infants and mothers. In the event of an undesired exit, the system will interface with the access control, CCTV, nurse call, wireless messaging, and fire alarm systems to create a delayed egress to prevent the immediate exit from the unit and record and report all activities associated to the event.

Patient Monitoring

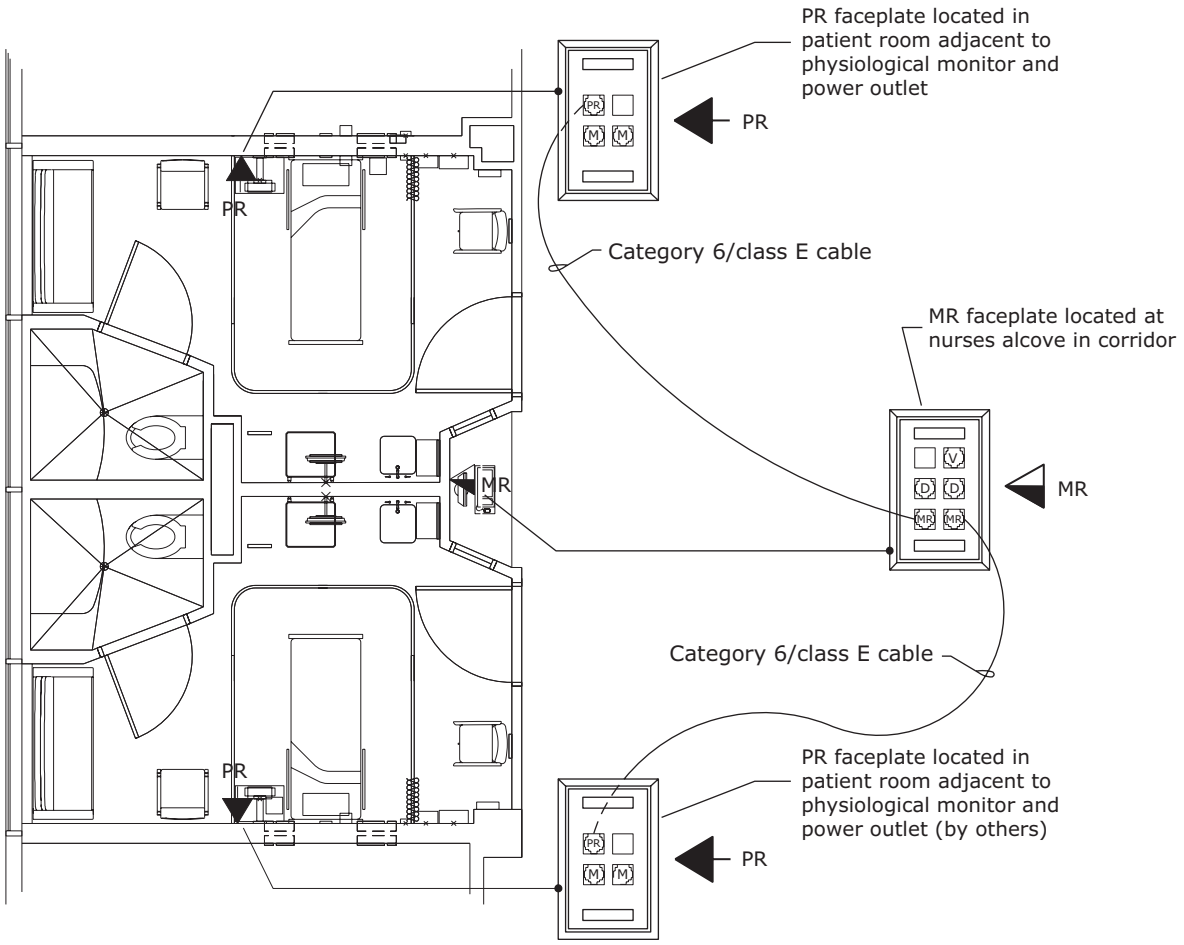
Patient monitoring is a dedicated system that monitors seriously ill patients' breathing, heartbeat, and other vital signs, and it sends an alarm if they exceed certain parameters. Typically, the individual monitors (one per bed) are connected via an Ethernet network to the nurses' station, and they are often connected to a central monitoring center located elsewhere in the hospital or off site. More sophisticated versions include CCTV-style video to enable visual observation of patients.

Patient monitoring typically requires a dedicated Ethernet jack at every bed in the emergency department, intensive care units (ICUs), critical care units (CCUs), postanesthesia units, and possibly in operating rooms (ORs), but this is often done using different systems. Beds set up for monitoring are typically provided in additional inpatient units so that a cart can be rolled up when it is needed. It is best practice to always install a pair of dedicated Ethernet outlets wherever a cart may be deployed.

Figure 9.4 illustrates a workstation alcove between multiple rooms that contain monitoring. In this example, an additional cable must be installed between the physiological monitor within the patient room and the remote monitor.

Special Systems, continued

Figure 9.4
Typical physiological monitor remote wiring diagram



D = Data outlet connection
M = Monitor outlet connection
MR = Monitor remote outlet connection
PR = Patient remote outlet connection
V = Voice outlet connection

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Special Systems, continued

Wireless Medical Telemetry System (WMTS)

A wireless medical telemetry system (WMTS) is the remote monitoring of a patient's health. The use of wireless medical telemetry gives patients a greater mobility and increased comfort by freeing them from hardwired connections to the hospital equipment otherwise required to monitor their conditions.

Radio Paging Messaging System

A radio paging messaging system, in addition to its typical business functions, is used to summon emergency teams for patients who stop breathing, suffer cardiac arrest, or otherwise need immediate skilled medical attention. Pages for these functions must be reliable and fast. Signals often must penetrate into areas with lead walls and magnetic shielding; therefore, internal repeaters may be required.

Enabling a smooth switch to the backup paging system is important, and it may require more complex cabling. Providing a solution that allows someone to rapidly activate the backup system without climbing to the penthouse that houses the transmitters and moving cables is a significant advantage.

Picture Archive and Communications System (PACS)

The picture archive and communications system (PACS) is an application used for storing and viewing digital (radiology) image files captured from various equipment (e.g., magnetic resonance imaging [MRI], computed tomography [CT]). The system employs high-resolution image viewers, large-capacity storage servers (e.g., sometimes in the form of a storage area network [SAN]), and a robust network capable of delivering digital imaging and communications in medicine (DICOM) images to the viewing stations throughout the facility. This may also include a physically separate network, or it could also be supported on the main data network using virtual local area networks (VLANs), depending on the expected load.

Pneumatic Tube (PT) System

The pneumatic tube (PT) system is a dedicated set of large tubes routing carriers with air pressure, which are loaded with various materials throughout the facility. The most advanced systems are computer based and can be programmed and controlled remotely.

PT systems are typically used to deliver specimens to laboratories from a unit and drugs from the pharmacy to a unit. Additionally, they are also used to move paperwork quickly across the facility.

The PT system's use of very large tubing (typically 203 mm [8 in] diameter) above the ceilings has a significant impact on the work of the ITS installer. These tubes require a very large bend radius, which impedes the pathway of ITS in the ceiling void.

NOTE: Cable trays, conduits, pull boxes, and all other building systems routed in the ceiling spaces require close coordination with the installation of PT devices, tubing, and stations.

Special Systems, continued

Electronic Medical Record (EMR)

An electronic medical record (EMR), also known as an EHR, is the digital equivalent of a patient chart. While EMRs are not common in today's health care industry, over time, the use of EMRs will become the industry standard for patient information.

Nurse Call

Nurse call is a dedicated network of devices that allows a patient confined to the bed/room to call for care. These systems range from a set of buttons on the wall with lights in the corridors and nurse stations to a fully digital, computer-based system integrated with wireless telephones to deliver text messages to the nurse when calls are placed. These systems act as the code blue system. Code blue is a call placed to the preassigned code blue team in the event a patient becomes critically unstable. A code call is typically routed to the nurse, the nurse station, the PBX operator (e.g., for overhead paging), and the rest of the code blue team.

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Installing Nurse Call Stations

Overview

Nurse call systems provide signaling of patient and staff needs from a variety of call devices (stations) located in different room types. The events generated from these systems annunciate at several types of devices (e.g., master stations, annunciators, wireless devices). Nurse call design is impacted by regulatory agencies. Consult the local standard for your country, region, or state for specifics.

Detailed Nurse Call System

Nurse Call Equipment

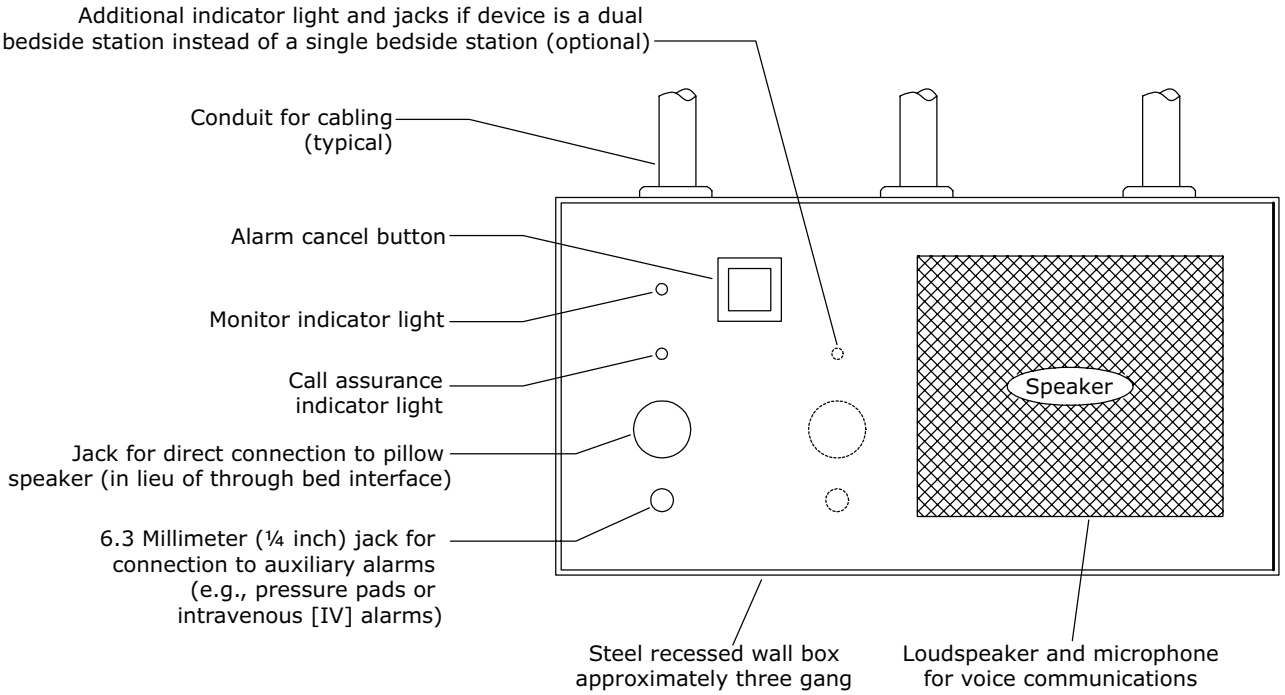
Patient interface devices that may be included in patient rooms are shown in Table 9.1 and Figure 9.5.

Table 9.1
Patient interface devices

Category	Specification
Function	It provides two-way audio capability. The pillow speaker or call cord is connected here. There may be additional signaling buttons (e.g., assist or code blue built into the station). Only normal patient calls can be cancelled at the nurses' station upon answering.
Location	Generally at the headwall (above the patient's head). Locate the patient interface device on the door side of the patient bed to allow for easy operation of the device by staff.
Pathway required	Conduit to dome light.
Back box required	Generally three gang.
Considerations	These stations are available in single- or dual-bed configurations. There may be no need to add peripheral staff assist and code stations if these buttons already exist on the patient interface device.

Detailed Nurse Call System, continued

Figure 9.5
Typical nurse call bedside station



Staff interface devices that may be included in patient rooms are shown in Table 9.2 and Figure 9.6.

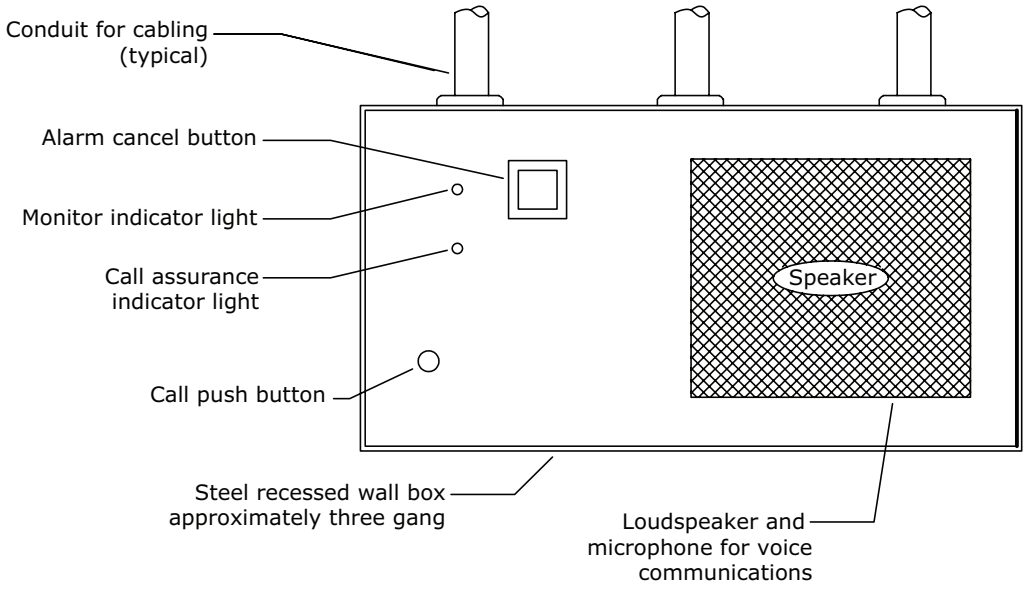
Table 9.2
Staff interface devices

Category	Specification
Function	An optional configuration is to place this device on the footwall where staff can access it and use a basic pillow speaker receptacle in the headwall.
Location	Footwall or near the door.
Pathway required	Conduit to dome light.
Back box required	Generally three gang.
Considerations	These stations are available in single- or dual-bed configurations. There may be no need to add the peripheral staff assist and code stations if these buttons already exist on the staff interface device.

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Detailed Nurse Call System, continued

Figure 9.6
Typical nurse call staff station



Bathroom interface devices that may be included in patient rooms are shown in Table 9.3.

Table 9.3
Bathroom interface devices

Category	Specification
Function	It provides signaling of a bathroom assist call. This level of call cannot be canceled at the desk; it must be canceled at the originating device.
Location	These stations are located in the patient's bathroom, shower, or in a stand-alone area (e.g., sitz bath).
Pathway required	Generally, a conduit goes to the patient or staff/duty station in the room. A conduit goes directly to the dome light in a stand-alone application (sitz bath).
Back box required	Generally one gang.
Considerations	Bathrooms generally require two pull cord emergency stations because of the bathroom size. A patient lying on the floor should be able to reach the cord hanging from the station. If mounting the station in the actual shower, ensure that the station is splash proof.

Detailed Nurse Call System, continued

Code blue station devices that may be included in patient rooms are shown in Table 9.4 and Figure 9.7.

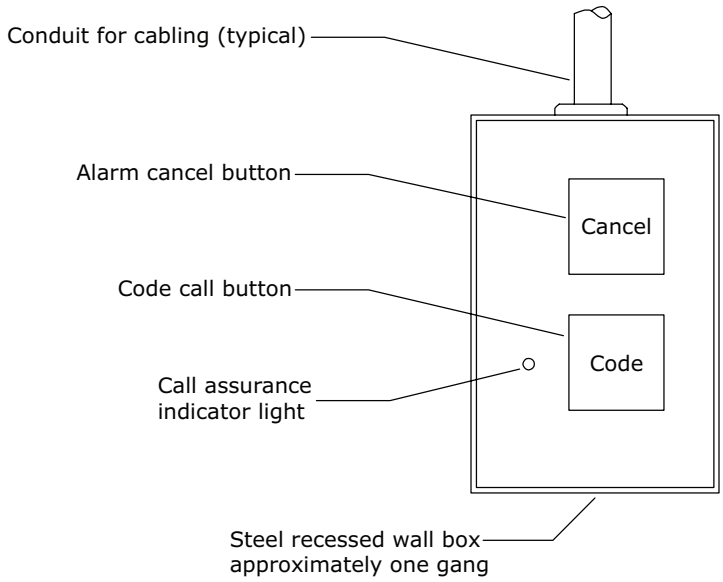
Table 9.4
Code blue station

Category	Specification
Function	It provides signaling of a cardiac or respiratory arrest. The code call annunciates as a very high priority in the nurse call system and can optionally automatically page the code (crash) team with the room and bed number. Code calls can also annunciate at an Underwriters Laboratories Inc.® (UL)-listed nurse call annunciator in the PBX so that the code team can be summoned by overhead paging. These calls cannot be canceled at the desk; they must be canceled at the originating device.
Location	These stations are located near or in the headwall. These buttons need to be very accessible for staff, so avoid placing them near apparatus that covers them up (e.g., medical gas lines, blood pressure cuffs). Consult the local state health code to identify the required locations for code blue stations. Generally, these locations are the ICU, coronary care unit (CCU), emergency room (ER), nursery, and OR.
Pathway required	Generally, a conduit goes to the patient or staff/duty station in the room. A conduit goes directly to the dome light in a stand-alone application.
Back box required	Generally one gang.
Considerations	There may be a redundant code button on the patient station that is permitted if it provides a bigger pressing area or an easier access. Locating the code button is important, but so is knowing how and where it annunciates.

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Detailed Nurse Call System, continued

Figure 9.7
Typical nurse call code call station



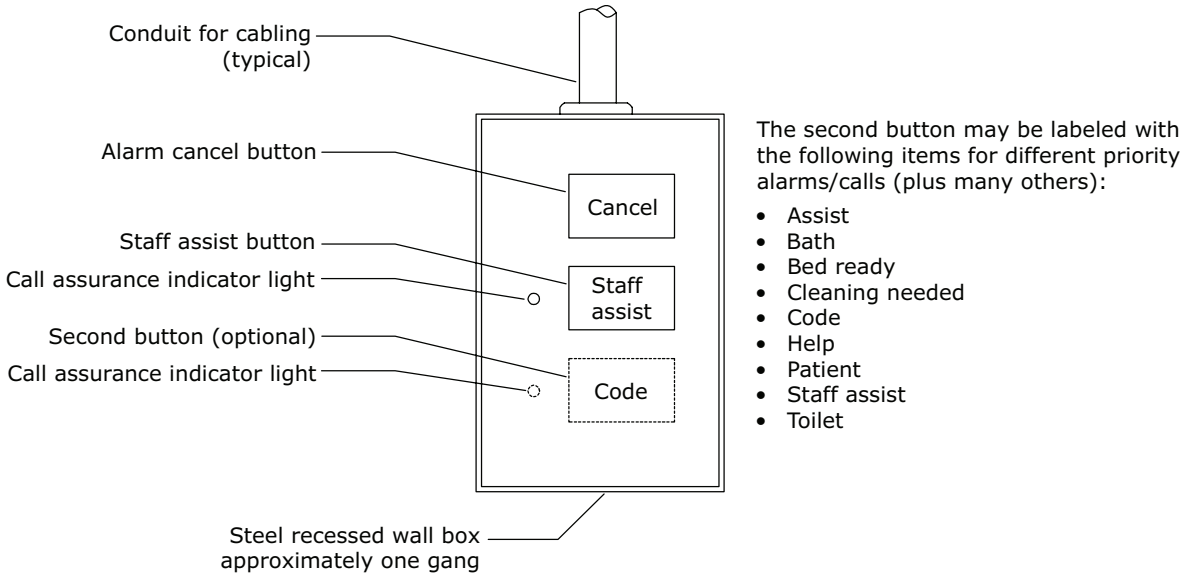
Staff emergency station devices that may be included in patient rooms are shown in Table 9.5 and Figure 9.8.

Table 9.5
Staff emergency station

Category	Specification
Function	It provides signaling of staff assistance. Examples of this type of call are when a patient falls out of the bed and the staff needs help or some other emergency not related to code blue. These stations are generally not required by the state code. Consult with the end users to ascertain their needs.
Location	These stations are located near or in the headwall. These buttons need to be very accessible for staff, so avoid apparatus that covers them up (e.g., medical gas lines, blood pressure cuffs).
Pathway required	Generally, a conduit goes to the patient or staff/duty station in the room. A conduit goes directly to the dome light in a stand-alone application.
Back box required	Generally one gang.
Considerations	The addition of this station is purely optional.

Detailed Nurse Call System, continued

Figure 9.8
Typical nurse call staff emergency station



Other call station devices that may be included in patient rooms are shown in Table 9.6.

Table 9.6
Other call station

Category	Specification
Function	Other types of calls may be generated from a nurse call system (e.g., code pink [infant abduction], family call, room dirty).
Location	These stations are usually located in the headwall.
Pathway required	Conduit to the patient station.
Back box required	Generally one gang.
Considerations	These additional call types will vary per manufacturer.

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Detailed Nurse Call System, continued

Auxiliary interface station devices that may be included in patient rooms are shown in Table 9.7.

Table 9.7
Auxiliary interface station

Category	Specification
Function	It allows for contact closure input from medical devices (e.g., pulse oximeters [measures oxygen levels in the blood]), IV drip monitors, bed exit devices that alarm when patient leaves the bed, and other UL 544 listed devices. These calls cannot be canceled at the desk; they must be canceled at the originating device.
Location	These stations are usually located in the headwall.
Pathway required	Conduit to the patient station.
Back box required	Generally one gang.
Considerations	Auxiliary input stations are typically nonlocking, so they trigger a nurse call event only as long as the input device is in alarm. They are usually electrically isolated to avoid stray electric charges from infiltrating the nurse call system.

Entertainment interfaces that may be included in patient rooms are shown in Table 9.8.

Table 9.8
Entertainment interfaces

Category	Specification
Function	It provides an interface to TVs, radio, lighting, and motorized drapes.
Location	The location of the interface varies based on the entertainment device.
Pathway required	Conduit from the patient station to the interface device (e.g., TV and lighting controller).
Back box required	Generally one gang.
Considerations	Health care-grade TVs are available in two distinct types, standard and smart. The main differences are: • Smart TVs use the data from the pillow speaker for control. Standard TVs use voltage. • Smart TVs generally have channel up/down and closed captioning capabilities. Standard TVs use the same button to turn the power on, sequentially step through the channels, and then power off.

Detailed Nurse Call System, continued

Bed interface devices that may be included in patient rooms are shown in Table 9.9.

Table 9.9
Bed interface

Category	Specification
Function	It allows for connectivity of the patient bed equipped with side rail communications (e.g., nurse call, TV, lighting).
Location	Behind the bed, 0.3 meters (m [1 foot (ft)]) above floor.
Pathway required	Conduit to the patient interface device.
Back box required	Generally one gang.
Considerations	Avoid placing the device where the bed frame can come in contact and cause damage to the receptacle.

Dome light location devices that may be included in patient rooms are shown in Table 9.10.

Table 9.10
Dome light

Category	Specification
Function	It provides visual annunciation of nurse call events. This light can come in one, two, three, four, five, or six sections, and it may consist of incandescent lamps or light-emitting diodes (LEDs), depending on the manufacturer. This light will annunciate the pending calls in color and also visually indicate if a staff is located in a room if a location system is integrated.
Location	Dome lights are located outside the patient room on the wall or the ceiling.
Pathway required	The dome light back box often serves as the point where the main data, power, and audio cables are spliced and run into the patient station. The conduit requirement is a connection to the main cable run down the hallway.
Back box required	Generally two gang.
Considerations	Avoid placing dome lights directly under cove lighting. The direct light will drown out the dome lights. In this situation, mount the dome light on the ceiling.

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Detailed Nurse Call System, continued

Staff and duty location specifications are shown in Table 9.11.

Table 9.11
Staff and duty locations

Category	Specification
Function	Both staff and duty stations may place and receive calls from the master station. The difference is that duty stations annunciate system activity by flashing LEDs and sounding tones. This is used to alert the staff in the areas (e.g., clean/soiled utility and break rooms). Staff stations only place calls to the master station.
Location	Locate staff stations in the areas where staff will need to communicate with the nursing station through the nurse call system. Staff stations can also be used in the areas where stand-alone peripheral stations (e.g., staff emergency, code blue) have been located and where intercom audio is needed. The local state code will specify where duty stations must be located (e.g., clean and soiled utility, medicine preparation, and nourishment areas).
Pathway required	Generally, a conduit goes to a junction box where other nearby patient rooms connect to a main cable run to the central equipment cabinet.
Back box required	Generally three gang.
Considerations	Be careful when adding these stations over and above the state's requirements. They add cost and generally add noise because of the use of the system to page and the system tones (e.g., duty mode). Additional functionality may be added by connecting peripheral devices (e.g., code blue, staff assist, and bath emergency stations).

Stand-alone push-to-call stations, bath emergency, staff emergency, and code blue stations areas (e.g., physical therapy, dressing rooms, stand-alone bathrooms) may require emergency signaling capability. The type of nursing unit and the patient acuity determines the need for these specific areas.

Detailed Nurse Call System, continued

Zone light specifications are shown in Table 9.12.

Table 9.12
Zone lights

Category	Specification
Function	It provides relative direction and visual annunciation of nurse call events. Zone lights are associated with a group of dome lights. The zone light's illumination will mirror that of any of its associated dome lights. This allows the staff at the nurses' station who may not be able to see the individual dome light outside the patient room to be visually alerted by an active call from that hallway.
Location	Locate zone lights outside the fire doors. This is done so that if a call is active and the doors are closed, the staff will know about it. Zone lights should also be located near the nurses' station to indicate activity from patient rooms that are not visible from the nurses' station.
Pathway required	Conduit to a junction box on the main nurse call cable run.
Back box required	Generally two gang.
Considerations	Zone light location is important because the lights will provide visual annunciation of nurse call events even if the main nurse call central processing unit (CPU) or master station has failed. Zone lights will also help the team members to locate the code blue.

Master station specifications are shown in Table 9.13.

Table 9.13
Master stations

Category	Specification
Function	It provides annunciation at a central area (e.g., nurses' station) of nurse call activity. It provides two-way intercom audio to the patient's room.
Location	These stations are located at the nurses' station.
Pathway required	Conduit to the central equipment cabinet.
Back box required	Generally one gang for the receptacle that the desk unit plugs into.
Considerations	Space, size, and location are of critical importance.

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Detailed Nurse Call System, continued

Annunciator specifications are shown in Table 9.14.

Table 9.14
Annunciators

Category	Specification
Function	It provides visual (e.g., lamp, LED, text) and tone annunciation of incoming nurse call events. It is primarily used for the display of code blue calls at the PBX or other continuously staffed areas.
Location	It is wall mounted at the PBX or other continuously staffed areas (e.g., staff lounges, satellite nursing stations) where intercom audio is not required.
Pathway required	Conduit to the central equipment cabinet.
Back box required	Generally, three-, four-, or custom-gang back box.

Central equipment cabinet specifications are shown in Table 9.15.

Table 9.15
Central equipment cabinets

Category	Specification
Function	This is the heart of the system. One cabinet may serve one, two, or three floors, depending on the capacity limitations of the system.
Location	The central equipment will likely occupy a 1.2 m (4 ft) by 2.4 m (8 ft) section of wall in the data closet for that floor.
Pathway required	Conduits from each master station, zone, and annunciators will terminate at the cabinet.
Back box required	The cabinet back box would be custom and most likely surface mounted.
Considerations	The nurse call system should be connected to the emergency power. Allow for room and connectivity of other systems (e.g., telephone ports, IR location sensors, network connections).

Detailed Nurse Call System, continued

Physical Requirements for Space, Power, Secured Access, and Cooling

Typically allow a 1.2 m (4 ft) by 2.4 m (8 ft) area of wall space for the central equipment and associated power supplies and amplifiers per floor. The nurse call system must be connected to emergency power.

Identifying Connectivity and Pathway Requirements

The following will assist in identifying connectivity and pathway requirements:

- Cabling—Most manufacturers have specific requirements for cabling. The core system components are typically connected to an intelligent device (e.g., patient station, corridor light, duty station), and this device communicates to the central processor via cable.

  There are two typical cable schemes for nurse call systems: star topology or ring topology. Some current systems utilize a hybrid design where data connections are provided in a star configuration while power is enabled in a ring configuration. This configuration requires installing a standard category 6/class E data connection to the intelligent device, a two-conductor 14 American wire gauge (AWG [1.6 mm (0.063 in)]) cable from the corridor light to the corridor light in a ring configuration, and a variety of cable schemes for all of the ancillary devices back to the intelligent device.
- Core nurse call devices—Each of the nurse call devices may be stubbed into the accessible ceiling space. If an all-conduit raceway is required by local code, the nurse call system raceway design will be unique per manufacturer.
- Other nurse call systems—Nurse call systems typically serve one or two floors. However, they can share data from system to system. Provide for a pathway to connect to the system's data network.
- Data network—Some nurse call systems require connectivity from the cabinet to the data network. Workstations running nurse call applications also need network connectivity. Peripheral systems (e.g., IR location, wireless telephone systems) may also require network connectivity.
- Telephone system—Some advanced nurse call features (e.g., wireless telephone integration) require connectivity to the PBX. Include a pathway for this interconnection.
- PBX operator (code annunciation)—Plan for providing a pathway from the nurse call system riser to the PBX operator location for code blue annunciator connectivity.
- Overhead paging system—Plan for connectivity from the nurse call system to the paging amplifier serving that nursing unit's overhead zone paging system.

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Ancillary System Interfaces

The key issue with nurse call systems is the fact that all of the ancillary system interfaces are intended to supplement the core UL-listed nurse call system. Many of the integrations are with general business class applications and are not considered part of the core nurse call system.

An ITS installer should always focus on activating the core nurse call system with all of its native functionality before adding any ancillary system interfaces by completing the following steps:

- Define all system component locations and call processes
- Verify all pathways
- Install all conduit and back boxes (e.g., wait for the framed wall to be installed)
- Install cables (do not terminate)
- Wait for the paint to dry on the new walls
- Terminate, test, and certify cables
- Install devices
- Install headend equipment
- Apply power
- Test basic functionality
- Program system
- Test complete functionality
- Test ancillary interfaces

Infection Control Risk Assessment (ICRA)

Overview

Construction and maintenance activities in and near health care facilities may increase airborne concentrations of dust and potentially pathogenic organisms. For additional information, refer to Construction and Maintenance, Overview, in this chapter.

NOTE: The purpose of this section is to inform the reader of the importance of ICRA and to make the reader aware of the related considerations. This section is not intended to provide the reader with the knowledge needed to produce a working document for ICRA.

The health care industry has experienced a rapid growth over the past few years in both new construction and renovations. There are many considerations in the design and construction or renovation of the health care facility. Each type of construction dictates different infection control environments and methods. The ITS installer wants to keep employees healthy, and the existing facility wants to keep existing patients from becoming sicker.

Poorly designed and maintained construction environments pose numerous risks for patients and workers from contaminated air, water, or environmental surfaces. For example, improper ventilation design during a renovation project has been associated with outbreaks of infections (e.g., aspergillosis). Airborne infections (e.g., tuberculosis) have caused outbreaks among patients, workers, and even visitors. Terrorism-related threats have highlighted the importance of purposing facility design to enhance the control of infectious agents.

Professional, accreditation, and oversight agencies have provided guidance for new construction and major renovations in health care facilities for the deployment of infection control methods.

When planning for new construction or major renovation, the ITS distribution designer should coordinate with architects, risk and safety professionals, infection control professionals (typically employed by the facility), and environmental care managers to ensure that infection control methods are included in the design process. A critical step is to establish if the owner has an ICRA in place. This assessment provides the foundation for planning of the project regardless of the project's size or scope.

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Construction and Maintenance

Overview

Construction and maintenance activities in and near health care facilities may increase airborne concentrations of dust and potentially pathogenic organisms. Patients with weak immune systems are typically at risk for acquiring an infection. Construction and maintenance activities may disturb contaminated dust and produce bursts of airborne spores. If patients with weak immune systems come in contact with these airborne spores, infection may develop. The cases of construction-associated infections documented in medical journals and other literature sources are numerous.

Patients are also at risk of developing infections from waterborne pathogens, which are commonly found in natural and man-made aquatic environments. Potable water systems in health care facilities may also contain waterborne pathogens (e.g., *Legionella*). Several factors have been identified as promoting the growth of *Legionella* in potable health care water systems, including water temperatures in the range of 25 to 42 degrees Celsius (°C [77 to 108 degrees Fahrenheit (°F)]) and stagnation. Patients with weak immune systems, smokers, and elderly patients are susceptible to such infections. In documented health care outbreaks of waterborne pathogens, the exposure was traced to contaminated aerosols generated by cooling towers, showers, faucets, respiratory therapy equipment, and humidifiers.

Specifics to the Installer

These factors change the total work environment during and after construction. During construction on a health care facility, ITS installers typically will not be allowed to eat or drink except in certain controlled areas of the project site. The ITS installers must ensure that nothing is left that may become trapped in a wall cavity.

Standing water and mold prevention begins early during the construction process. Any spills or standing water should be addressed immediately.

Work rules for postconstruction change by the area, depending on the type of patient and the risk factors involved. Many times, ITS installers are required to provide a barrier whenever they open a ceiling tile. In addition, they are required to vacuum any debris with a high-efficiency particulate air (HEPA) filter vacuum unit. They are not allowed to work in certain areas until after normal hours and may have to vacate an area immediately if an emergency procedure is required.

ITS installers must know the requirements before they begin any work in an active health care facility. Failure to follow the rules may result in extended hospital stays and even death for certain at-risk patients.

Construction and Maintenance, continued

Policy

Most facilities are committed to protecting the health and safety of their patients, staff, and visitors during construction and maintenance activities. They recognize that construction and maintenance projects may introduce health and safety risks into the health care environment. When performing these activities, ITS installers and maintenance personnel shall take the appropriate steps to minimize such risks. ITS installers shall adhere to provisions listed in their project-specific infection control work plan.

NOTE: Maintenance personnel and ITS installers shall follow the procedures outlined under Infection Control Directives in this chapter.

Infection Control Products

The following materials may be required to fulfill the facility's ICRA plan:

- HEPA/ultra-low penetration air (ULPA) vacuum cleaners—The vacuum shall trap 99.999 percent of particles 0.12 micrometers (µm [0.005 mil]) and larger. The vacuum shall have a minimum airflow of 2.5 cubic meters per minute (m^3/min [90 cubic feet per minute (ft^3/min)]).
- Polyethylene—0.15 mm (6 mil) or 0.2 mm (8 mil) thick reinforced laminated polyethylene film shall meet requirements of the National Fire Protection Association (NFPA) 701 large-scale flammability test and the American Society for Testing and Materials (ASTM) E84 Class A, including compatible fire-retardant tape.
- Adhesive-faced contamination control mats (sticky walk-off mats)—The size of mats shall be the width of the opening and 762 mm (30 in) minimum depth.
- Negative air machine—This machine has a fan or blower, typically with HEPA/ULPA filters, which is able to negatively pressurize a room or area for a continuous period of time. It provides a unit sized to meet the room requirements. Units shall include prefilters, final filters, HEPA/ULPA filters, and filter static pressure gauges. HEPA/ULPA filters shall be 99.997 percent efficient at 0.3 µm (0.01 mil) particle size.
- Zipper-lock entrance—It has fire retardant, reinforced vinyl construction with reinforced stitching.
- Temporary prefabricated enclosure units—The units provide the enclosure with an inspection window and pressure-differential porthole.
- Airflow direction indicator—This product is for framed walls or other hard or nonplastic partitions. Where plastic dust barriers are used, the plastic barrier will serve this purpose.
- Dust-catching device—Disposable, dry, electrostatic cloths or mitts for dust removal or disposable, wet cloths, presoaked with cleaning solution for dust removal.

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Infection Control Directives

Infection Control Training

Installer personnel shall attend infection control training sponsored by the owner. No ITS installer shall be permitted to work on the site until such training is completed.

ITS installer superintendents, managers, supervisors, and foremen shall typically attend a four-hour infection control seminar provided by the owner.

Other ITS installers shall typically attend a 30-minute infection control seminar. Such training shall be provided as often as necessary to accommodate the needs of the ITS installer; however, no more than one seminar shall be provided per week.

Information Transport Systems (ITS) Installer Work Schedule

The ITS installer may be required to schedule certain activities at times that are convenient according to the owner's schedule. Such activities may produce excessive amounts of noise or vibration and need to be appropriately scheduled.

Those activities may include:

- Connection of existing utility systems to new utility systems.
- Temporary shutdown of existing utility systems.
- Load-in of building materials through occupied areas.
- Pile driving.

These activities have the potential to disrupt patient care activities. The ITS installer shall schedule such work with the facilities director.

Storage of Building Materials

The ITS installer shall store building materials (e.g., plywood, ceiling tiles, floor tiles) in a location and manner that protects them from the exposure to rain and exterior dust. Prior to being moved into the building, building materials shall be stored in an enclosed, protective environment, or they shall be wrapped in a water-resistant material.

If building materials become wet, they shall be discarded or dried within 48 hours of first becoming wet to prevent mold growth.

Protective Clothing for Information Transport Systems (ITS) Installers

ITS installers shall wear prescribed protective clothing when entering clean, restricted areas (e.g., surgical suite). Prescribed protective clothing includes coveralls, shoe covers, and head covers. ITS installers shall wear (put on), take off, and dispose of protective clothing in accordance with posted instructions at the entrances to such areas.

When accessing occupied indoor areas, ITS installers shall wear protective clothing if their street clothes are visibly contaminated with dust. Such clothing shall be put on before ITS installers enter the building or exit an interior work zone.

Information Transport Systems (ITS) Installer's Access to Occupied Areas

The ITS installer shall not be permitted in occupied areas unless permission is obtained from the appropriate personnel or otherwise listed in this work plan. Contact between ITS installers and the staff and patients shall be minimized. Specific paths of travel for each phase have been carefully selected to minimize such interaction between ITS installers and the staff and patients.

It is anticipated that ITS installers will need access to mechanical and electrical rooms located in occupied areas. Access to these areas shall be scheduled in advance with the appropriate personnel.

During times when ITS installers must access occupied areas, their clothes shall not be visibly soiled with dust.

Construction of Short-Duration Barriers

Short-duration barriers shall be constructed of 4 mil, flame-retardant polyethylene (or similar) sheeting. Short-duration barriers shall run from the floor to acoustical ceiling unless otherwise specified. Duct tape shall be used to hang the polyethylene sheeting. Openings (entries) for short-duration barriers shall be constructed with overlapping sheeting or an adhesive zipper that attaches to adjacent polyethylene sheets. ITS installers may use prefabricated, noncombustible plastic barriers (e.g., environmental containment unit) instead of flame-retardant polyethylene sheeting.

Prior to dismantling the short-duration barriers, the ITS installer shall clean the floors and wall surfaces in the short-duration work zone. The ITS installer shall use a HEPA-filtered vacuum to clean such surfaces.

Construction of Long-Duration Barriers

Unless otherwise noted, long-duration barriers shall be constructed of a layer of 16 mm (5/8 in) thick Type X framed walls applied on each side of noncombustible studs spaced 610 mm (24 in) in the center. The seams on the occupied side of the barriers shall be taped or caulked. The occupied side of the barriers shall be painted. Long-duration barriers shall run from the floor to the upper deck unless otherwise specified.

Unless otherwise noted, openings for long-duration barriers shall be constructed with 45 mm (1 3/4 in) thick, solid-bonded core wood doors set in noncombustible frames. Such door openings shall have a minimum clear width of at least 711 mm (28 in). The doors shall be in a suitable condition with no holes or cracks. The doors shall be equipped with positive-latching hardware.

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Construction of Long-Duration Barriers, continued

The ITS installer shall construct a short-duration barrier to enclose any construction or dismantling of a long-duration barrier to minimize the release of dust into occupied areas during construction and demolition of the long-duration barrier. Such short-duration work enclosures shall be negatively pressurized with respect to adjacent occupied areas. The ITS installer shall use HEPA-filtered fan units to generate negative pressure within these work enclosures. The short-duration barrier may be dismantled after the long-duration barrier construction is complete. For the dismantling and removal of a long-duration barrier, the short-duration barrier shall be erected prior to dismantling activities and shall not be removed until all components of the long-duration barrier are removed from the building.

Negative Pressurization of Work Zone

No construction activity may take place in a work zone until the work zone is placed under negative pressure with respect to adjacent occupied areas.

High-Efficiency Particulate Air (HEPA) Filtered Fan Units and HEPA-Filtered Vacuums

HEPA-filtered fan units are specified in select areas to generate negative pressure within work zones. HEPA-filtered fan units typically have volumetric flow rates of 1.42 m^3/m (50 ft^3/m) to 56.6 m^3/m (2,000 ft^3/m). HEPA-filtered fan units may have two or three filters, including at least one prefilter and one final HEPA filter. The HEPA filter within the fan unit shall be capable of removing 99.97 percent of particles with a diameter of 0.3 µm (0.01 mil) from the air stream.

HEPA-filtered vacuums are specified for cleaning operations. The HEPA filter within the vacuum shall be capable of removing 99.97 percent of particles with a diameter of 0.3 µm (0.01 mil) from the air stream.

The ITS installer shall be responsible for providing power to HEPA-filtered fan units and vacuums.

Construction in Occupied Areas

The ITS installer is prohibited from performing indoor construction activities outside of designated work zones, including roof penetration, above ceiling, and corridor work in occupied areas unless the facilities director has granted permission.

When ITS installers perform construction activities in occupied areas, they shall erect a short-duration barrier around the work zone. Such barriers shall remain in place until the work is complete and ceiling tiles are replaced. The work zone within the short-duration barrier shall remain under negative pressure with respect to adjacent occupied areas. In order to generate negative pressure within these work zones, the ITS installer shall use HEPA-filtered fan units. The HEPA-filtered fan units shall be exhausted to an indoor location deemed appropriate by the facilities personnel.

Construction in Occupied Areas, continued

The ITS installer shall establish an anterior area within the work enclosure and make available the following items for personal and equipment decontamination:

- HEPA-filtered vacuum
- Spray bottle with hospital-grade cleaning solution
- Disposable towels
- Protective clothing (e.g., coveralls, shoe covers, head covers)

Peel-off adhesive mats shall be placed at the entrances to these work zones. Adhesive mats shall be replaced at least once per workday or as often as needed to remove the dust from shoe bottoms.

Demolition debris and other waste shall be loaded into covered wheeled containers. Such containers shall be transported directly to the building exterior for disposal of waste. The containers' wheels and exteriors shall be wiped with a wet towel before transport (e.g., to remove surface dust).

The ITS installer may be required to schedule such work at times convenient to the facilities personnel.

Enforcement

The safety officer and the facilities director are responsible for ensuring that ITS installers follow the provisions of the infection control work plans and the facilities personnel follow basic maintenance infection control measures.

NOTE: The safety officer and the facilities director have the authority to stop work within a construction or maintenance work zone if such activities are endangering the lives of patients, staff, or visitors.

For maintenance projects, the safety officer and the facilities director shall make periodic visits to maintenance work zones to verify that the facility personnel are following basic maintenance infection control measures.

For construction projects, the safety officer or the facilities director shall make at least one documented visit per week to each construction work zone. During the zone visits, the safety officer or the facilities director shall verify that ITS installers are following the provisions of the infection control work plan. Safety officers or the facilities directors shall record their observations on infection control evaluation forms.

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Chapter 10
Planning and Project Management

Chapter 10 highlights the elements of a well-defined project plan and offers the information technology systems (ITS) installer strategies for successfully managing a project.

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Planning and Project Management

Introduction

Planning and project management are key to a successful information technology systems (ITS) cabling installation project. Taking the time to develop a well-defined plan before a project starts will help deliver a proper installation on time, within budget, and ensure that the job can be performed and meets all customer requirements.

Project management is a discipline that encompasses planning, organizing, and managing resources to achieve successful completion of specific project goals and objectives.

A large project usually has several project managers (PMs), each of whom is responsible for a different organization or activity. In some cases, this individual may not have the formal title of project manager and may be called a team leader or a lead technician.

Larger and more complex projects require more time to plan. It is difficult to manage loosely defined objectives and the efforts of a large project team over an extended period of time.

The purpose of a project plan is to provide:

- An understanding of the work to be done and how the cabling installation fits into the overall project.
- A list of project objectives.
- A list of specific tasks.
- A project schedule to track time and resources.
- Staffing assignments and project responsibilities.
- The identification of potential roadblocks and strategies for addressing them.
- Definitions of the documentation forms and procedures used on the job.
- A tool for managing the project.
- A way to get commitment from the project team.

This chapter describes the components of a project plan and outlines how to use the plan to manage a project more effectively.

Developing a Project Plan

Overview

An ITS project plan must address all aspects of the installation.

Developing this plan involves a series of tasks, including:

- Gathering and reviewing customer documents, including drawings, specifications, material list, scope of work (SoW), and contract.
- Developing the project schedule.
- Developing project documentation, including a project log, an acceptance plan, and forms for request for information (RFI), submittals, job change orders, and punch lists.
- Conducting a site survey to verify all gathered information.
- Reviewing and incorporating the company's safety plan.

An understanding of the following will contribute to the success and effectiveness of the plan:

- Cabling installation standards (structured wiring)
- National and local codes (safety issues)
- BICSI® manuals (design elements)
- Manufacturer's specifications (e.g., installation methods, product quality)
- Voice, data, and video fundamentals
- Customer's requirements

Gathering Information

Customer's Documents

When an ITS cabling installation is requested, the customer has several ways of soliciting bids—a request for proposal (RFP), a request for quote (RFQ), formal contract, purchase order (PO), or other document. These plans are transmitted to the cabling company.

The customer's plans typically contain drawings and specifications that identify the materials to be used, the standards by which they will be installed, and the individual installation locations.

In addition to these plans, the customer's documents may include the following:

- ITS designer's drawings (cabling installation drawings)
- List of materials
- SoW
- Contract that includes any other documents that dictate the progress or method of installation for the project
- Overall project schedule
- Customer safety plan

For some projects, the cabling company or a member of the ITS team will be responsible for developing a set of installation drawings, a list of materials, and the installation SoW.

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Gathering Information, continued

Customer's Drawings

Usually, the customer's drawings are scaled plans prepared by a licensed architect or registered professional engineer and other professionals. They usually will be accompanied by a document containing written specifications. The following can be used to determine which drawing set(s) are necessary:

- A—Architectural drawings, referred to as A drawings, show a plan (top) view of each floor in a building. Architectural drawings include all aspects of the physical construction of the building, which provide the detail for such items as walls, windows, ceilings, doors, flooring, cabinetry, and furnishings. If the architect employs interior decorators, their work will be reflected on these drawings.
- M—Mechanical drawings, referred to as M series drawings, indicate the size and route of the heating, ventilating, and air conditioning (HVAC) and plumbing systems within the structures. In addition, the M series drawings may indicate potential obstructions to the installation of wires and cables inside the building. M series drawings may indicate if the main water pipe serving the building is metallic.
- E—Electrical drawings are very important to ITS installers. The drawings indicate where the electrical services are installed inside the building and the pathways that may be installed by the electrical contractor for use by the cabling installation team. The drawings indicate the grounding system designed by the electrical engineer; the location of supporting structures installed by the general contractor (e.g., plywood backboards); and the layout of ceiling lights, called a reflected ceiling plan.
- T—With the 2004 MasterFormat®, use of telecommunications drawings will increase throughout the building trades industries. See Appendix A: Specifications and Appendix B: Telecommunications Drawings for additional information. When separate electrical and telecommunications drawings are provided, the telecommunications drawings will show the pathways, distribution room layouts, and media required for the project.

  Drawing packages provide the telecommunications pathways on E or T drawings and telecommunications outlet/connectors on a separate set of drawings. In large complex installations (e.g., school buildings, hospitals), there may be separate drawings for electrical, telephone, data, video, fire alarm, and intrusion detection systems.

  In some cases, pathways shown on design documents are schematic in nature. They do not reflect the actual route or path but, rather, indicate beginning and end points. The specific cable installation routes are left up to the ITS installers. If this is the case, it will be indicated on the drawings
- S—Structural drawings are important because the drawings indicate the location of all components of the building structure itself—the steel beams, concrete floors, exterior walls, and other components that make up the basic structure. The plans contain detailed sectionalized drawings that give both a plan (top) view and an elevation (side) view of the structures.

Gathering Information, continued

The following are types of drawings that can be found within each set:

- Site drawings can be provided by civil, landscape, or electrical engineers or by other members of the design team. These drawings indicate locations of exterior pathways that are being installed for use by the ITS contractor. The drawings indicate the size, quantity, and route of the pathways as well as the service each will support. Site drawings usually identify service entrance pathways that will be used by the local service providers (SPs) in bringing service to the building from the public network.
- Cross-sectional drawings (riser diagrams) show the building profile and the floor-to-floor relationships within each building. This should show all pathways and spaces for ITS.
- Floor plans are an overhead view showing dimensional relationships on each individual floor that provides telecommunications rooms (TRs), work area outlets, and cabling or pathway routes.
- Room detail drawings provide details of cable terminations, equipment locations, cross-connects, and electrical services within the room.
- The drawing package generally contains one or more sheets for general notes, legends, symbols, and abbreviations as well as a drawing list. It is important to check this information to:
  - Identify all plans that impact cabling installation work.
  - Understand how the overall project is expected to come together.
  - Note any special requirements or limitations.
  - Understand who is responsible for installing the ITS pathways. Do not assume that others will be responsible.

Construction Specifications

Plans provide a pictorial representation of the project. The details required to accomplish such tasks (e.g., material ordering) are contained in the specifications. Specifications provide a written description of the work to be performed and the responsibilities and duties required of the architect, engineer, contractor, and owner. The plans identify the materials to be used as well as applicable standards, performance criteria, and testing methods. Together with the drawings, the specifications form the basis of contractual requirements.

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Gathering Information, continued

Designer's Drawings

A BICSI Registered Communications Distribution Designer (RCDD®) may be employed by the customer, architect, engineer, or cabling installation company to develop the required telecommunications drawings and specifications. If not, a member of the ITS installation team may develop the drawings and specifications.

These drawings and documents indicate the size, quantity, description, and route of the cables to be installed as well as the type of hardware used for supporting and terminating the cables. The drawings and documents should indicate the type of cable to be installed (e.g., performance rating, type of construction, fire rating), the splicing sequences (if any), and the cables to be terminated in all TRs. In addition, the drawings should show the type of connecting hardware by size, quantity, and configuration as well as the supporting structure required (e.g., cable tray, conduit, hangers).

At times, separate drawings may be prepared for each type of ITS infrastructure to be installed. Separate drawings may be prepared for copper cables, optical fiber cables, coaxial cables, and other low-voltage cables. However, there should be a schematic showing the placement of the cables and sleeves so that backbone routing can be determined. If the project is small enough, all of the information may be contained on a single drawing.

Elevation drawings of the TRs and the placement of various equipment items should be part of these drawings. A detail of each wall and rack in each TR as well as a plan view of the floor-mounted hardware should be included.

NOTE: See Example A: Designer's Drawings at the end of this chapter.

Materials List

To submit an accurate proposal, a list of materials should be prepared during the bidding phase. This list should contain all of the installation items by:

- Description.
- Catalog number.
- Quantity.
- Unit price.
- Total price.

The list should have columns indicating the materials received and the materials dispensed. Field personnel can use these two columns to manage inventory during the actual installation work. Many contractors prepare similar lists for installation labor units, indicating the amount of time allocated for each portion of the installation. In addition, the list should contain labor hours allocated for the project by work process.

NOTE: See Example B: Materials List and Example C: Labor List at the end of this chapter.

Gathering Information, continued

Scope of Work (SoW)

The SoW for the project covers the requirements for the ITS team. The SoW document lists all of the elements of the installation, and it is usually generated by the customer or the designer. However, the SoW can be developed by the cabling installation company when bidding or responding to a customer's RFP.

The SoW should indicate:

- People and firms involved in the project and their responsibilities.
- Work.
- Time frame.
- Permits or licensing required and persons responsible for obtaining them.
- Materials.
- Methodology.
- Known limitations, restrictions, or potential problems with the job (e.g., notes, assumptions).
- Identification, labeling, and documentation systems.
- Testing and test documentation methods.
- When and how the installation will be turned over to the customer.
- Clarifications or understandings that elaborate on the various items involved in the installation.

NOTE: Refer to Example H: Scope of Work at the end of this chapter. This SoW is an example only and is not intended to be all encompassing.

Contract

A project contract documents the understanding between the customer and the contractor. Some customers generate a PO that refers to other documents associated with the project (e.g., SoW, materials list). If a contract is used, ensure that copies of the contract and any supplementary documents it lists are provided to the cabling installation team.

Contracts may list penalties associated with not completing the work correctly or delays in completion. Pay particular attention to liquidated damages. Performance bonds and insurance may be required as part of the contract. When a new or customer's contract is used, it is always a good idea to have an attorney review the document to determine if the ITS installer's understanding is consistent with the actual legal issues involved.

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Project Schedule

Once all of the items associated with planning a cabling installation have been identified, a project schedule needs to be developed. The schedule should list all project tasks, beginning with the award of the contract and ending with acceptance by the customer and collecting the final payment.

The detail required for each task is directly proportional to its importance in completing items that precede or follow it. The project schedule should indicate the planned time required for each item as well as provide space for inserting the actual time to perform the job task.

Developing the Project Schedule

When developing a schedule for cabling installation work, the first schedule to obtain and refer to is the general contractor's construction schedule. It includes all of the trades working on the project and indicates their specific timeframes for accomplishing the project work.

Of particular concern are the schedules for completion of the supporting structure inside the building. For example, installation of the backbone cables or the horizontal cables cannot be scheduled until the person or firm responsible has completed installation of the pathways and spaces used to house these cables.

With new building construction and many retrofit projects, coordination and communications with other trades is a must. For example, faceplates cannot be installed until the wall covering is completed. Racks may not be installed until the floor covering is installed. This can mean multiple trips to the job site for the cabling installation team.

The cabling project schedule should complement the general contractor's project schedule. Failure to coordinate the cabling project schedule with the general contractor's schedule may result in conflict between the two companies as well as related trades and could jeopardize timely completion of the project.

Companies use a variety of project management styles and software to develop project schedules and track installations.

Automated systems can reflect:

- Start and end times for specific tasks.
- Resources necessary to undertake specific tasks (e.g., some systems reflect people only while others tie into materials lists).
- Interrelationship of tasks (e.g., what tasks must be completed before others, what tasks must wait until several other tasks are completed).

Project Schedule, continued

As actual project information is entered in an automated schedule, the system can display:

- Percentage of completion.
- Progress payment schedule.
- Materials or other resources expended.
- Time delays or advancements.
- "What if" analyses to review the impact of moving dates or resources.

Manually generated project schedules can be used, especially when the project is small and not complex. Copies of the completed schedule should be provided to all concerned parties.

NOTE: Two project schedule documents are shown in Example D: Project Timeline and Example E: Project Schedule at the end of this chapter.

Developing the Project Documentation

All projects require documentation. Some documentation is required by the contract, and some is kept to ensure the project meets time and budget requirements. Documentation depends on project size and complexity.

Most projects will include the:

- Job log.
- RFI.
- Submittal forms and logs.
- Job change orders.
- Acceptance plan.
- Punch list.
- As-built drawings.
- Maintenance and equipment documentation.
- Test documentation.

Job Log

If a standard form for tracking daily activities is not available, a job log should be developed. This log should reflect all work undertaken each day, whether it is complete, and the plans for the following day.

It should provide a place to record detailed notes on any issues that arise, including the:

- Date.
- Time.
- Installation problems and individuals involved.
- Description of the problem.
- Resolution.

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Developing the Project Documentation, continued

The person in charge at the project site will use the job log to record all activities associated with the project. It is especially important to log occurrences that may result in scope changes that could have a financial impact on the cabling installation company. Sometimes, a contract requires copies of this log to be submitted to the customer and general contractor on a periodic basis.

Request for Information (RFI)

The contract documents cannot cover every detail about the materials, procedures, and testing requirements to be used on the project. RFIs are used to request clarification, supplemental information, or approval of materials substitution. The RFIs can provide direction when unforeseen circumstances arise; however, they are not intended to be used to request information on time-critical issues (e.g., gaining access to a work site).

The RFI form must provide a place to assign an identification tracking number to the RFI and to record the date and time, a description of the request, who is sending the request, and who will receive the request. This information must be entered in an RFI log along with the date and time the response is received and the content of the response. This log provides a way to track when an RFI was sent, read, and acted upon.

EXAMPLE: The drawings indicate that all station cables are to be fished through existing office walls. However, the ITS installer finds the walls are constructed with multiple fire barriers, prohibiting a top to bottom pathway. An RFI asking for direction from the owner or contractor should be prepared. If a surface raceway is installed without obtaining approval in writing, it may be difficult to receive compensation for the extra work and materials. In addition, the owner may state that a surface raceway should not be used in such a situation, and the work may have to be redone.

Submittals

Submittals are a form of communication between the cabling installation team and the contractor or owner defining the specifics of how a job will be undertaken. In the construction industry, these most often consists of two components—shop drawings and product cutsheet submittals.

Specialty contractors (e.g., HVAC, fire suppression, audiovisual installers) most often provide shop drawings. The drawings reflect the specific details of products to be used and the method of their installation within the new or renovated spaces. Shop drawings are often scaled drawings similar to the original construction blueprints showing the specific methods of interconnection, size of components, or individual routes that will be used when installing the product.

Developing the Project Documentation, continued

Product cutsheet submittals are used for documenting the specific items or product models that will be used on the job. These submittals note the product name or specification number and complete performance specifications.

Submittals that might be required of the cabling installation team are:

- Products, including:
  - Cable—each type and model.
  - Outlet components (e.g., jacks, faceplates, connectors).
  - Ladder racks.
  - Equipment racks.
  - Firestopping materials.
- Shop drawings, including:
  - Backboard layouts.
  - Equipment rack placement and component layouts.
  - Cable routing—horizontal and vertical.
  - Cable suspension methods.

Submittals that are a contractual requirement must be tracked to determine compliance with submittal methods and terms. This tracking can be a simple log defining when a specific submittal was made, when it was returned, and whether it was approved or requires resubmission.

Job Change Orders

Few projects are completed without changes to the original work plan. Even on small projects, changes occur. The changes may be insignificant, but they must be documented. When accounting for all materials and work operations at the completion of the project, unless the changes are documented and approved by duly authorized agents, compensation may not be received. A contractor should never perform additions, deletions, or material changes to the SoW without written authorization.

When submitting a change order, keep the original and provide copies to the customer and any other interested parties. Be aware of the consequences of change orders prior to implementing them, especially their impact on the project schedule.

NOTE: Refer to Example G: Job Change Order at the end of this chapter.

The cabling installation company may have forms prepared for this purpose. If not, and if the attached form (see Example G) is not used, copies of an approved American Institute of Architects (AIA) change order form may be used on the project. For many projects, this may be the only approved change order form.

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Developing the Project Documentation, continued

Acceptance Plan

An acceptance plan outlines the tasks, tools, staff, and skills necessary to test and document the successful completion of a project. Many manufacturers and individual project plans provide copies of the documentation required to fulfill the contract needs but leave the logistics of how to conduct the tests up to the ITS contractor.

To reduce the duplication of effort and provide an effective plan, the following items must be defined:

- When the testing will take place (once, several times, every day).
- Who will conduct the tests (e.g., how many people with what type of training).
- Who will witness the tests (if required).
- What tools, supplies, or other materials are required.
- Who needs to be notified or forewarned of the testing.
- How the tests will be documented.
- How the results will be transmitted to the contractor or owner.

Punch List

As with an acceptance plan, many firms use a specific form to document the work that remains to be completed. A punch list is simply a formal listing of items or issues needing resolution before the project is designated as complete. The punch list should be prepared during a joint inspection of the work site and should reflect the agreements reached between the owner or contractor, the cabling installation firm, and any impacted subcontractors.

A punch list is not simply a list of all the problems or mistakes at the job site. The punch list needs to define clearly and dispassionately the specific steps or work tasks that need to be completed. Rather than stating, “Faceplate crooked on station 342,” the punch list should state, “Realign faceplate on station 342.” A punch list should clearly define the person(s) or firm responsible for that work.

To be effective, the punch list must be in writing and must reflect the expected time for completion. Using this approach, the ITS installer knows exactly what needs to be done and has a document that defines when the work is finished. Once a punch list is completed and signed off, it becomes difficult for the owner or contractor to request additional improvements or changes without compensation.

Developing the Project Documentation, continued

Record Drawings (As-Built Drawings)

The format to be used for the as-built drawings must be agreed upon before beginning the project, so information can be gathered in a proper fashion throughout the project. The most common type of as-built uses the original floor plans and reflects the actual placement of outlets, the configuration, and the station or jack numbers. Other information, such as cable routing, backboard layouts and configuration, length of cables, and firestopping materials, may be required as part of the original contract.

The ITS installer must keep in mind the need for this information and the format that will be used. It is generally a good idea to keep a set of drawings updated on a weekly or daily basis with completed work. Not only can these drawings be used for discussion purposes, but the form and content can be reviewed and approved by the general contractor or owner before a great deal of effort is expended.

As with any documentation required for submittal on a project, do not make assumptions (e.g., that the general contractor or the original designer will input all as-built information into electronic form). Some contracts require the cabling installation company to complete all computer-aided design (CAD) work and produce multiple sets of final drawings. The cost of this work must be taken into consideration before the proposal is submitted to the owner.

Maintenance and Equipment Documentation

An operations and maintenance (O&M) manual should contain the title of the project and the names and contact information for the architect or engineer, ITS designer, and ITS contractor. Information for each product or system should be included identifying the specific products and components installed for the project. Each sheet should include the manufacturer's installation steps and any maintenance procedures along with a list of replaceable parts. Mark each sheet to clearly identify specific products, component parts, and data applicable to the installation. Include a list of local suppliers from whom replacement parts may be obtained.

The ITS installers should retain all printed material that comes packed with the components installed for inclusion in the O&M manual. The format to be used for O&M manuals must be agreed upon before beginning the project, so information can be gathered in a proper fashion throughout the project.

Test Documentation

Specific test documentation may be required under the terms of an agreement between a cabling installation company and a manufacturer's product warranty program. This should be discussed with the owner or contractor before the work begins to determine the documentation required. It may be necessary to negotiate with the owner, the general contractor, and the product manufacturer to develop an acceptable form of documentation.

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Developing the Project Documentation, continued

The automated test sets used for documenting balanced twisted-pair cable generally provide a simple and clear method of identifying and documenting station cable. It is necessary for the ITS installer to be aware of any additional procedural requirements that may be part of this testing (e.g., certifying the accuracy of the testing equipment, recalibrating the equipment).

Some contracts require tests to be witnessed by the owner's representative. In these cases, it is important for the ITS installer to be aware that the witness has a specific contractual responsibility and is not simply looking over the ITS installer's shoulder. It is always best to discuss procedural issues before beginning work and to maintain a dialogue as testing continues.

Conducting a Site Survey

After all of the contract documents are obtained and reviewed, a member (or members) of the cabling installation team will visit the installation site. The purpose of the survey is to:

- Ensure that local and national codes are met.
- Ensure that all telecommunications standards are met.
- Compare design documents with existing conditions.
- Identify potential conflicts or concerns.
- Define any additional support required (e.g., access, pathways, electrical services) and determine who is responsible for these additional services.
- Identify situations that will require special equipment or skills.
- Determine the amount of support material required to complete the project (e.g., hangers, cable ties, surface raceway).
- Determine the work hour requirements, including the number and skill level of the cabling installation crew needed.
- Locate storage and staging area space.

Reviewing Gathered Information

When preparing for the site survey, include the following items:

- Designer's documents—Allow identification of specific locations related to the project and the work to be performed there. The drawings may indicate obstacles not visible from floor level.
- Checklist—Based on the criteria for the project, a checklist is used to ensure that everything is taken into consideration during the site survey and to double-check development of the project plan. If problems are found, plans can be formulated to overcome them while still on site rather than having to return.

  NOTE: Refer to Example F: Site Survey Checklists for checklists for new and retrofit construction at the end of this chapter.

- Tools—To perform the work required for a thorough site survey, personal protective equipment (e.g., hard hat, safety glasses, leather gloves, leather boots, hearing protection) might be needed. Additional items that may prove useful are a ladder, flashlight, measuring wheel, handheld tape recorder, digital camera, or video camera.
- Contacts—List of site contacts, telephone numbers, and e-mail addresses.

Conducting a Site Survey, continued

Reviewing Responsibilities with Team Members

The first stop at a job site should be at the general contractor's site office. While at the office:

- Introductions can be made.
- Work to be performed for the customer can be explained.
- Other contractors working for the general contractor can be identified, and the impact of their work can be discussed.
- A copy of the general contractor's construction progress schedule can be obtained.

NOTE: Use this document to determine how the installation schedule can be coordinated with other contractors working on the project site.

It is important to review responsibilities with the general contractor's representatives so that they understand the role the cabling installation company will play in the completion of the overall project. Remember, the general contractor owns a new building until the owner accepts it and has ultimate authority and responsibility for the project.

Verify who will construct the pathways and spaces. The customer's documents should state whether they would be provided by the general contractor or by others. In many cases, the pathways and spaces of a new building project are part of the responsibility of the general contractor or the electrical subcontractor. It is important to discuss the details of the pathways and spaces with the person or firm responsible. Do not assume they know the impact of their work on the installation of ITS cabling.

The contractor responsible for the pathways must determine how to install these pathways, observing what obstacles and obstructions must be overcome. Failure to make this determination might result in additional site surveys.

Some of the obstacles that may be encountered include:

- HVAC ducts and equipment.
- Elevators.
- Stairways.
- Fire- or smoke-rated walls, floors, ceilings, and partitions.
- Sprinkler systems.
- Structural forms or beams.
- Interstitial space.

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Conducting a Site Survey, continued

Examining the Site

While on site, be sure to observe all locations where the cabling installation work will be performed. Determine the physical location of all TRs; the size, type of construction, and configuration of utilities within TRs; and the responsibilities required to interface with other trades.

Identify the location of pathways that have been constructed by the general contractor or the subcontractors, and determine the state of completion.

Determine, at a minimum, the answers to the following questions:

- Have the subcontractors adhered to the architect's and designer's drawings and specifications?
- Are there any change orders that will affect the pathways and spaces? If so, how do they affect the project?
- How is the bonding and grounding (earthing) infrastructure installed? Does the infrastructure comply with codes, regulations, and standards?
- When will the telecommunications spaces be completed?
- When will the pathways be completed?
- When will the inspector or fire marshal be on site to perform interim inspections and the certificate of occupancy inspection?
- When will the project be turned over to the owner (tenant)?

Answers to many of these questions should come from the materials contained in the customer's and the designer's documents. However, do not leave anything to chance. Review all requirements of the project before concluding if additional pathways, spaces, or building facilities are required. If they are and they have not been included in the original plans and specifications, job change orders may be required. At the very least, these concerns need to be documented and discussed with the general contractor or the owner's representative.

All information gathered during the site survey should be carefully documented and placed in the project file. This information will become invaluable later, especially if new team members are assigned to the cabling installation after it starts.

NOTE: If the project is a retrofit, identify all of the existing pathways and spaces used for ITS and their size, capacities, usability, congestion, and compliance with local codes and standards. See Chapter 11: Retrofits and Upgrades for additional information.

Project Safety Plan

The safety of workers, the customer's personnel, and the subcontractors is of paramount importance. Workplace accidents can disrupt the best-planned job and cause costly delays.

Each company should have an occupational safety plan. Before beginning any work operation, the contents of that safety plan should be reviewed with each employee working on the project. Each employee should fully understand how the rules of safety should be implemented as each cabling installation task is performed. Take the time to ensure that each employee is equipped with the proper safety equipment and has the knowledge to use the equipment safely. As a contractor or subcontractor, attending periodic safety meetings may be contractually required.

All employees should attend an initial safety meeting prior to commencing the work. All safety plans should be reviewed. Many general contractors and customers have safety orientation and drug screening programs that all employees must complete prior to beginning the project work. Only through knowledge, understanding, and on-the-job awareness can employees perform their work safely.

NOTE: Refer to Chapter 1: Installation Foundations, Section 2: Professionalism for further information.

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Project Implementation

Overview

Just as a drawing provides a blueprint for cable installation, a good project plan is a blueprint for managing and tracking the project. From the initial construction meeting to closeout activities, the plan helps assess the progress and monitor the project. This section defines the typical tasks included in a plan and the methods used for implementing them.

Initial Construction Meeting

After completing the site survey and formulating the project plan, the cabling installation PM should hold an initial meeting with the entire cabling installation team. At this meeting, the PM and the team leader should lay out the responsibilities of everyone involved. The project plan can be reviewed and updated as necessary. Communication between all personnel involved in the project is critical to its success.

Updates to the project plan and minutes of all meetings should be maintained, and printed copies should be provided to each person attending and additional persons having a position of responsibility on the project. Meeting minutes must be prepared and distributed shortly after each meeting and must provide a mechanism to allow attendees to update or correct the material.

Preinstallation Meeting

After the initial construction meeting is held and the project plan is updated, the PM should conduct a preinstallation meeting. This meeting should include the cabling installation team and appropriate contractors. All aspects relating to the project should be addressed and discussed. If necessary, adjustments should be made to the project schedule based on the results of the meeting. To ensure that the work is performed in a timely and professional manner, the project should be reviewed in detail so that team members can work in concert with each other and with the other contractors.

Progress Meetings

Periodic progress meetings should be held for every project. These meetings can occur as often as once a week or as necessary to ensure that team members know the status of the project and what is expected of them. Work progress as well as roadblocks and ways of overcoming them should be discussed and agreed upon by all concerned parties. Each team member can contribute to the success of the project by thoughtful participation in these meetings.

When a project involves several contractors, the general contractor and subcontractors should attend and participate in these meetings. The PM should attend the general contractor's construction meetings to ensure that all concerns are addressed. This facilitates proper coordination between the cabling installation team and other contractors working on the project.

If the owner or general contractor does not keep meeting minutes, the PM should keep notes of the meeting and submit them as the PM's understanding of items discussed. This applies to all meetings.

Ordering Materials

The person responsible for ordering the materials should place the order as soon as possible after the project plan is accepted. Easily overlooked are items termed consumables. Consumables are normally shown as a lot on the materials list because they are too small to be detailed as a line item. Items could include tape, screws, tie wraps, and similar materials.

An order for materials is often placed using a PO. The PO should be in writing, and a copy of each material PO should be kept in the project file. These POs can be used to develop the inventory for the project and to check against materials received and stocked.

Receiving Materials

Receiving materials is one of the most important tasks on a project. It can affect the cost of the project just as much as the labor employed. Determining where to store the materials, how they will be dispensed, how to secure them from theft or damage, and how to dispose of unused materials is critical to the project's success.

As the materials arrive, the responsible team member must receive the materials, inventory them, and stage them in preparation for transportation to the job site. If the materials are delivered to the job site, a company representative should be there and should be responsible for receiving, documenting, and storing them in a secure location.

All received items should be inspected and inventoried upon receipt. Each package should be checked against the packing slip for quantity, identity, and condition. If the packaging is damaged in transit, the contents of the package may be damaged. Verify this with the delivering agent prior to signing for the package. This is especially true with large reels of copper and optical fiber cable. If damaged materials are kept, indicate the extent of damage on the packing slip and the shipper's manifest for future claims processing.

If there is a visual indication that reels of cable are damaged, consider refusing to accept responsibility for them, or immediately notify the supervisor to determine the proper course of action. When optical fiber cables are received, check the cable even when no damage is visible, using an optical fiber flashlight, optical loss test set (OLTS), or some other type of testing device to determine the continuity of the strand end to end. Copper and coaxial cable may require testing with a time domain reflectometer (TDR) or other device to identify and document unseen damage.

Check the project plan for specific methods to be used in accepting costly materials. It may be necessary to conduct and document physical tests on various types of cable prior to accepting them. For example, it is a common practice to conduct an optical time domain reflectometer (OTDR) test on optical fiber cable while it is on the reel.

If materials delivered to a job site are visibly damaged upon arrival, the materials should be refused and the delivery service instructed to return them to the distributor or manufacturer. If materials are accepted and then found to be defective, they should be stored separately from other materials and returned to the appropriate source via prearranged instructions from that distributor or manufacturer. If it is not possible to identify the defect and document it, enclose a copy of the documentation with the materials to aid the distributor or manufacturer in properly replacing it and correcting the problem that caused the defect.

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Storing Materials

Three basic locations for storing materials for a project are the:

- Job site.
- Company-controlled location.
- Distributor from which the materials were purchased.

Each has its advantages and disadvantages. These storage options should be of prime concern when considering how to plan for materials distribution and use on a job. Depending on the size of the project, the best alternative may be a combination of all options.

Job Site

The job site offers immediate availability of materials. However, there are risks associated with storing materials at a job site. Is a secure space inside the building available? Is an exterior space (e.g., trailer, other building) available and secure? Will only authorized persons have access to the space? Most of the time, the security of materials is the first concern. Until the materials are installed and accepted by the customer, they are the property and the responsibility of the contractor installing them.

Some customers may make space available for storing job materials, but few, if any, will agree to accept liability for loss or damage until the materials are installed and accepted. Risk of loss insurance may be needed to protect against loss of both materials and tools. Although this insurance will cover the loss, delays in obtaining replacement materials may make it undesirable to store them on the job site unless significant security can be assured.

If space is not available for storage inside the building, a job-site trailer might be needed. In most locations, a permit is required prior to locating a job trailer on a construction site. If the trailer will be used only for materials and tool storage, temporary utilities will not normally be required.

Office trailers requiring temporary electrical power, telephones, and sanitation utilities may require additional permits or coordination with the local utility companies providing these services. In most cases, local telephone and power companies will bill the contractor requesting the temporary service for the actual cost of constructing the facilities. The contractor's company may be required to sign a contract for a minimum period of time that the service will be used.

If large cable reels are to be used on the project, a security fence may be required. Fencing can be rented, and the rental company will usually install the fencing. The degree of security associated with job-site fencing will depend on what is stored inside the fence and the social environment associated with the job-site location. In most locations, chain link fencing will be adequate. In other locations, concertina wire may be needed for maximum security. In some cases, private security might have to be hired during nonworking hours.

Storing Materials, continued

Company Location

If the project is in the same city as the cabling installation contractor's office and adequate space is available, materials can be stored at the company location and sent to the job on a daily basis. Security may be less of a concern at the contractor's home location. Break-ins, however, occur even at the most secure locations. The cabling installation company should have insurance to protect against losses when materials are stolen or lost.

Distributor

Most distributors are in the business of stocking materials. Most distributors will deliver materials to a job site or to a company location on demand. Distributors use a process called assemble and hold, which allows companies to order materials for a specific project and stage them at the distributor's closest branch location until picked up or delivered.

Security is not an issue for the contractor in this situation because the materials are the property of the distributor until they are picked up or delivered. In addition, distributors generally have adequate space to hold materials for specific jobs and can deliver them in bulk or by partial order. Normally, the contractor is not billed for the materials, regardless of how long they stay in the staging area, until they are picked up or delivered.

Distributing Materials on Site

Control of the access to job materials will determine who is allowed to distribute them to the ITS installer. Only designated persons should be allowed to distribute materials on the job site or receive them at the end of the workday. Allowing full access to the job materials by the entire work crew invites abuse and loss of materials.

When materials are distributed, some record of accountability should be made to track where the materials are used. Excess materials should always be accounted for at the end of each workday and stored for use later on the job or returned to the company storage area for use on another project. They may eventually be returned to the distributor or manufacturer for credit after the project is completed and accepted. In addition, the records of the distributed materials must be returned to the company PM to ensure proper accounting.

Plan for a distribution area on site regardless of where the bulk of the materials and tools are being staged. The ITS installers will always know where to get their materials, and accounting and control are easier from a single location.

Managing the Project Schedule

Once the project has started, the original project schedule should be compared with the other construction schedules, and the various schedules should be updated at least weekly for accuracy.

The cabling installation schedule should be updated daily, indicating the progress of the day's work and whether the project is on schedule, ahead of schedule, or behind schedule. Any supporting documentation that will lend credibility to delays encountered in the project should be referenced in the project schedule updates.

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Managing the Project Schedule, continued

Revise the schedule after each meeting or activity where revisions have been recognized or made. Issue the updated schedule concurrently with the report of each meeting.

The project schedule should include all materials and services required from the sources that are not under the cabling contractor's direct control to include actions required by the owner. The PM should describe any dependencies upon the owner and third parties as well as all project assumptions, expediting methods, active system interfacing requirements, and other management-related issues critical to the timely and successful completion of this project. The plan should describe the manpower and mobilization requirements in terms of functional responsibility, level, and head count.

Maintaining the Project Log

A person on site should keep a project log during all work operations. This log should begin on the first day of activity on the project site and continue until the company vacates the site. All activities relevant to the work should be logged on a daily basis, including the work completed and any problems encountered.

Contractual obligations that are affected by the work of others should be logged and accompanied by detailed notes. This document could prove valuable when others have caused delays. Accuracy and timeliness are, therefore, critical to the credibility of the log.

It is good practice for the PM to document certain elements of the project on a weekly basis and to record the following information concerning events at the site:

- List of subcontractors at the site
- Approximate count of personnel at the site
- Accidents and unusual events
- Meetings and significant decisions
- Stoppages, delays, shortages, and losses
- Emergency procedures
- Change orders received, implemented, and in process
- Services connected and disconnected
- Equipment or system tests and start-ups
- Status of material orders
- As-built documentation status report
- Status of punch list
- Weather conditions
- Timesheets
- Daily job reports

Summary

All ITS projects require project management. An ITS PM will sequence the work and ensure that the job proceeds as anticipated. As projects become larger and more complex, there is more risk. As projects become larger or new team members become involved in the work, project management tools provide great benefits.

A good project plan is essential for the successful completion of the work. The communication that takes place between the team members while building the plan is often more important than the actual documents.

These techniques help ITS projects to be:

- On time.
- Under budget.
- Within specification.
- Above customer expectations.

The project plan should reflect each aspect of the work and the company's effort to ensure that this work will be performed in a timely, safe, and efficient manner.

It should include:

- Customer documents.
- Documentation to be submitted to the general contractor and customer.
- Job requirements.
- Security and safety plan.
- Acceptance plan.
- Materials list.
- Tools list.
- Task list and description.
- Labor estimates.
- Overall job schedule.
- Cabling installation schedule.
- Scheduled meetings.
- Inspection schedules.
- Resources required for compliance with the schedules.
- Materials staging.
- Coordination with other trades on the project.

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Additional Resources

Following are useful resources for further reference:

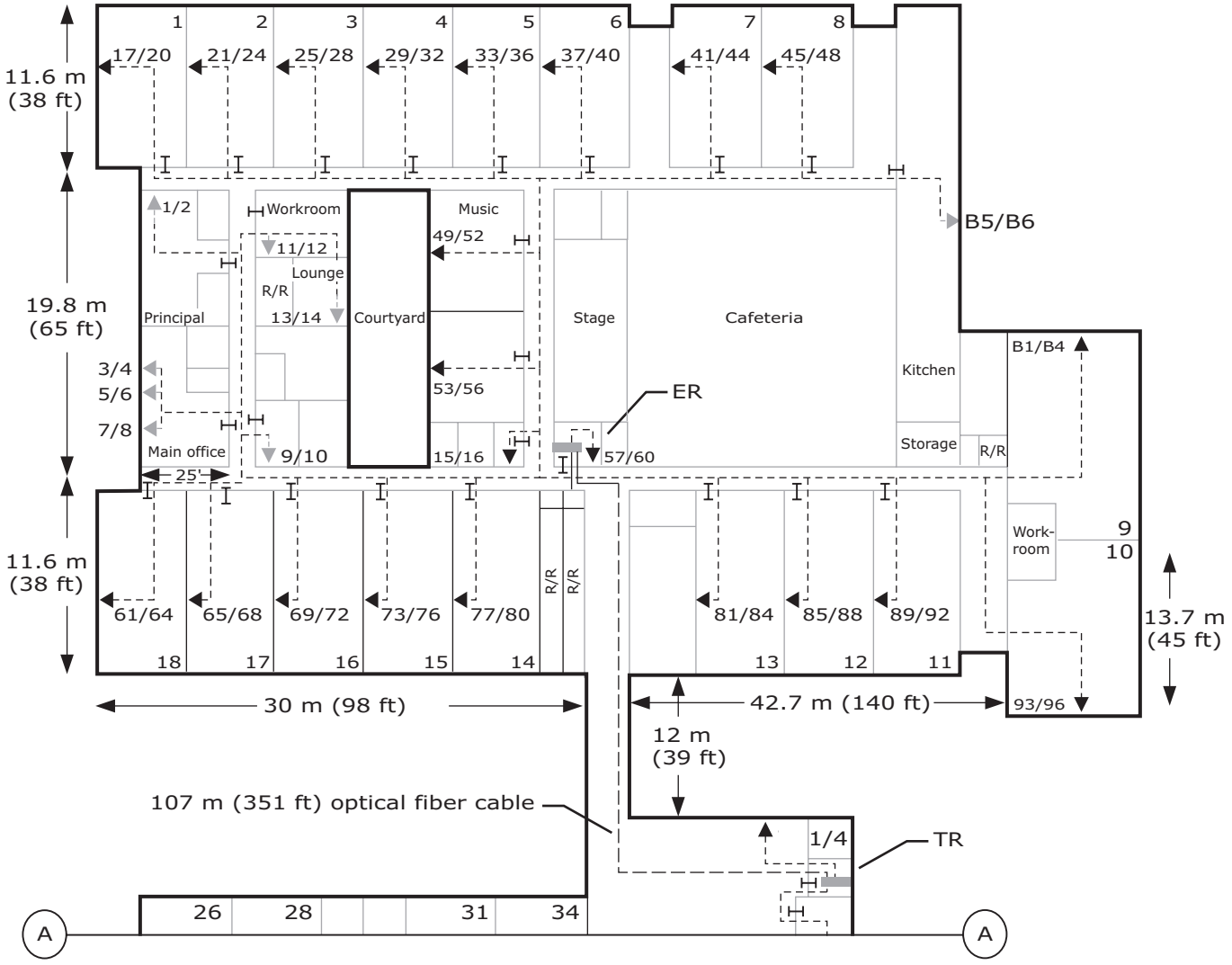
- AIA (contracts):
  - A101. Standard Form of Agreement Between Owner and Contractor
  - A201. General Conditions of the Contract for Construction
  - B141. Standard Form of Agreement Between Owner and Architect
  - C141. Standard Form of Agreement Between Architect and Consultant
  - G701. Change Order
  - G702. Application and Certificate for Payment
  - G704. Certificate of Substantial Completion
  - Web site—www.aia.com
- Association for Project Management (APM):
  - Web site—www.apm.org.uk
- BICSI® Publications (latest editions)
  - *AV Design Reference Manual (AVDRM)*
  - *Outside Plant Design Reference Manual (OSPDRM)*
  - *Electronic Safety and Security Design Reference Manual (ESSDRM)*
  - *Network Design Reference Manual (NDRM)*
  - *Residential Network Cabling Manual (RNCM)*
  - *Telecommunications Distribution Methods Manual (TDMM)*
  - *Wireless Design Reference Manual (WDRM)*
  - *BICSI Information Transport Systems (ITS) Dictionary*
- Construction Specifications Institute (CSI):
  - Manual of Practice—A reference containing theories, techniques, and formats to aid in all aspects of construction documentation.
  - MasterFormat
  - SectionFormat™/ PageFormat™
- Design-Build Institute of America (DBIA):
  - Web site—wwwdbia.org

Additional Resources, continued

- Engineers Joint Contract Documents Committee (EJCDC):
  - Web site—www.ejcdc.org
- InfoComm International®:
  - Web site—www.infocomm.org
- National Systems Contractors Association (NSCA):
  - Web site—www.nsca.org
- Project Management Institute (PMI):
  - Project Management Institute (Body of Knowledge [PMBOK])
  - Web site—www.pmi.org
- Telecommunications Project Management Association (TPMA):
  - Web site—www.telpm.org

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Example A: Designer's Drawings



◄— = One 41080-XAP faceplate equipped with four 41108-RX5 category 5e, T568A, modular jacks; academic locations

◄— = One 41080-XAP faceplate equipped with two 41108-RX5 category 5e, T568A, modular jacks; administrative locations

═══ = External building wall (masonry constructions)

─── = Interior building wall (may or may not be fire/smoke rated)

- - - - - = Category 5e wire route (proposed)

– – – – = Optical fiber cable route (proposed)

▬ = One 55053-703 relay rack E/W (2) 11374-703 vertical management panels

17/20 = Data/voice

ER = Equipment room

ft = Foot

m = Meter

R/R = Restroom

TR = Telecommunications room

Example B: Materials List

Project Number: XXXXXXXXXXXXX
Project Name: Anywhere Elementary School
Address: Anywhere, USA

Item	Material Description	Catalog Manufacturer	Catalog Number	Unit Each	Total Price	Price
1	Wire, 4-pair, 24 AWG, UTP, CMR	Mfg. A	530141-TP	54000	0	$0.00
2	Surface raceway, small	Mfg. B	MT1ABC5	350	0	$0.00
3	Surface mount box, single gang	Mfg. C	WT12DB	56	0	$0.00
4	Category 5e equipment rack E/W wire management	Mfg. D	55053-703	2	0	$0.00
5	Vertical wire management hardware	Mfg. E	11374-703	2	0	$0.00
6	Patch panel, 48-port, T568A	Mfg. F	49485-C96	8	0	$0.00
7	Patch panel, 24-port, T568A	Mfg. G	49485-C24	2	0	$0.00
8	Faceplate, single gang, dual port	Mfg. H	41080-2AP	9	0	$0.00
9	Faceplate, single gang, quad port	Mfg. I	41080-4AP	47	0	$0.00
10	Modular jack, category 5e, orange, T568A	Mfg. J	41108-RO5	208	0	$0.00
11	Horizontal wire management panel	Mfg. K	49253-BCM	16	0	$0.00
12	Rear cable bars	Mfg. L	49258-TWB	36	0	$0.00
13	Firestop compound	Mfg. M	AA529	10	0	$0.00
14	Electrical metallic tubing, 19 mm (3/4 in)	Mfg. N	34EMT	150	0	$0.00
15	Electrical metallic tubing, 51 mm (2 in)	Mfg. O	2EMT	160	0	$0.00
16	Cable, optical fiber, 6 strand, OFNR	Mfg. P	PDRCB3510/15	300	0	$0.00
17	Fiber distribution panel	Mfg. Q	4R130-OTA	2	0	$0.00
18	Connector panels	Mfg. R	4F100-6TM	2	0	$0.00
19	ST connectors	Mfg. S	95-100-01R	12	0	$0.00
20	10/100BASE-T 24-port switches	Mfg. T	AT3624TR-15	1	0	$0.00
21	10/100BASE-T 24-port switches	Mfg. U	AT3624TRS-15	3	0	$0.00
22	Chassis	Mfg. V	AT-36C3	2	0	$0.00
23	Optical fiber transceivers	Mfg. W	AT-MX26F-05	2	0	$0.00
24	Duplex, STST, 3 m (10 ft) optical fiber jumpers	Mfg. X	STST3M	2	0	$0.00
25	Data patch cords	Mfg. Y	42454-030	104	0	$0.00
26	Data patch cords	Mfg. Z	42454-050	104	0	$0.00
27	Data patch cords	Mfg. AA	42454-100	208	0	$0.00
28						$0.00
29						$0.00
30						$0.00
31	Exempt materials	various	various	1 lot	N/A	$0.00
32	Transportation					$0.00
Total Materials						**$0.00**

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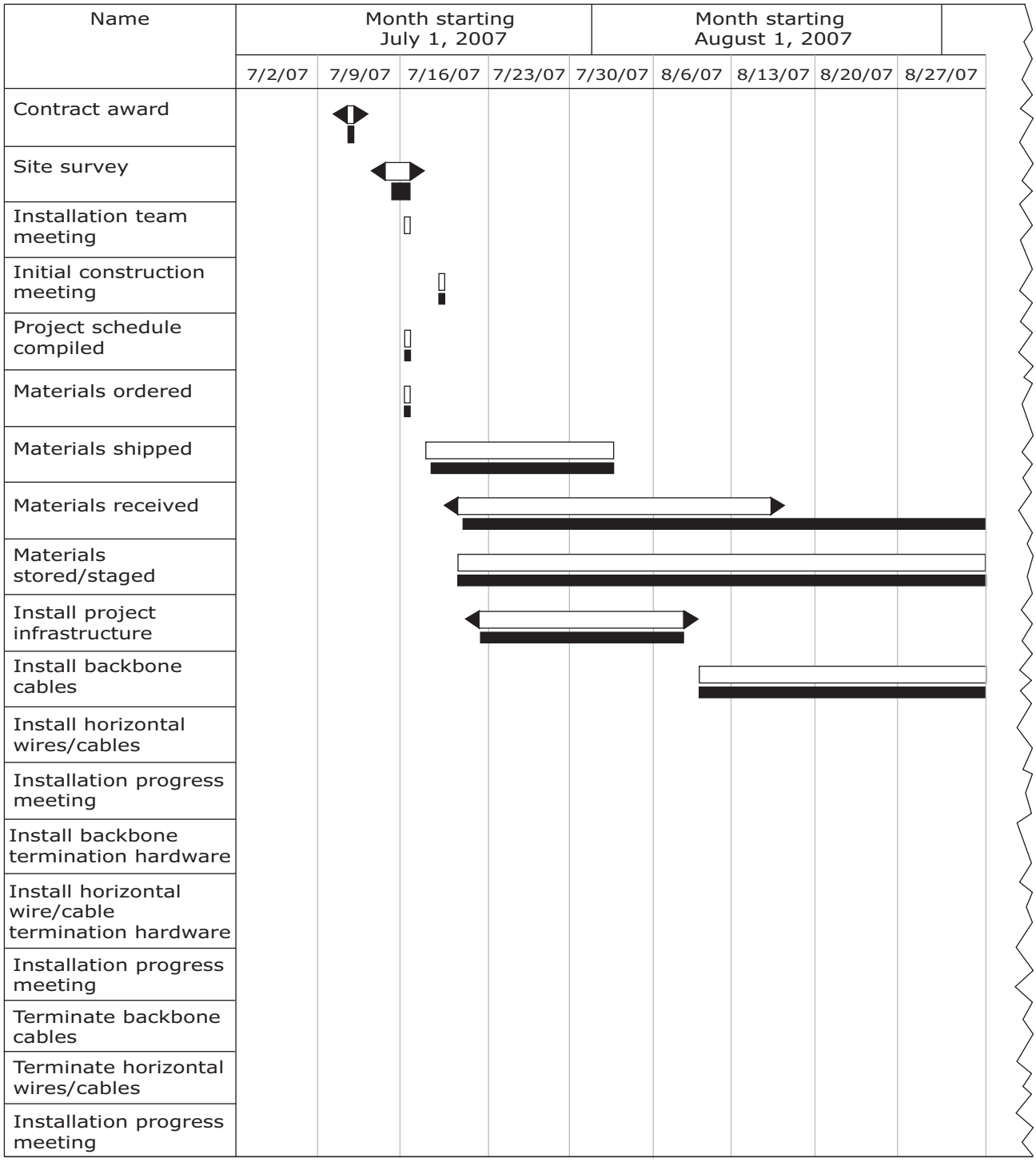
Example C: Labor List

Project Number: XXXXXXXXXXXXX
Project Name: Anywhere Elementary School
Address: Anywhere, USA

Item	Material Description	Units/Quantity	Unit Rate	Total Price
1	Installing horizontal cables (2 per run)	9	0	$0.00
2	Installing horizontal cables (4 per run)	47	0	$0.00
3	Installing faceplates and jacks	208	0	$0.00
4	Installing equipment racks	2	0	$0.00
5	Installing patch panels	6	0	$0.00
6	Terminating cables at patch panels	208	0	$0.00
7	Certifying category 6 wire	208	0	$0.00
8	Installing surface raceway	56	0	$0.00
9	Installing surface mount boxes	56	0	$0.00
10	Installing backbone optical fiber cables	300	0	$0.00
11	Installing optical fiber connecting hardware	4	0	$0.00
12	Terminating optical fiber cables	12	0	$0.00
13	Testing optical fiber cables	6	0	$0.00
14	Install fire-/smoke-rated partition penetrations	59	0	$0.00
15	Mount switches on relay racks	4	0	$0.00
16	Installing backbone conduit from main building to portables	120	0	$0.00
17	Installing horizontal conduit between backbone conduit and portables	48	0	$0.00
18				
19				
20				
Total Labor				**$0.00**

Total cost		**$0.00**
Materials markup	**50%**	**$0.00**
Labor markup	**50%**	**$0.00**
State sales tax on materials	**6%**	**$0.00**
Total price to customer		**$0.00**

Example D: Project Timeline



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Example E: Project Schedule

Name	Start Constraint	Finish Constraint	Actual Start	Actual Finish	Percent Done
Contract awarded	›|‹ 7/9/07	›|‹ 7/9/07	›|‹ 7/11/07	›|‹ 7/11/07	100%
Site survey	›|‹ 7/13/07	›|‹ 7/16/07	›|‹ 7/14/07	›|‹ 7/16/07	100%
Installation team meeting	›|‹ 7/16/07	›|‹ 7/16/07	›|‹ 7/16/07	›|‹ 7/16/07	100%
Initial construction meeting	›|‹ 7/19/07	›|‹ 7/19/07	7/19/07	7/19/07	100%
Project schedule compiled	›|‹ 7/16/07	›|‹ 7/16/07	7/16/07	7/16/07	100%
Materials ordered	›|‹ 7/16/07	›|‹ 7/16/07	7/16/07	7/16/07	100%
Materials shipped	›|‹ 7/17/07	›|‹ 8/3/07	›|‹ 7/17/07	›|‹ 8/3/07	100%
Materials received	›|‹ 7/19/07	›|‹ 8/16/07	›|‹ 7/19/07	›|‹ 9/25/07	100%
Materials stored/staged	›|‹ 7/19/07	›|‹ 10/19/07	7/19/07	10/19/07	100%
Install project infrastructure	›|‹ 7/20/07	›|‹ 8/9/07	›|‹ 7/20/07	›|‹ 8/9/07	100%
Install backbone cables	›|‹ 8/10/07	›|‹ 9/10/07	8/10/07	9/8/07	100%
Install horizontal cables	›|‹ 9/10/07	›|‹ 12/21/07	9/10/07	12/22/07	100%
Installation progress meeting	›|‹ 9/10/07	›|‹ 9/10/07	9/10/07	9/10/07	100%
Install backbone connecting hardware	›|‹ 1/2/08	›|‹ 1/18/08	1/2/08	1/18/08	100%
Install horizontal cable connecting hardware	›|‹ 1/19/08	›|‹ 2/26/08	1/19/08	2/26/08	100%
Installation progress meeting	›|‹ 2/26/08	›|‹ 2/26/08	2/26/08	2/26/08	100%
Terminate backbone cables	›|‹ 1/19/08	›|‹ 2/9/08	1/19/08	2/9/08	100%
Terminate horizontal cables	›|‹ 2/27/08	›|‹ 3/29/08	2/27/08	3/29/08	100%
Installation progress meeting	›|‹ 3/29/08	›|‹ 3/29/08	3/29/08	3/29/08	100%
Label all facilities	›|‹ 3/22/08	›|‹ 4/5/08	3/22/08	4/5/08	100%
Test backbone cables	›|‹ 4/5/08	›|‹ 4/12/08	4/5/08	4/12/08	100%
Test horizontal cables	›|‹ 4/15/08	›|‹ 5/3/08	4/15/08	5/3/08	100%
Compile all test results	›|‹ 5/6/08	›|‹ 5/8/08	5/6/08	5/8/08	100%
Installation progress meeting	›|‹ 5/3/08	›|‹ 5/3/08	5/3/08	5/3/08	100%
Punch list	›|‹ 5/9/08	›|‹ 5/10/08	5/9/08	5/10/08	100%
Correct all items on punch list	›|‹ 5/16/08	›|‹ 5/17/08	›|‹ 5/16/08	›|‹ 5/17/08	100%
Final punch list	›|‹ 5/16/08	›|‹ 5/16/08	5/16/08	5/16/08	100%
Customer punch list	›|‹ 5/17/08	›|‹ 5/17/08	5/17/08	5/17/08	100%
Customer acceptance	›|‹ 5/20/08	›|‹ 5/20/08	5/20/08	5/20/08	100%
Prepare as-built package	›|‹ 5/20/08	›|‹ 5/24/08	5/20/08	5/24/08	100%
Provide all project documents to customer	›|‹ 5/27/08	›|‹ 5/27/08	5/27/08	5/27/08	100%
Return surplus materials to distributor for storage	›|‹ 5/20/08	›|‹ 5/22/08	5/20/08	5/22/08	100%
Complete billing to customer	›|‹ 5/28/08	›|‹ 5/28/08	5/28/08	5/28/08	100%
Review billing with customer	›|‹ 5/29/08	›|‹ 5/29/08	5/29/08	5/29/08	100%
Receive final payment	›|‹ 5/30/08	›|‹ 5/30/08	5/30/08	5/30/08	100%
Close project	›|‹ 5/31/08	›|‹ 5/31/08	5/31/08	5/31/08	100%
Clear punch list	›|‹ 5/10/08	›|‹ 5/13/08	5/10/08	›|‹ 5/13/08	100%
Clear customer punch list	›|‹ 5/17/08		5/17/08	›|‹ 5/20/08	100%

›|‹ = Indicates completion

Example F: Site Survey Checklists

Checklist for Site Survey—New Construction

Issue	Responsibility	Date Scheduled	Date Ready
1. Owner's telecommunications needs defined and documented			
2. Telecommunications design complete			
3. Modifications (if required) submitted and approved			
4. Drawings and specifications distributed			
5. Building construction complete for:			
• Telecommunications spaces			
– Backboards			
– Lighting			
– Electrical			
– Grounding			
– HVAC			
– Fire suppression			
– Alarms and controls			
• Backbone pathways			
• Horizontal pathways			
• Work area spaces			
6. Secure storage identified			
7. Work site conditions defined			
• Safety plan posted			
• Permits approved			
• Safety equipment in place			
• Office and meeting area defined			
• Elevators available			
• Loading dock/access			
8. Cable placement needs defined			
9. Access to all floors for reels			
10. Secure anchor points identified			
11. Start work approval date			
12. Firestopping complete Inspection			
13. Date			
14. Completion date			

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Checklist for Site Survey—Retrofit Installations

Issue	Responsibility	Date Scheduled	Date Ready
1. Owner's telecommunications needs defined and documented			
2. Telecommunications design complete			
3. Modifications (if required) submitted and approved			
4. Drawings and specifications distributed			
5. Plan defined for moving or working around building occupants			
6. Modifications to existing rooms or construction of new spaces complete for:			
• Telecommunications spaces			
– Backboards			
– Lighting			
– Electrical			
– Grounding			
– HVAC			
– Fire suppression			
– Alarms and controls			
• Backbone pathways			
• Horizontal pathways			
• Work area spaces			
7. Secure storage identified			
8. Work site conditions defined			
• Safety plan posted			
• Permits approved			
• Safety equipment in place			
• Office and meeting area defined			
• Elevators available			
• Loading dock/access			
9. Cable placement needs defined			
10. Access to all floors for reels			
11. Secure anchor points identified			
12. Start work approval date			
13. Firestopping complete			
14. Inspection date			
15. Cutover/transition date			
16. Completion date			

Example G: Job Change Order

Company Name
Company Address

Job Change Order
Project Name
Project Location
Project Number

Change Order No. _____

Initiated by: _____ Date: _____

Details of request or nature of change:

Labor $ _____ Materials $ _____ TOTAL $ _____

Verified by (Signature) _____ Date _____

The undersigned hereby accepts the prices quoted on this Job Change Order and agrees to pay _____ the amount stipulated at the TOTAL above upon satisfactory delivery of the goods and services described above. Acceptance also authorizes the materials to be ordered and/or the work to be performed.

_____
Authorized signature

_____
Title

_____
Date

Date work completed: _____ Verified by: _____

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Example H: Scope of Work

Anywhere School District One, Anywhere Elementary School

General

This project provides for the installation of a category 6/class E structured cabling system at Anywhere Elementary School. The primary media is a 4-pair category 6/class E communications plenum cable (CMP) horizontal cable and a 6-strand optical fiber backbone cable between TRs. A TR will be located in the storage area adjacent to the stage. An ER will be located in the office of the media center. Each of these spaces will serve its respective areas as indicated by the zone division line.

Copper Horizontal Cable

The cable to be used on this project is manufactured by Manufacturer C and is 4-pair, 24 American wire gauge (AWG) (0.51 millimeter [mm (0.020 inch [in])]), twisted-pair, CMP-rated. It is available in 305 meters (m [1001 feet (ft)]) boxes.

Patch Panels

Category 6/class E patch panels, wired in accordance with T568A, will be provided in each TR. Patch panels will be mounted on 483 mm (19 in) relay racks in each room along with the switches and wire management panels. The patch panels will be provided in two sizes—48-port and 24-port. In both TRs, four 48-port and two 24-port patch panels will be required.

Equipment Racks

Two 483 mm (19 in) by 2.1 m (7 ft) equipment racks will be installed as part of this project. One of the racks will be installed in the TR, and the second will be installed at the media center. Manufacturer A manufactures both racks, catalog number xxxxx-xxx. The racks are black in color. Both racks will be equipped with vertical and horizontal wire management systems to ensure orderly installation of patch cords between various components on the equipment rack.

These racks provide enough rack space for all of the equipment to be mounted on them at their respective locations. The racks will be bolted to the floor, and a ladder rack will be provided for additional support and routing of cables. The equipment will then be mounted on the racks. Each rack will be grounded to its respective telecommunications main grounding busbar (TMGB) or telecommunications grounding busbar (TGB) with a 6 AWG [4.1 mm (0.16 in)], stranded, green insulated wire.

Faceplates and Modular Jacks

Faceplates will be provided in two port sizes. The dual-jack installation will be a 2-port faceplate while the classrooms will have four-port faceplates equipped with four modular jacks. The faceplates are manufactured by Manufacturer A, catalog number XXXX-XXX. They will be off white in color.

Modular jacks will be provided at each location shown on the attached illustration. The modular jack will be category 6/class E, T568A pinout and will be one of four colors (orange, black, red, or yellow).

Anywhere School District One, Anywhere Elementary School, continued

Raceways and Associated Equipment

Where wire or cable cannot be concealed within the walls at a device location, surface raceway will be installed. This raceway will be 19 mm (0.75 in) electrical metallic tubing (EMT) conduit. The conduit will originate above the suspended ceiling and continue down to a surface-mounted box. The surface-mounted box will house the faceplate and modular jack(s) and provide mechanical protection for the terminations.

Between the main building and the portable classroom buildings, a 51 mm (2 in) EMT conduit will be installed. Junction boxes will connect the 51 mm (2 in) conduit to the 19 mm (0.75 in) conduits that will be installed in each portable classroom building. These conduits will provide mechanical protection and support for installation of the wires to the portable classroom buildings.

Optical Fiber Backbone Cable

A 6-strand optical fiber cable will be installed from the ER to the TR. Manufacturer C manufactures the cable listed by Underwriters Laboratories Inc.® (UL®) as optical fiber nonconductive riser (OFNR) to comply with all applicable building codes. The cable will be installed in the suspended ceiling area between the TR at the stage area and the media center.

Optical Fiber Connecting Hardware

Rack-mounted optical fiber distribution centers manufactured by Manufacturer A will be installed in each TR. They are catalog number XXXX-XXXX and are equipped with catalog number YYYYY-YYY connector panels.

The optical fiber distribution centers will be equipped with sufficient connecting hardware to accommodate all six strands of glass that originate or terminate at their respective locations. Subscriber connector (SC) type optical fiber connectors manufactured by Manufacturer B Corporation, catalog number ZZ-ZZZ-ZZZ, will be used to terminate the strands of glass.

Data Patch Cords

A category 6/class E data patch cord will be provided for equipment interconnection. Data patch cords will be installed in the length required to provide proper wire management between components installed on the relay racks. They are orange in color.

A category 6/class E data line cord will be provided for each category 6/class E horizontal wire installed. These data line cords will be provided to Anywhere Elementary School for installation when the actual computer installation occurs. They are 3 m (10 ft) in length and orange in color.

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Anywhere School District One, Anywhere Elementary School, continued

10/100BASE-Tx Switches

We are providing pricing for Manufacturer D Ethernet 10/100BASE-Tx switches to allow for the networking of each category 6/class E horizontal cable installed. As per your direction, we are sizing the switches to facilitate a maximum of two devices in each classroom and the administrative area. The switches will be equipped to allow connection to the optical fiber backbone as well as to each other. Each switch will be mounted in its respective relay rack. Patching from the switches to the patch panels will be accomplished using the data patch cords and optical fiber patch cords provided.

Optical Fiber Patch Cords

Duplex SC/SC 3 m (10 ft) optical fiber jumpers will be provided to allow connection of all switches.

Firestopping

In each classroom and firewall in the hallways, a horizontal penetration must be made to facilitate installation of the horizontal wires and optical fiber cables. Each penetration will be made, and then the fire rating will be restored using approved materials and methods. Manufacturer E Model No. AAAAA firestop compound will be used to restore penetrations. Sleeves will be installed where required by code.

Installation Methodology

All work will be completed to conform to applicable codes, standards, and regulations, including:

- Manufacturer's specifications.
- Latest edition of the BICSI *Telecommunications Distribution Methods Manual.*
- Latest edition of the BICSI *Network Design Reference Manual.*
- Latest edition of the BICSI *Information Transport Systems Installation Methods Manual.*

NOTE: Where a conflict exists, the local authority having jurisdiction (AHJ) will supersede all other requirements.

Inspection and Testing

Each horizontal cable will be tested for compliance with applicable cabling standards using a Manufacturer E tester. The tests will be conducted on the basic link configuration. A hard copy and an electronic media of choice as selected by the owner (e.g., compact disc [CD], flash card) containing the test results will be provided to the District.

Each strand of the optical fiber cable will be tested using a Manufacturer BOLTS. The results will be recorded and provided to the District in hard copy and an electronic media of choice selected by the owner (e.g., CD, flash card) upon completion of the project.

Anywhere School District One, Anywhere Elementary School, continued

Record Documentation

Upon completion of the project, Datawireinstaller, Inc. will provide record documentation (formerly named as-built) to the District that will contain the following items:

- Updated floor plans
- Wire/cable routing schematic
- Facility assignment records
- Horizontal cable test results
- Optical fiber cable test results
- Photographs or videotape
- Manufacturer's documentation

Warranty

The project will be warranted for a period of 15 years from completion of installation.

Schedule

We anticipate this project will take approximately two weeks to complete. This is contingent upon the absence of unforeseen delays during installation. We plan to perform the work with minimum impact on the staff by working during the hours most advantageous to both the school and Datawireinstaller, Inc. This is contingent upon the school providing access to the building at these times. If weekend work is required, we are prepared to perform the necessary work during these times. We would, however, prefer to work during normal working hours.

Most of the materials required for the project are available from our distributors as stock, and the other items have short lead times.

Delays to Project

Delays caused by Anywhere School District One, their employees, students, agents, assignees, contractors, subcontractors, or any other person(s) not directly employed by Datawireinstaller, Inc. will result in proportional delays in the completion of the project. All costs incurred by Datawireinstaller, Inc. as a result of the said delay will be passed along to Anywhere School District One on a cost-plus basis.

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Anywhere School District One, Anywhere Elementary School, continued

Damage to Installed Physical Plant

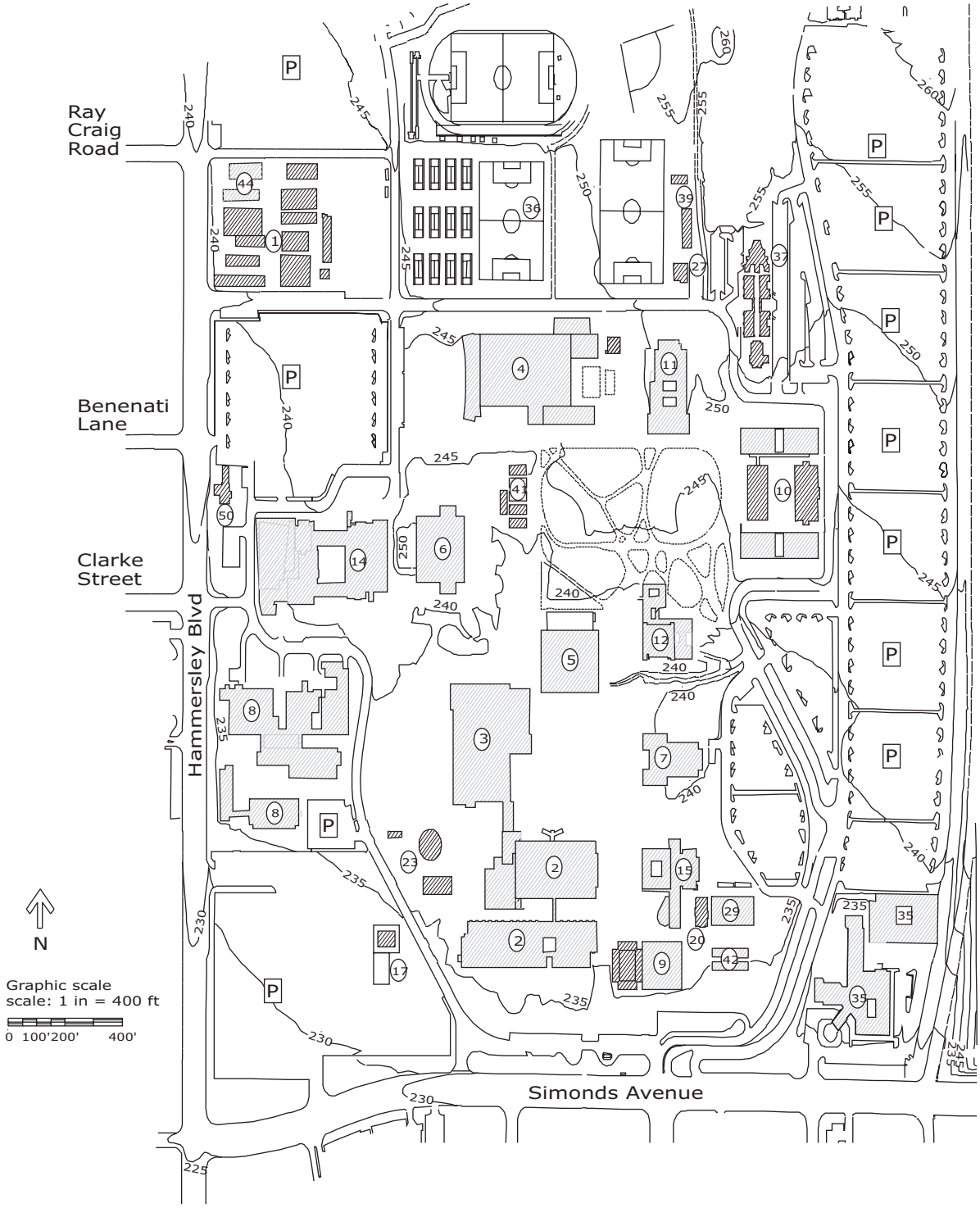
Damage caused to physical plant installed by Datawireinstaller, Inc., by Anywhere School District One, their employees, students, agents, assignees, contractors, subcontractors, or any other person(s) not directly employed by Datawireinstaller, Inc. will be repaired or replaced at the District's option. All cost associated with the said repairs or replacement work will be passed along to Anywhere School District One on a cost-plus basis. Any delays caused by the said work will result in a proportional delay in the completion of the project.

NOTE: See Figure 10.1 for a sample site plan, Figure 10.2 for a sample floor plan, and Figure 10.3 for a sample room detail.

The information contained within this proposal is considered business proprietary and is not to be duplicated in any manner, by hand, electrically, mechanically, or any other means, without the written permission of Datawireinstaller, Inc. Information Systems Sales and Services. It is not to be disseminated outside of Anywhere School District One without the written permission of Datawireinstaller, Inc. Information Systems Sales and Services.

Anywhere School District One, Anywhere Elementary School, continued

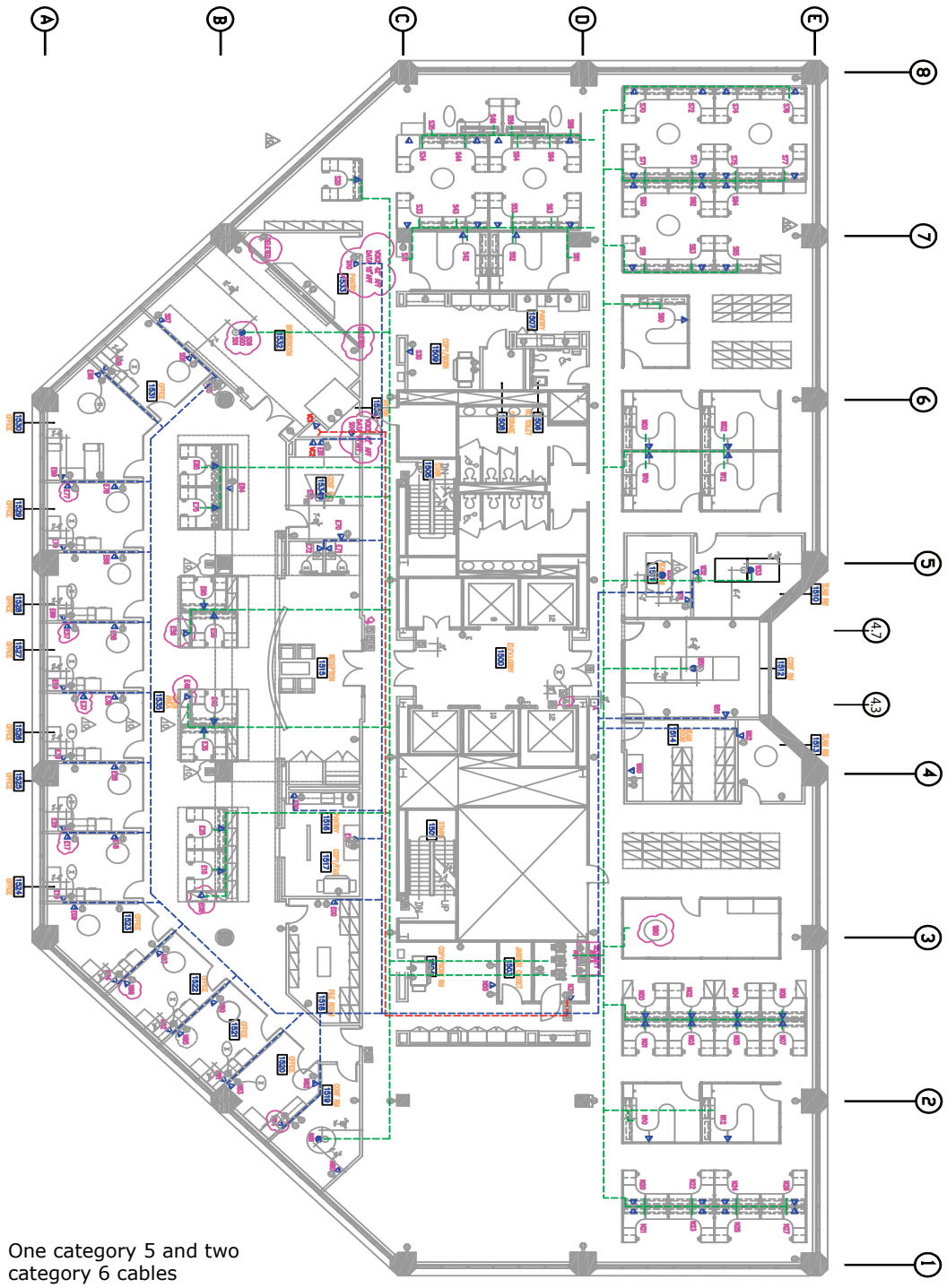
Figure 10.1
Sample site plan



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Anywhere School District One, Anywhere Elementary School, continued

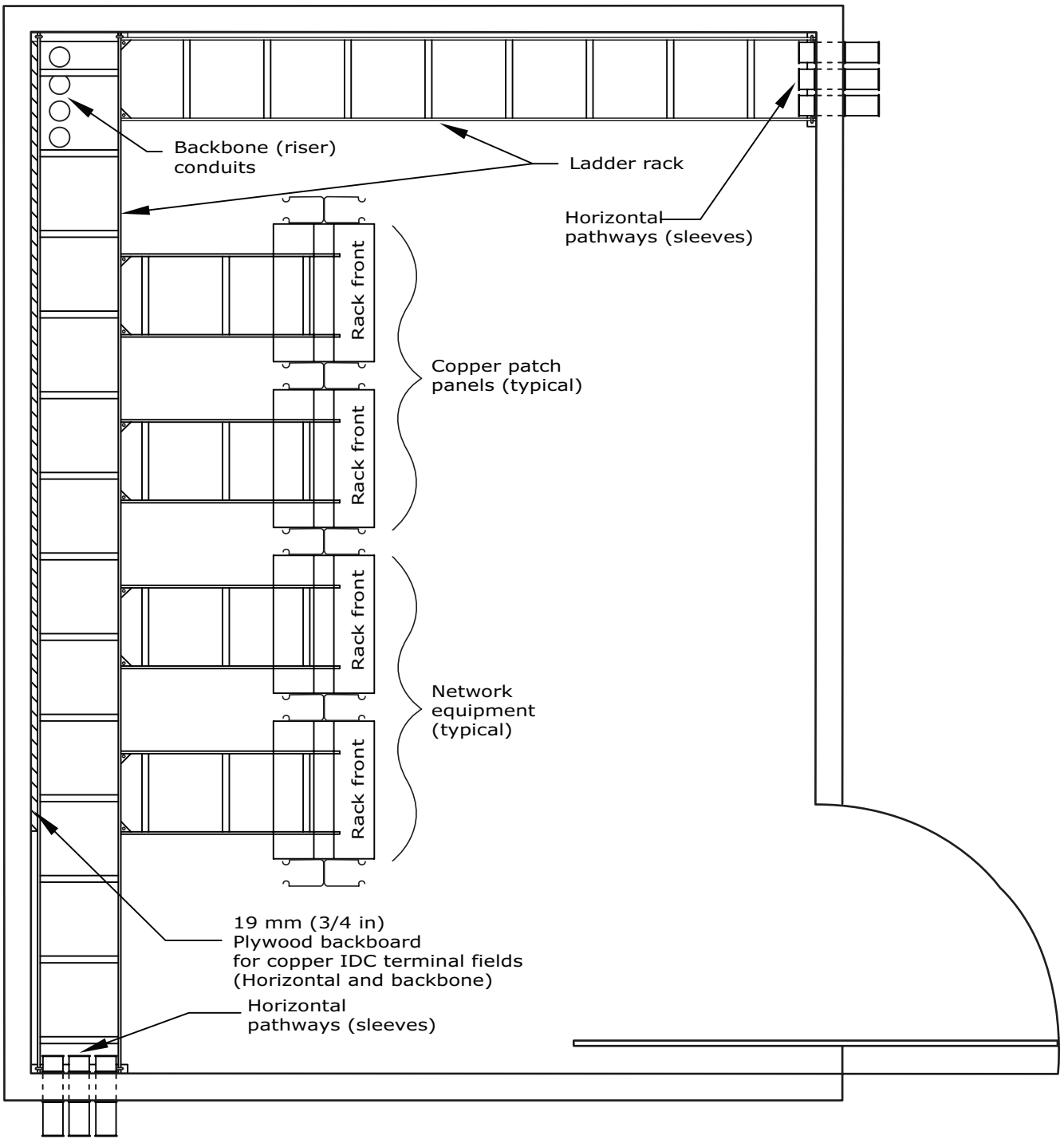
Figure 10.2
Sample floor plan



= One category 5 and two category 6 cables
= Three category 5 cables for integrated services digital network
– – – = Cable pathways through aerial
– – – = Cable pathways for video conferencing
– – – = Cable pathways through trench

Anywhere School District One, Anywhere Elementary School, continued

Figure 10.3
Sample room detail



IDC = Insulation displacement contact

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Appendix A: Specifications

Specifications

Specifications are one of the elements produced during the design phase of a construction project.

The four main types of specifications that can be used to define the requirements are:

- Performance—The focus is on results. Contractors can choose the materials and installation methods to provide the desired results.
- Proprietary—Specifications call out brand names and models.
- Descriptive—The focus is on exact properties and installation methods.
- Reference—Requirements are based on an established standard.

Construction documents in North America use a standardized format jointly produced by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).

These standards are currently being harmonized worldwide. The SectionFormat™/ Page Format™ document standardizes how the text on each page in a specification is presented and organizes the information in each section and then organizes each section into three parts:

- Part 1—General
- Part 2—Products
- Part 3—Execution

The MasterFormat® is a list of numbers and titles compiled to organize the activities and requirements of a construction project. Before the 2004 edition, the MasterFormat included 16 divisions as well as a summary of the front-end requirements. Telecommunications SoW was included within the electrical scope of Division 16, and work areas were found on the "E" drawings. This format is still prevalent within the North American design and construction industry.

The MasterFormat structure was developed by CSI because construction projects can use many different delivery methods, products, and installation methods. Successful completion of these large and complex projects requires effective communication among the people involved. Information retrieval is nearly impossible without a standard filing system familiar to each user. The MasterFormat serves as this standard filing system.

MasterFormat numbers and titles are suitable for use in project manuals, organizing cost data, placing reference keynotes on drawings, filing project information and other technical data, identifying drawing objects, and presenting construction market data.

When combined with the work breakdown structure (WBS) numbering for task assignments and tracked in a visual information system (VIS) or geographic information system (GIS), the end user will be able to track what was installed, who installed it, and when the installation was completed. The system also will link to test records, pictures, drawings, and other project information in the customer computer-aided cable management (CAFAM) system.

Specifications, continued

MasterFormat® 2004—Numbering Revision

In 2004, the CSI published a new format for the organization of project information within the construction industry (see Table 10.1). Adaptation of this format continues today. One of the most significant changes in the MasterFormat 2004 revision is the adoption of a six-digit numbering system in place of a five-digit system for organizing various subcategories.

Table 10.1
MasterFormat® 2004—numbering revision

Division	Title
PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP	
Division 00	Procurement and Contracting Requirements
SPECIFICATIONS GROUP	
General Requirements Subgroup:	
Division 01	General Requirements
Facility Construction Subgroup:	
Division 02	Existing Conditions
Division 03	Concrete
Division 04	Masonry
Division 05	Metals
Division 06	Wood, Plastics, and Composites
Division 07	Thermal and Moisture Protection
Division 08	Openings
Division 09	Finishes
Division 10	Specialties
Division 11	Equipment
Division 12	Furnishings
Division 13	Special Construction
Division 14	Conveying Equipment
Division 15	Reserved for future expansion
Division 16	Reserved for future expansion
Division 17	Reserved for future expansion
Division 18	Reserved for future expansion
Division 19	Reserved for future expansion

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Specifications, continued

Table 10.1, continued
MasterFormat® 2004—numbering revision

Division	Title
Facility Services Subgroup:	
Division 20	Reserved for future expansion
Division 21	Fire Suppression
Division 22	Plumbing
Division 23	Heating Ventilating and Air Conditioning
Division 24	Reserved for future expansion
Division 25	Integrated Automation
Division 26	Electrical
Division 27	Communications
Division 28	Electronic Safety and Security
Division 29	Reserved for future expansion
Site and Infrastructure Subgroup:	
Division 30	Reserved for future expansion
Division 31	Earthwork
Division 32	Exterior Improvements
Division 33	Utilities
Division 34	Transportation
Division 35	Waterway and Marine
Division 36	Reserved for future expansion
Division 37	Reserved for future expansion
Division 38	Reserved for future expansion
Division 39	Reserved for future expansion
Process Equipment Subgroup:	
Division 40	Process Integration
Division 41	Material Processing and Handling Equipment
Division 42	Process Heating, Cooling, and Drying Equipment
Division 43	Process Gas and Liquid Handling, Purification and Storage Equipment
Division 44	Pollution Control Equipment
Division 45	Industry-Specific Manufacturing Equipment
Division 46	Reserved for future expansion
Division 47	Reserved for future expansion
Division 48	Electrical Power Generation
Division 49	Reserved for future expansion

Specifications, continued

An example of the new six-digit format is:

27 13 00 Communications Backbone Cabling

As was the case with the old system, the first two digits, in this case "27," still represent the division number, which is also known as "level one." The next pair of numbers, in this case "13" and the third pair "00," represents level three. Generally, level four numbers are not defined, but when they are, an additional pair of digits is attached to the end preceded by a "dot."

An example is:

27 13 43.33 DSL Services Cabling

Additional recommendations for the use of level four and level five is included in the MasterFormat 2004 application guide and throughout the full publication, preserving the level of user modifiable numbers for flexibility. More importantly, because each level of classification is represented by a pair of digits, there is room to address over 10 times as many subjects at each level, providing flexibility and room for expansion that the five-digit numbers could not provide and addressing future needs for expansion for new subject matter.

MasterFormat® 2004 Division Number Changes Affecting Information Transport

- Division 16 has been reserved for future expansion, and material has been relocated to Divisions 26—Electrical and 27—Communications in the facility services subgroup.
- Division 21—Fire Suppression: Fire suppression subjects relocated from Division 13.
- Division 25—Integrated Automation: Expanded integrated automation subjects relocated from Division 13.
- Division 26—Electrical: Electrical and lighting subjects relocated from Division 16.
- Division 27—Communications: Expanded communications subjects relocated from Division 16.
- Division 28—Electronic Safety and Security: Expanded electronic safety and security subjects relocated from Division 13.
- Division 31—Earthwork: Site construction subjects, chiefly below grade, from Division 2.
- Division 33—Utilities: Expanded utility subjects relocated from Division 2.

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Appendix B: Telecommunications Drawings

CLA Series System Drawings

The T series drawings include:

- T0—Campus or site plans: Exterior pathways and interbuilding systems.
- T1—Layout of complete building per floor: Serving zone boundaries, backbone distribution systems, and horizontal pathways.
- T2—Serving zones: Drop locations and cable IDs.
- T3—Communication equipment rooms: Plan views, tech and architectural, electrical, mechanical, and plumbing (AMEP)/elevations, racks and walls, and elevations.
- T4—Typical detail drawings: Faceplate labeling, firestopping, ADA, safety, and DOT.
- T5—Schedules (cabling and equipment spreadsheets) for cutovers.

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BICSI®. *Outside Plant Design Reference Manual,* 4th ed. Tampa, FL: BICSI, 2007.

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Chapter 11
Retrofits and Upgrades

Chapter 11 outlines the best practices for planning and executing retrofit installations and upgrades to existing systems. Included in this chapter are the steps for implementing a system cutover and evaluating the existing infrastructure.

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Retrofit Installations

Introduction

An information technology systems (ITS) retrofit involves the replacement or augmentation of an existing installation. Performing a retrofit or extensive system upgrade will always be far more complicated and labor intensive than a new ITS installation in unoccupied spaces.

Planning the Cutover

Planning for a retrofit installation involves a multitude of tasks. All of these tasks must be completed before cabling is removed or installed. When all of these planning tasks are completed, a comprehensive plan will have been developed, and the ITS cabling installation team should be fully prepared to proceed with the project.

Determined by the scope and design of the cabling installation, each retrofit will require that the ITS cabling installer addresses a unique set of circumstances. Some retrofits may involve a simple expansion of a telephone system or a data network. Other retrofits may involve voice and data systems, security and fire alarm systems, and upgrades to the backbone or horizontal cabling infrastructure.

Good communication with the customer is essential when determining what part, if any, of the existing cabling system infrastructure will be reused. Obtain as much information as possible from the customer, and verify that the information is accurate. If the existing documentation is questionable or does not exist, it may be necessary to trace and document the current system.

If the customer wants to utilize portions of the present cables and equipment, the existing components will have to conform to the new requirements. In addition, the ITS installer must test the existing cabling to verify the level of service it can support. In many cases, system upgrades require a new cabling configuration that prevents the use of the current infrastructure.

Existing System Considerations

There are two main considerations concerning the existing cabling:

- Grandfathered system that is not code compliant
- Abandoned cable

Grandfathered systems consist of cables that were installed in an air-handling space (e.g., ceiling space, access floor space) prior to the mandated use of cables that meet the flame-spread and smoke-index requirements of applicable codes, standards, and regulations. These systems may be said to be acceptable because they were installed prior to the current code. Check with the local inspectors or authority having jurisdiction (AHJ).

When replacing these types of systems, the ITS installer may be required to replace all of the cables. Many localities have the rule of percentage. This means that if a substantial percentage of the cable is being replaced, it will be necessary to bring the entire installation up to the current code requirements. Check with the local inspectors or AHJ to determine if the rule of percentage exists for the area.

The criteria for abandoned cable removal are now specifically addressed in several codes, standards, and regulations. These codes, standards, and regulations may be very specific about what cables shall be removed and how to identify cables for future use. This requirement is discussed in greater detail later in this chapter.

In ideal situations, the retrofit is placed in unoccupied spaces. This allows for the removal of all equipment and cables that will not be part of the new installation. With these items removed, valuable pathway and telecommunications room (TR) space is freed up for the installation of new system components.

In most cases, the new system or components to be integrated into the existing working system must be installed with minimal disruption to the customer. This may involve installing the new system parallel to the existing system while working during the hours when the office is closed. After the new cables and equipment have been installed and tested, the transfer to the new system can take place.

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Cutover Plans

When transferring to the new system, a detailed plan must be developed to cut over the new components into the final working configuration. This final cutover from the old to the new system is one of the most detailed and critical steps in a retrofit.

To help ensure a quality transition and to expedite the cutover, cutsheets are used. Cutsheets are a type of documentation that contains the existing cross-connect terminations and shows the changes that must be performed to execute the transition to the new system (see Table 11.1). A poorly planned cutover could cause unnecessary interruptions to the customer's communications.

Table 11.1
Detailed cutover plan

Cutsheet **Project: BICSI, Tampa**

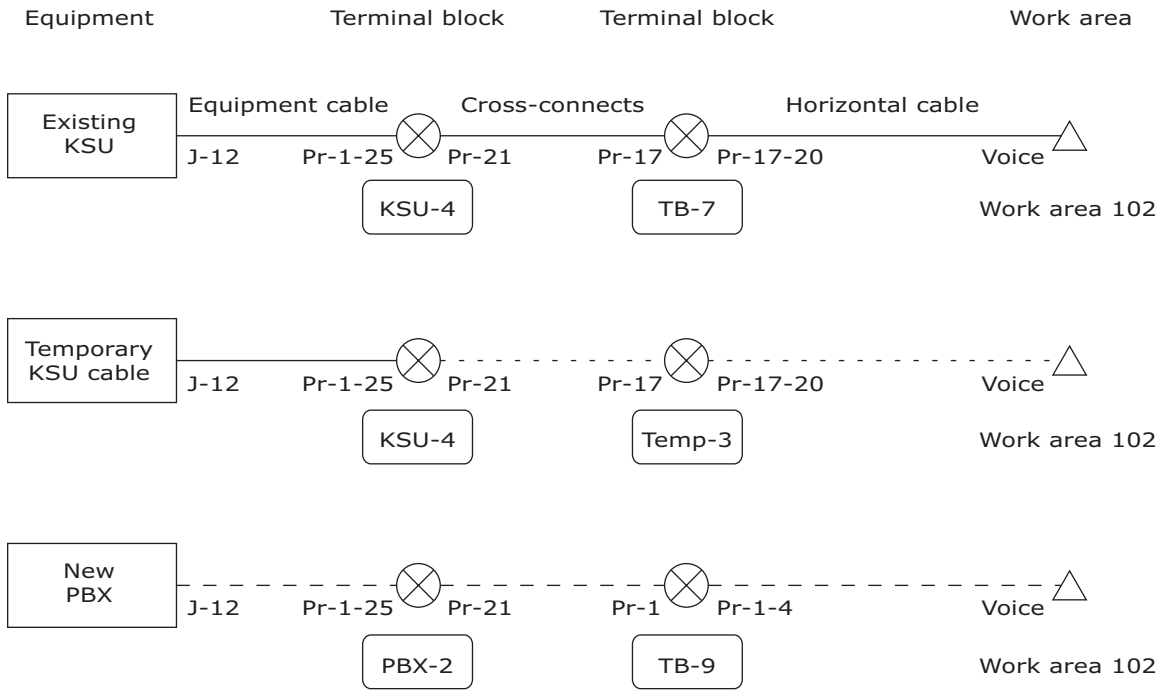
Existing		Temporary Cabling		New System		Description
KSU-4-12	TB-7-17	KSU-4-12	Temp-3-17	PBX-2-21	TB-9-1	Work area 102 telephone
KSU-4-13	TB-7-21	KSU-4-13	Temp-3-21	PBX-2-22	TB-9-5	Work area 103 telephone
KSU-4-14	TB-8-1	KSU-4-14	Temp-5-5	PBX-3-1	TB-11-9	Work area telephone

KSU = Key service unit
PBX = Private branch exchange (new telephone system)
TB = Terminal block
Temp = Temporary cabling

Cutover Plans, continued

Another way of documenting each circuit is with a circuit layout record (CLR). CLRs provide a quick graphical representation of how the circuit is laid out. It shows all equipment, cables, cross-connects, and their termination locations. CLRs are extremely beneficial when trouble-shooting (see Figure 11.1).

Figure 11.1
Circuit layout records



——— = Existing cable and cross-connects
– – – – = New cable and cross-connects
- - - - - = Temporary cable and cross-connects
KSU = Key service unit
PBX = Private branch exchange
Pr = Pair
TB = Terminal block
Temp = Temporary cabling

The first CLR shows:

- The existing key service unit (KSU) has a 25-pair cable plugged into its J-12 jack, and the other end is terminated on block KSU 4, pairs 1 through 25.
- The voice cable for work area 102 terminates on terminal block (TB) 7, pairs 17 through 20.
- A cross-connect is terminated between block KSU 4, pair 12, and TB 7, pair 17.

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Cutover Plans, continued

The second CLR shows:

- The existing KSU has a 25-pair cable plugged into its J-12 jack, and the other end is terminated on block KSU 4, pairs 1 through 25.
- A temporary voice cable for work area 102 terminates on TB temporary 3, pair 17.
- A cross-connect is terminated between block KSU 4, pair 12, and TB 3, pair 17.

The third CLR shows:

- The new private branch exchange (PBX) has a 25-pair cable plugged into its J-05 jack, and the other end is terminated on block PBX 2, pairs 1 through 25.
- The new voice cable for work area 102 terminates on TB 9, pairs 1 through 4.
- A cross-connect is terminated between block PBX 2, pair 21, and TB 9, pair 1.

Types of Cutovers

Depending upon the size and scope of the retrofit, either a flash cutover or a phased cutover may be necessary (see Table 11.2).

Table 11.2
Types of cutovers

Cutover Name	Cutover Procedure	Continuous Use Effects of the Cutover
Flash cutover	One continuous process until completed.	May be a hot cut, with the customer momentarily without communications. May be a rolling cut; cross-connects relocated one pair after another until completed.
Phased cutover	Portions of the old system are transferred to the new system in groups.	Both the new and old systems work in parallel until the transfer is completed.

Types of Cutovers, continued

Abandoned cable is a fire hazard. If a fire were to break out, the old cable could become fuel. The cable also provides a path to spread the fire throughout the building. Abandoned cable takes up valuable pathway space, places an unnecessary strain on the supporting hardware, and may even cause the support system to fail. The cable that the customer does not plan to use in the future should be removed and disposed of properly.

Carefully remove cables to avoid damaging or disturbing the other cables. Ensure that written permission has been obtained from the owner to remove the cable.

Regardless of the particular situations, every retrofit requires:

- Working with the customer to determine new system specifications.
- Obtaining, reviewing, and verifying existing documentation.
- Determining safety concerns and requirements for the project.
- Performing a site survey.
- Developing an installation or job plan.
- Installing in compliance with current codes, standards, and regulations.
- Developing cutover sheets.
- Precutover field testing.
- Performing cutover.
- Postcutover field testing.
- Preparing final documentation.
- Removing abandoned cable and equipment.
- Firestopping.
- Postcutover support.

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Planning for a Retrofit Installation

Overview

When retrofit installations are requested, customers have likely developed an idea of what they want. In most cases, the cabling installation company will have copies of the bid proposal, the request for proposal (RFP), the formal contract, the purchase order (PO), or some other official document that conveys the customer's intentions. These documents typically include the drawings and specifications that identify the materials, the installation schedule, and the standards that will govern their installation.

The development of a set of installation drawings, a list of materials, an installation scope of work (SoW), and an overall project schedule will further enhance these documents. The larger the project, the more complex and important these documents are for a successful installation.

Gathering Information

The ITS installer should obtain the documentation for the existing installation from the customer, including the cross-connect records and any information on the proposed system. Existing documentation may only contain information from the initial installation and may not reflect the moves, adds, or changes (MACs). The ITS installer should plan the time to verify the existing infrastructure.

A BICSI Registered Communications Distribution Designer (RCDD®) may have been employed by the customer, the architect, or the installation company to develop the required telecommunications drawings and specifications for the retrofit installation. If not, a member of the ITS installation team may have to develop them. Many organizations request that the design be reviewed and approved by an RCDD to ensure both code compliance and adherence to current standards.

Separate drawings should be prepared for each type of ITS to be installed. Specific drawings should be prepared for copper cables, optical fiber cables, coaxial cables, and other low-voltage system cables. (If the project is small enough, all of this information may be contained on a single drawing.) It is recommended that a single system drawing be prepared regardless of the magnitude of the project.

Larger retrofit projects may require a series of drawings and complex project schedules. The first set of drawings could include the existing TRs and infrastructure. The second set could include temporary facilities needed to free up space for the final installation, and a third set could show the final configuration.

Gathering Information, continued

Elevation drawings of the TRs and the arrangement of the various types of equipment should be part of these sets. Details of each wall and rack in each TR as well as a plan view of the floor-mounted hardware should be included. The drawings should indicate the cable-supporting structure.

Developing a Job Plan

Members of the selected ITS installation team must conduct a site survey to identify all aspects of the installation and how the team will address each portion. The results of the site survey will be used to develop the project schedule and the installation job plan.

Developing an ITS installation job plan must involve all aspects of the retrofit. The project should have a detailed Gantt chart to convey the installation plan to the end user. This will enable the customer to notify employees in the event personal effects, contents of desks, or other items need to be relocated.

An understanding of installation standards, national and local codes, BICSI best practices and manuals, the manufacturer's specifications, and basic telephony and data telecommunications principles will contribute to the success of the ITS installation plan. The complexity of the plan is directly proportional to the size of the installation and the number of systems being integrated.

In large retrofits that require extensive work area recabling, it is advantageous to have temporary office spaces where personnel can relocate until their section of the retrofit is completed. The personnel are then moved back into their recabled office spaces, and another group is relocated into the temporary office spaces. This practice is referred to as swing-space phasing because groups of personnel are swung from one space to another as they are phased into service. This form of swing-space phasing requires each group of users to relocate twice before they are in their final offices.

Another approach to swing-space phasing is to work with the customer to develop a master plan of swapping office areas (e.g., accounting department moves into temporary trailers while the old accounting spaces are rewired). The purchasing department then relocates into the old accounting spaces, and the vacant purchasing department spaces are rewired. Telemarketing then relocates into the rewired purchasing spaces and so on until all office spaces are rewired, and the accounting department can move back into the last rewired space. This form of swing-space phasing requires the accounting department to move twice while all other departments only move once. This saves the customer time and expenses.

Additional factors to consider are whether the customer wants to utilize the present cable and equipment and, if so, whether the existing components meet the new requirements. In many cases, the upgrade of systems requires a new cabling configuration that does not allow the use of the current infrastructure. An example of this would be upgrading an existing 10BASE2 coaxial system to a twisted-pair category 6 cabling system. This change in physical topology necessitates removal of the coaxial, daisy-chained network and the installation of a star-wired balanced twisted-pair cabling network. However, the customer may require that the coaxial system remain operational until the new system is completely installed, tested, and ready to be cutover.

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Developing a Job Plan, continued

In the case of voice services, the client may be upgrading from a KSU or an electronic key system (EKS) to a PBX. In this event, each KSU telephone set would be using 25-pair cable, and the EKS could be using two-pair jacketed quad cable. Quad cable is also known as plain old telephone service (POTS) cable originally used for voice service and consisting of four conductors colored green, red, black, and yellow. Jacketed quad cable is usually not twisted.

If the existing cables do not meet the requirements of category/class cabling, they must be replaced to meet the standards. This could require the present cabling to remain in place until the cutover to the new voice system is completed. It may require additional space as both telephone systems will be operational until the new system is completed.

Scope of Work (SoW)

An SoW for a project provides guidelines for the ITS installation team and lists all elements of the installation. SoWs can be generated by the customer, the designer, or the installation company when bidding or responding to a customer's RFP.

The SoW should indicate:

- The people and firms involved in the project and their responsibilities.
- The work to be performed.
- The time frame for completing the work.
- The permits needed and the persons responsible for obtaining them.
- The materials to be installed.
- The installation methodology to be used.
- Known limitations, restrictions, or potential problems with the job.
- The test methods to be used.
- How the completed installation will be tested.
- The identification, labeling, and documentation systems to be used on the project.
- When and how the installation will be turned over to the customer.
- The identification of cables and equipment to be removed and the disposal of these items.
- Clarifications or understandings that elaborate on the various items involved in the installation.

Contract

The contract is a written document that states the entire understanding between the customer and the contractor. Some customers do not use a contract; they simply generate a PO that refers to the other documents associated with the project. If a contract is available, ensure that copies of the contract and any supplemental documents it lists are provided to the ITS installation team.

Contracts may list penalties associated with not completing work or delays in completion. The ITS installer should pay particular attention to these liquidated damages, especially when performance bonds are required as part of the contract.

Site Evaluation

Prior to installing a new cabling system in a retrofit installation, it is necessary to determine if the existing cabling system or any portion of it can be reused. The ITS installer should obtain as much information as possible from the customer and verify that the information obtained is accurate. If the existing documentation is questionable or does not exist, the ITS installer may have to document the current system. In addition, the existing cabling must be tested to verify the level of service it can support.

After the existing infrastructure has been verified and tested, the ITS installer can determine which pathways, cables, and equipment can be reused. The challenge is then to incorporate the new components into the ones that are to be reused.

If the TR does not have adequate space for the old and new components, the following options are available:

- Build additional TRs.
- Expand the existing TR.
- Float the existing equipment and cables. In a small TR, the existing equipment and cables may need to be extended into the hallway to make room for the new system. The new plywood and system components can be installed, tested, and prepared for cutover. The old system components can be removed after the cutover is completed.
- Install temporary cabling. Temporary cabling provides service until the cutover is completed and then is removed.

Large office retrofits may require extensive work area recabling and TR renovations. Temporary cabling can be either backbone or horizontal cables. It may be easier to temporarily relocate a small telephone system from the TR into an office and run all horizontal cables around the perimeter of the floor until the new system is installed. This allows the equipment and termination hardware to be installed in the TR while the new horizontal cables are installed in the work area outlets.

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Site Evaluation, continued

Retrofit projects require identification of all existing pathways and spaces used for ITS, including their size, capacities, usability, congestion, and code compliance.

When surveying a retrofit project, some important considerations are:

- What is the size of the existing TRs?
- How much space is available in them?
- Will new hardware fit in the available space?
- Will additional equipment racks be required, and will they fit in the available space?
- Is it necessary to expand any of the existing TRs?
- Are new TRs required?
- Are any existing pathways vacant?
- Does any pathway have usable space?
- Will pathway space be available after the abandoned cable is removed?
- Will the existing pathways support additional weight?
- Are new pathways required?
- Will any temporary cabling be required?
- Can existing facilities be utilized to assist installation of the new cable?
- Is the telecommunications grounding infrastructure installed? Does it comply with local codes, standards, and regulations?
- What, if any, are the requirements for maintaining dual service?
- Can any existing cable, hardware, or equipment be removed?
- Are the floors composed of prestressed or poststressed concrete?
- Who is responsible for firestopping any existing noncompliant penetrations?
- Do any safety hazards exist?

The answers to these and other questions will determine how the ITS installer plans to implement the project.

Most of the answers to these questions should be available from the materials contained in the customer's and designer's documents. Do not leave anything to chance. Review all of the project's requirements before concluding additional pathways and spaces are not required. If additional pathways and spaces are required and have not been included in the original plans and specifications, job change orders may be required. At the very least, these changes may alter the ITS installer's approach to the installation methodology. All concerns should be documented and discussed with the general contractor and the owner's representative.

Verifying Existing Infrastructure

The first step in verifying the existing infrastructure is to review the existing documentation with the customer. Copies of the blueprints should be made, and one copy used for note taking.

Items that should be noted on the blueprints include the locations of all:

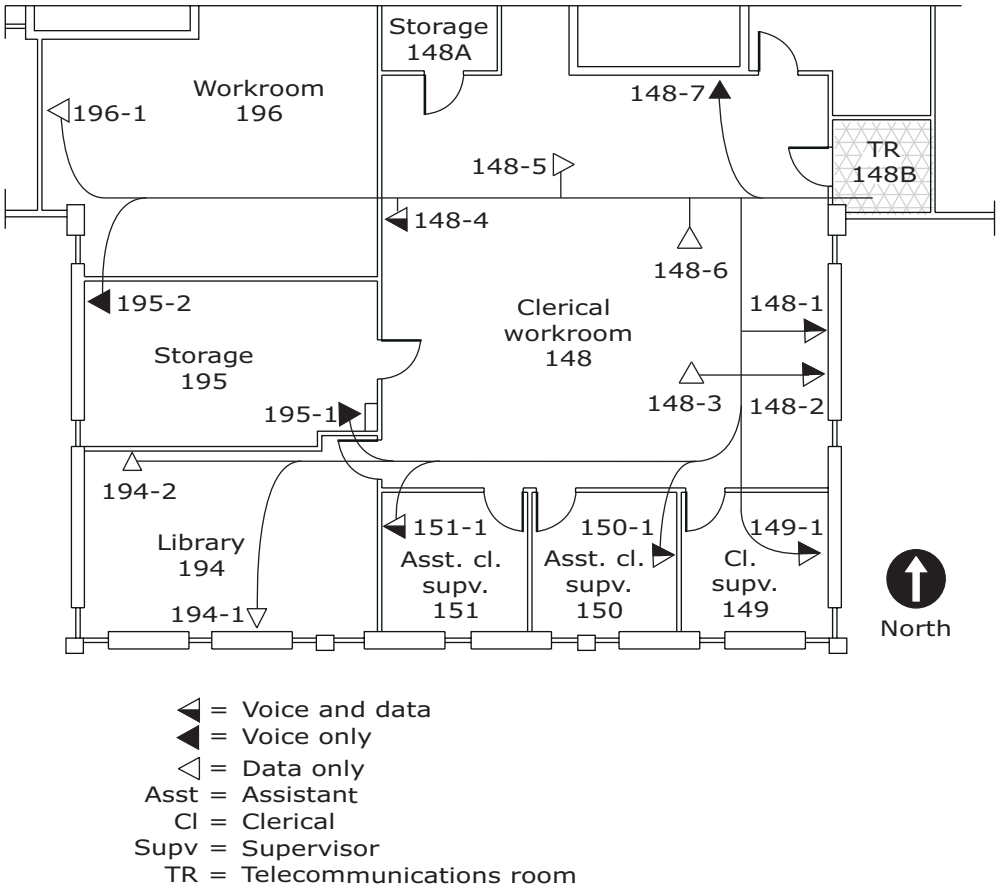
- Active circuits.
- Low-voltage devices that will be involved in the retrofit such as:
  - Computer terminals and peripherals.
  - Printers and copiers.
  - Telephones and facsimile machines and their telephone numbers.
  - Credit card terminals.
  - Modems and their telephone numbers.
  - Cash registers.
  - Bar code readers.
  - Security touch pads and intrusion detectors.
  - Fire alarms.
  - Public telephones.

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Verifying Existing Infrastructure, continued

Even though the ITS installer may not deal with all of these devices, it is necessary to identify their cables to avoid disturbing them during the installation phase and the removal of abandoned cables (see Figure 11.2).

Figure 11.2
Typical as-builts



Because an interoffice telephone directory is usually kept more current than the cable records, obtain and use the interoffice telephone directory as a reference to cross-check discrepancies in the cabling documentation. The directory usually lists all employee telephone numbers and may include the incoming central office numbers.

The next step is to perform a walk-through of the office spaces affected by the project to locate active devices. An active device is any equipment that is operational and plugged into a face plate outlet. When a computer is plugged into an outlet, it is a good indicator that it is active, but this is not guaranteed. When users move to a new desk, the patch cord in the TR is moved, but the old computer and telephone may remain plugged into a face plate even though they may not be operational.

Verifying Existing Infrastructure, continued

If a computer is not turned on, have someone test to see if the computer can log onto the network while testing for a dial tone on the telephone. The ITS installer should verify that each piece of equipment has been identified by the customer and is noted on the blueprints. Verify its workstation identifier and telephone number if applicable.

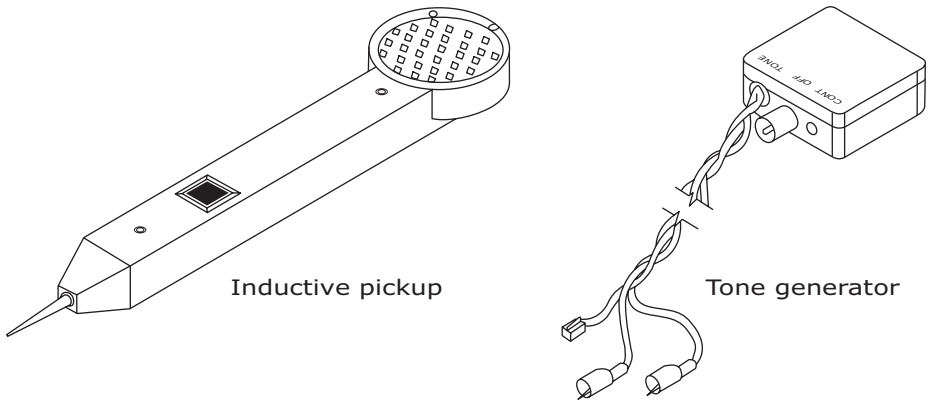
The existing cross-connect records can be used to verify that each documented cross-connect is actually terminated where it should be. The fastest way to do this is with three ITS installers. One person reads aloud to the other two ITS installers. One ITS installer finds the first end of the cross-connect wires and gently tugs at them. If there is any slack in the cross-connect wires, the wires will move. The third ITS installer can trace the wires to their end point of termination. The person reading aloud should note any corrections to the documentation.

Remove all cross-connects that are not in service. Performing a cutover when the cross-connects are filled with abandoned wires and patch cords can be extremely difficult. If a cross-connect is not being used, document its termination points and note that it was removed. If a later discovery indicates that it was in use, use the notes to reinstall it.

Locating Copper Cables

Another way to verify cable and cross-connect termination points is to tone them out. The tone generator induces a steady or warbled tone on a pair of copper conductors within the cable being traced. An inductive amplifier (probe or wand) is used to detect and amplify the tone at the far end of the cable (see Figure 11.3).

Figure 11.3
Tone generator and inductive amplifier



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Verifying Existing Infrastructure, continued

When toning out cable and cross-connect termination points, disconnect the equipment at the workstation and inject the tone on one or more pairs in the cable. If a tone were placed on the cables as they leave the TR, every outlet on a floor would have to be checked until the correct one is found. Sending a tone from the work area and locating the TR where the cable is placed can save a lot of time.

Using a voltage meter, determine if the cable pairs are active. Do not use the active pairs to transmit the tone because the:

- Ringing current from the telephone switch may damage a tone generator.
- Tone will disrupt and possibly damage a digital telephone circuit.
- Tone may damage data network equipment.
- Tone will disrupt network traffic on a computer circuit.

NOTE: For additional information on testing, refer to Chapter 5: Copper Structured Cabling Systems and Chapter 6: Optical Fiber Structured Cabling Systems.

Steps—Verifying Existing Infrastructure

Step	Verifying Existing Infrastructure and Documentation
1	Request information from the customer. Ask: • Which equipment is active. • Which circuits are in use. • For the cabling system documentation. • For the location of TRs and any other cable distribution points.
2	Check the existing documentation for accuracy. • Compare the existing documentation and any subsequent MACs documentation with the installed cabling system. • Verify all discrepancies between the documentation and the actual installation.
3	Visually determine if circuits are attached to active devices. Perform a walk-through of the facility, and document active devices connected to the installed infrastructure.
4	Check for labels and tags throughout the cabling system. • Inspect the cable pathways, cables, termination points, and any equipment for labels, tags, or other indications of the equipment attached to each circuit. • Label items as they are identified if not present or correct.

Steps—Verifying Existing Infrastructure, continued

Step	Verifying Existing Infrastructure and Documentation
5	Inspect for terminations or cross-connections. • Trace cables to their terminations, and document the findings. • Trace cross-connections (jumpers) to determine their termination points, and document the findings.
6	Use an appropriate test set for copper cable identification and tracing. Use the multimeter or tone generator (toner) and inductive amplifier on a pair of conductors not in use. The signal generated by the toner may interfere with other signals in the cable. The multimeter test will not interfere with adjacent conductor signals. **Tone Generator** • Attach tone generator to the cable pair at the work area. • Use the inductive amplifier to detect the signal. • Trace and identify the cable from the detected signal. **Multimeter** • Check cable at the work area for stray voltages. • Set the multimeter for resistance or continuity. • Attach the multimeter to the cable pair at the work area. • Short the distant end of the tested pair. • Check for continuity. **Office Locator Kit** • Plug locator modules into workstation outlets. • Connect tester to suspected cables in the TR. • Document the cable information when a locator module is detected. **Certification Test Set (if equipped with a tone generator)** • Attach a tester with tone generator to the cable at the work area. • Use an inductive amplifier to detect the signal. • Trace and identify the cable from the signal detected. • Connect the remote tester, and perform autotest to verify cable performance.

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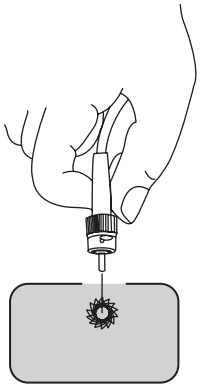
Steps—Verifying Existing Infrastructure, continued

Step	Verifying Existing Infrastructure and Documentation
7	Use appropriate testers for optical fiber identification and tracing. **WARNING**: Never look into the end of an optical fiber. Looking into an energized fiber can cause a serious damage to the eyes. **Fiber Flashlight** • Ensure that fiber is not energized. • Connect a flashlight. • Look for the colored distant fiber end. **Light Source and Optical Power Meter** • Inject a light (at a proper wavelength). • Measure and record the results at the distant end. • Test in the opposite direction, and record the results. **Fiber Strand Identifier** • Clamp the light detector around fiber. • Check for the presence of light. **Visual Fault Locator** • Connect the light source to fiber. • Look for the visible light at the remote end. It is not necessary to look directly into the fiber to see the light.

Steps—Verifying Existing Infrastructure, continued

Step	Verifying Existing Infrastructure and Documentation
7 cont.	**Infrared Conversion Card** (see Figure 11.4) • Place the optical fiber connector about 6.1 millimeters (mm [0.25 inches (in)]) away from the card, and point the ferrule toward the card's surface. • Look for luminescence across the phosphorus surface of the card.

Figure 11.4
Infrared conversion card



8	Hand trace the cables. From any active equipment, trace the cable to its termination to determine the path of the active circuit.
9	Verify the backbone cabling. Document the: • Path and termination points. • Number of conductors and fibers at each point of termination. • Splice locations and configurations. • Number of conductors and fibers in use (vacant or tagged poorly).
10	Label both ends of the cables and all termination devices by: • Determining which circuits are active. • Labeling both ends of all circuits that are identified.
11	Test the remaining cables that are being considered for reuse but have not been tested.
12	Check the existing firestopping installations, and document any that do not comply with applicable codes.

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Evaluating Existing Infrastructure

The site survey provided the opportunity to investigate the building's physical layout, verify the installed infrastructure, and test the cabling system against today's standards. Now, the ITS installer must determine what portion, if any, can be reused with the new system.

Gathered earlier in the site evaluation, the following information should be available to assist the ITS installer in evaluating the existing system's potential for reuse:

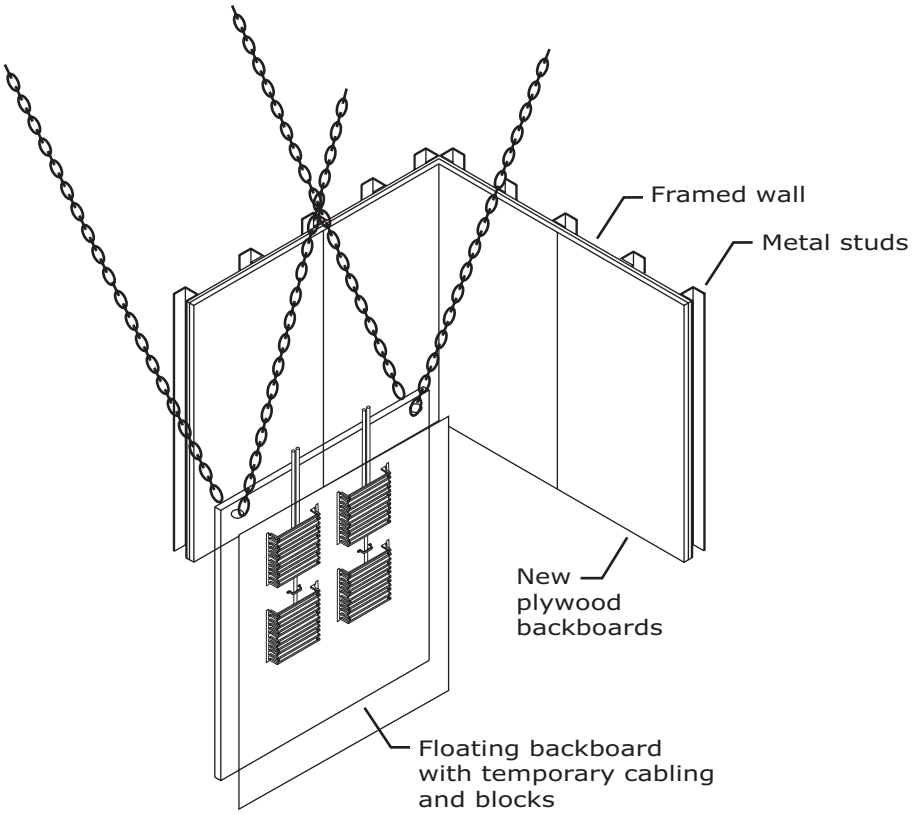
- List of all active devices, including:
  - Telephones
  - Computers
  - Fax machines and other equipment
- Existing TRs, pathways, and floor plans
- Installed equipment and functional block diagrams
- Verified existing cabling records and cross-connect sheets
- Initial system test results
- List of TRs, pathways, cables, and equipment to be installed or modified
- Backbone cable routing and splicing sequences (if any) and the cable pairs to be extended to all TRs
- Type of connecting hardware by size, quantity, and configuration (shown on the drawings)
- List of service providers (SPs) with their contact numbers, circuit identifiers, and circuit descriptions
- List of expected changes to the entrance facility (EF)

Evaluating Existing Infrastructure, continued

If the TR does not have adequate room for the old and new components, consider the following options:

- Build additional TRs—This provides the needed extra space and shortens the length of the horizontal cables. Shorter cables use less material and are easier to install. Equipment and cables are easily installed in a new TR because there are no existing components to work around. However, new TRs often require the customer to give up valuable floor space.
- Expand the existing TR—This may be accomplished by knocking out one of the nonload-bearing walls and expanding into the customer's office spaces. This can be more complicated than new TRs because equipment and termination devices on the wall may need to be removed, and the equipment must remain in service (see Figure 11.5).

Figure 11.5
Floating backboard



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Evaluating Existing Infrastructure, continued

To remove the wall, the equipment and hardware must be floated. To float a backboard, the cables and cross-connects are lengthened to allow the entire wall to be relocated a few meters (feet).

This practice gets its name because the plywood (or a large portion of the actual wall) is disconnected from the building structure and hung from the overhead supporting structure. The components are floating by their new temporary supports. The temporary relocation of an equipment rack can be referred to as floating a rack.

Floating a backboard or rack allows the contractor to work around the existing system to rebuild the room and install and test the components of the new system prior to the cutover.

To do this:

- Float the existing equipment and cables. In a small TR, the existing equipment and cables may need to be extended out into the hallway to make room for the new system. The new plywood and system components can be installed, tested, and prepared for cutover. The old system components can be removed after the cutover is completed.
- Install temporary cabling. Temporary cabling is used to provide service until the cutover is completed, and then it is removed.

Temporary cabling is usually installed as quickly and cheaply as possible. It is often laid along the outside perimeter of the room or simply left hanging out of the ceilings. It is designed as a temporary solution and should never violate fire or safety codes. Routing through air-handling spaces (e.g., ceiling spaces, access floor spaces) should be avoided because of the cost and complexity of the installation.

Large office retrofits may require extensive work area recabling and TR renovations. Temporary cabling can be either backbone or horizontal cables. It may be easier to temporarily relocate a small telephone system from the TR into an office and run the horizontal cables on the floor until the new system is installed. This allows the equipment and termination hardware to be installed in the TR while the new horizontal cables are installed out to the workstations.

Changes in the EF may impact the space requirements within the TR. The ITS installer must be aware if the customer plans to add optical fiber cable or new T-1 circuits. These facilities require termination space and may need electronics that require valuable space. Contact the SPs, determine their requirements, and clearly mark their designated areas within the TR.

Steps—Evaluating Existing Infrastructure

Step	Evaluating Existing Infrastructure
1	Determine the planned use of systems. • Verify the customer's planned use of the data systems. • Will a new voice system be installed, an existing system be expanded, or the current system remain? • How many cable pairs does the voice system require? • List cables to be reused if applicable. • List cables to be removed.
2	Determine the backbone cabling requirements. • Verify if an optical fiber backbone is required and, if so, the number of strands. • Will both multimode and singlemode optical fiber be required? • Determine if a copper backbone cable is required and, if so, the pair count and category.
3	Determine the physical parameters. • Is the cable rated for the environment in which it is installed? • If the existing cable does not comply with the fire code, must it all be replaced even though it meets transmission performance specifications? • Confirm equipment rack configurations and space requirements. • Will firewalls be penetrated? If so, which firestop systems are acceptable to local authorities? • Will it be necessary to bring the existing penetrations into compliance with the fire code? • Confirm the need for the removal of the existing cable from conduits and pathways prior to the installation. • Confirm the status, if any, of asbestos within the facility. If present, has it been abated? If not, what planning is required? • Confirm that the system layout complies with distance limitations for both horizontal and backbone cables. • Confirm that the system layout complies with distance limitations for backbone cables established by the application's equipment requirements. • Verify that the grounding system is properly designed.
4	Confirm the findings with the customer. • Meet with the client to verify analysis. • Determine if any portions of the existing system will be reused.

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Site Survey

While site surveys were discussed in great detail in Chapter 10: Planning and Project Management, this section gives an overview of the common practices and details the steps taken when dealing with procedures unique to retrofit installations.

After the initial project documents are obtained and reviewed, a site survey must be performed. A retrofit installation's site survey is usually far more involved than one for new construction. When dealing with new construction, the site survey is performed to verify that the proposed installation is sound and will proceed as planned. In addition, site surveys for retrofit installations must verify that the existing documentation accurately depicts the installed infrastructure.

If the customer is not confident that the documentation reflects the actual installation, the ITS installer may have to trace and document the entire infrastructure. The ITS installer may be required to test the existing system components to determine if they meet the requirements of the new equipment as well as current codes, standards, and regulations.

The process of verifying the existing documentation may be tedious, but it must be done thoroughly to establish the necessary framework to begin the job plan. Once the existing infrastructure has been identified, labeled, documented, and tested, an informed decision can be made on what portions, if any, of the old infrastructure may be reused.

In most cases, the existing infrastructure must not be disturbed during the survey. It may be necessary to document some parts of the existing infrastructure after normal business hours.

Site surveys of retrofit installations usually require a team of ITS installers to visit the installation site. While there, the team should observe all locations where installation work will be performed.

When making this site survey, the team should carry the following items:

- The customer's and ITS designer's documents—These documents allow the team to identify specific locations related to the project and work to be performed. The documents may indicate obstacles not visible from floor level.
- A checklist—The checklist is used to ensure that all items of concern are addressed. If problems are found, plans can be formulated to overcome them while still on-site, rather than having to return to the site.

  NOTE: See Example F: Site Survey Checklists in Chapter 10: Planning and Project Management.

- Tools to perform any work required for a thorough site survey—Some suggested tools are personal protective equipment, including a hard hat, safety glasses, a dust mask, leather gloves, leather boots, and hearing protection. Additional items that may prove useful are a ladder, flashlight, measuring wheel, handheld tape recorder, camera (preferably digital), or video camera.

All information gathered during the site survey should be placed into the project file. This information will be valuable throughout the project, especially if new team members are assigned after the installation begins.

Site Coordination

The first stop at a job site should be with the project contact. While there, the ITS installer can:

- Explain the work to be performed for the customer.
- Identify the other contractors working for the general contractor and the impact their work will have on the cabling installation process.
- Obtain a copy of the project's safety program, security guidelines, and construction progress schedule.

NOTE: The construction progress schedule can be used to determine how the ITS installation schedule can be coordinated with the contractors working on the project.

It is important for the ITS installer to review with the general contractor (the customer on a small project) the responsibilities of the ITS installation team. This allows the general contractor to fully understand the role the ITS company will play in the completion of the overall project.

The ITS installer should determine who is responsible for the construction of the pathways and spaces. The customer's documents should state whether they are being provided by the general contractor or others. Usually the pathways and spaces of a new building are the responsibility of the general contractor or the electrical subcontractor. Retrofit installations often require the ITS contractor to assume responsibility for the pathways. If the ITS contractor is responsible for the pathways, the ITS installer must determine how to install these pathways and what obstacles must be overcome.

NOTE: More detailed information on installing support structures can be found in Chapter 5: Copper Structured Cabling Systems.

On larger jobs, it is necessary to coordinate the ITS installation team's schedule with other trades. This may require that the on-site ITS installation representative attends the general contractor's weekly progress meetings. The installation success may depend on the efforts of the electrical contractor to install necessary pathways prior to cable pulling or the carpenter's building or expanding the TRs. These are critical path items that can seriously affect the installation schedule.

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Verifying Codes and Standards Compliance

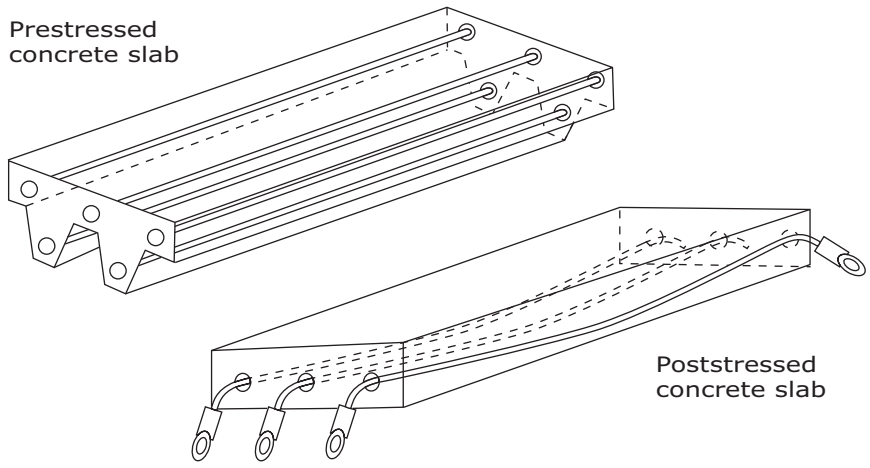
Another concern is the installation firestopping. In a retrofit installation, the ITS installation team may be required to bring the entire installation, including the existing cabling system, up to code. The ITS installer should document the status of the existing firestopping and check with the local authorities and the customer to clarify responsibilities concerning any existing noncompliant firestopping.

During the site survey, the ITS installer should note any obvious floor penetrations for further structural evaluation by qualified personnel (e.g., structural engineer). The "Swiss cheese" effect occurs in installations using poorly designed poke-thru distribution. Holes close together may result in a floor's or entire building's condemnation. The ITS installation company may be held responsible for the damages.

Before drilling into a concrete floor, consult the building owner, engineer, or architect to determine how it is constructed. The floor may be x-rayed to determine the location of rebar, conduits, and steel supporting strands. A bonded and insured coring firm that does this type of work on a daily basis may be hired.

Determine whether the floors are prestressed or poststressed concrete (see Figure 11.6). Both types are poured at the factory; however, each is constructed in a different manner, and lack of knowledge poses a great danger to the uninformed ITS installer. If an ITS installer core drills through one of these tensioned cables, the floor loses its midspan support while the walls lose their stability. This could cause the floor and, possibly, the building to collapse.

Figure 11.6
Prestressed and poststressed concrete



Verifying Code and Standards Compliance, continued

Prestressed concrete is made in a large form to produce a flat slab that will be used as part of a floor. It gets its name from the way it is constructed. Before the concrete is poured into the form, several large metal cables are placed in the form. The cables are run lengthwise in the form and are pulled with tons of force from each end. The concrete is then poured into the form and allowed to cure.

Once cured, the tension is released from the cables. The force from the cables now pulls both ends of the slab toward the center. This causes the slab to bow upward in the middle. When installed, the bow is on top. After office equipment and furniture are placed on top of the floor, it levels out. This design allows the builder to use fewer columns in an open office design.

Poststressed concrete is the exact opposite of prestressed. The metal cables are placed in the form with their ends sticking out. Each cable end has a factory-crimped eye on it. The cables are free of any tension when the concrete is poured into the form.

The concrete is cured and the slabs are sent to the construction site. When the slab is installed, the cable eyes are attached to the vertical supporting structure of the building. The turnbuckles are tightened so that the cables running through the slab are now holding the floor up and the walls in. The building is designed so the floors actually hold the walls in with less cross bracing.

WARNING: The ITS installer shall never drill into a prestressed/poststressed concrete floor or wall. A qualified contractor shall always be hired for that purpose.

When an ITS installer is working with an existing system, it is necessary to verify that the original installation meets current codes, standards, and regulations. Check the cable pathways and distances, firestopping, and grounding systems. These are the areas that frequently do not meet current codes, standards, and regulations.

Job Plan

Careful planning is required when performing a retrofit installation to ensure that customers receive the desired system upgrade with a minimum of interruption to their business. A thorough review of the implementation plan will eliminate any confusion and assist in making the transition to the new system as efficiently as possible.

In many cases, the customer must continue to use the equipment that will later be transferred to the new system. Therefore, the cutover must be scheduled to minimize the downtime and disruption of customer operations. Normally, such activity is scheduled after the business hours or on weekends; however, circumstances sometimes warrant that the cutover occurs during the normal office hours. Regardless of the cutover timing, the newly installed cabling system should be terminated, labeled, tested, and documented prior to the planned transition.

A good job plan is essential for the successful completion of the planned work. This plan should reflect all aspects of the work to be performed from a scheduling perspective. Job plans can range from simple documents for a small project (e.g., checklist) to complex documents for a large project.

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Job Plan, continued

Every job plan should reflect the company's effort to ensure the work is performed in a timely manner. It should include the following:

- Customer documents
- Documentation to be submitted to the general contractor and customer
- Overall job schedule
- Cabling installation schedule
- Inspection schedules
- Resources required for compliance with the schedules
- Coordination with other trades on the project
- Permit acquisition
- Material staging
- Scheduled meetings
- Security and safety plan
- Materials list
- Tools list
- Task list and description
- Job requirements
- Labor estimates
- Acceptance plan
- Special circumstances
- Labeling system

Routing for horizontal and backbone cables and their respective pathways should be identified. All labeling schemes should be discussed. TR layouts should be reviewed to ensure that all items can be installed in their respective places on both the floor and the wall spaces. Cables and equipment slated for removal should be identified.

Bonding and grounding (earthing) methods should be discussed to ensure compliance with the SoW, codes, standards, and regulations. Safety plans should be reviewed for applicability to the project. Appropriate personal protective equipment should be itemized.

Prior to beginning work on the project, the job plan should be reviewed by the ITS installation team as part of the initial construction meeting. If changes are required, they should be made at this time.

Initial Construction Meeting

After completing the site survey, verifying the existing infrastructure, and formulating the job plan, the ITS project manager (PM) should hold an initial meeting with the entire cabling installation team. At this meeting, the PM and the team leader should detail the responsibilities of everyone involved. This ensures that everyone is informed regarding every aspect of the project. The job plan can be reviewed and updated as necessary. Questions can be asked and answered. Communication among all personnel involved in the project is critical to its success.

Updates to the project plan and minutes of all meetings should be maintained. A printed copy should be provided to each person attending and any additional persons having a position of responsibility on the project. Meeting minutes must be prepared and distributed shortly after each meeting and must provide a mechanism to allow attendees to update and correct the material.

Materials

Materials should be ordered for the project, allowing time for any back orders and shipping delays. As the materials arrive, they must be inventoried, inspected for damage, and checked to ensure that the contents match the labeling on the boxes.

The materials list should contain the description of each item, the catalog number, and the quantity ordered. It should have columns for materials received and materials dispensed. Field personnel use these two columns to track the inventory during the actual installation work.

Materials can be stored at the job site, at the company location, or with the distributor. Ensure the safekeeping of the materials until the installation is completed. Depending on the size of the project, all of these options should be considered. The best alternative for the particular project may be a combination of all options.

Receiving materials is one of the most important tasks on a project. It can affect the profitability of the project just as much as the labor employed. Determining where the materials are to be stored, how they are to be dispensed, and how unused materials are to be disposed of is critical to the success of the project.

When receiving materials at a central location (e.g., warehouse), the materials need to be organized by job site and kept separately from other projects. Failure to do so may result in the delay of the project because another crew may use the materials. If the materials are to be delivered to the site, an on-site representative will be responsible for receiving, inventorying, and storing them in a secure location. Plan a storage area at the site regardless of where the bulk of the materials and tools are being stored.

Only designated persons should be allowed to distribute materials on the job site. When materials are distributed, some record of accountability should be made to ensure that the materials are not lost or misplaced. Excess materials should always be accounted for at the end of each workday and stored for use later or returned to the company storage area for use on another project.

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Developing a Project Schedule

Once the items associated with planning an installation have been identified, develop a project schedule. If the job is at a building under construction, the general contractor's construction schedule should be obtained and referenced. It includes all of the trades working on the project and indicates their specific timeframes for accomplishing their work on the project. Of particular concern are the schedules for completion of the supporting structure inside the building.

Backbone cables or horizontal cables cannot be installed until the electrical contractor or the general contractor has completed installation of the pathways and spaces that will be used to house these cables.

If new spaces are being constructed, identify the finishing schedules for other trades (e.g., faceplates cannot be installed until the wall covering is completed). Racks may not be installed until the floor covering is installed.

The project schedule should begin with the award of the contract and is completed upon the customer's acceptance. The detail required for each item is directly proportional to its importance in completing items that precede or follow it. The project schedule should indicate the planned time required for each item and provide space to insert the actual time used to perform the job task.

Project scheduling software is now available to simplify this task and provide information relating to the status of a project. Most types of project scheduling software track the resources, materials, tools, and expenditures as well as the actual work progress schedule.

A copy of the schedule should be provided to all concerned parties. This schedule should be updated daily, indicating the progress of the day's work and whether the installation is on schedule, ahead of schedule, or behind schedule. Any supporting documentation that will lend credibility to delays should be referenced in the project schedule updates.

Project Schedule

Companies use a variety of project management styles and software. Charts and graphs allow the ITS installation team to track the receipt and disbursement of materials, labor items completed, and the overall daily status of the project. Manually generated project schedules can be used when the project is small and not complex.

NOTE: Examples of project schedule documents are provided in Chapter 10: Planning and Project Management.

Preinstallation Meeting

Once the project schedule is compiled, the PM, the ITS installation team, and appropriate contractors should convene for an internal preinstallation meeting. All aspects of the project should be addressed and discussed, and adjustments should be made to the project schedule based on the results of the meeting. The project checklist should be reviewed, and everyone should be aware of individual responsibilities.

Progress Meetings

Periodic meetings should be held for every project. These meetings can be held as often as once a week or as necessary to ensure that everyone knows what is going on and what is expected. Work progress as well as roadblocks and ways of overcoming them should be discussed and agreed upon by the concerned parties. Each team can contribute to the success of the project by participating in these meetings.

On a project where the building is under construction, the general contractor and subcontractors should be called to attend and participate in these meetings. The PM should attend the general contractor's construction meetings to ensure that all concerns are addressed. This will ensure proper coordination between the ITS installation team and other contractors working on the project.

Project Safety Plan

Safety is the first item of importance on a project. The safety of workers, customer personnel, and subcontractors is of utmost importance. Workplace accidents can disrupt the best-planned job and cause costly delays.

The ITS installation company should have an approved safety plan. Before beginning any work operation, the contents of that safety plan should be reviewed with each employee working on the project. Each employee should fully understand how the rules of safety should be implemented as each installation task is performed. Time should be taken to ensure that each employee is equipped with the proper safety equipment and has the knowledge to safely use the equipment. As a contractor or subcontractor, the ITS installation team may be contractually required to attend periodic safety meetings.

NOTE: If questions of safety occur, it is better to halt a work operation rather than risk an accident.

Strategy

When unforeseen problems occur, plan how to overcome them, and implement a backup strategy. Proper project planning is essential for the successful completion of a project.

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Job Log

The person in charge at the job site should maintain a daily log that reflects all work performed each day and the plans for the following day. The log should begin on the first day of activity on the project site and continue until the ITS installation company vacates the site. All activities relevant to the work should be logged on a daily basis.

The area's work, equipment on-site, weather conditions, and received and dispersed materials should be documented. In addition, problems (e.g., occurrences that may result in scope changes and have a financial impact on the cabling installation company) should be documented.

Contractual obligations that are affected by the work of others should be logged and accompanied by detailed notes. If an incident occurs with another contractor, it should be written in the log and initialed by the person in charge as well as a representative of the other contractor. If the other contractor declines to initial the entry, the refusal should be indicated as well as the date and time of the entry. Accuracy and timeliness are critical to the credibility of this log.

A contract may require copies of this job log to be submitted to the customer or general contractor on a periodic basis. It is a sound practice for the PM to document certain elements of the project on a weekly basis and to record the following information concerning the events at the site:

- List of subcontractors at the site
- Approximate personnel count at the site
- Accidents and unusual events
- Meetings and significant decisions
- Stoppages, delays, shortages, and losses
- Emergency procedures
- Change orders received, implemented, and in process
- Services connected and disconnected
- Equipment or system tests and start-ups
- Status of material orders
- As-built documentation status report
- Punch list status
- Weather conditions
- Timesheets
- Daily job reports

System Cutover

Overview

With the system acceptance testing completed, the ITS installation team is ready to put the new system into service (a process known as system cutover).

The cutover is handled differently for every installation. Some are as simple as installing a new system, turning it on, and using it. Other retrofit systems are installed next to old systems but are completely separate so that both can operate at the same time until the final cutover.

Situations where the new system can be installed while the old system is left in service are the safest way to handle the cutover. The new system is installed, tested, and then put into service. The users are asked to start using the new equipment. The old system remains in operation as a backup. Any users who experience problems can go back on the old system until the new system can be corrected, or the users can be properly trained to use the new system.

The old system can be disconnected and removed after the users are comfortable with the new system and the system has had a chance to burn-in. The term burn-in refers to the electronic circuits getting warm when they are turned on. A new system should have a low percentage of its circuit boards fail after they have been initially turned on and allowed to heat up.

Each job may require different amounts of burn-in time, which can range from a week to six months. This provision may be phrased, "The new system shall be considered accepted after a 45-day burn-in and 31 days without a failure." This protects the customer from getting a new system that is losing a circuit board every other day.

NOTE: Some systems are not accepted for more than a year because of continuous equipment failures.

Ask the customer for the best cutover time and to specify how long the system can be out of service. Check for any critical circuits that must remain operational throughout the entire project.

Documentation and installation manuals for all the equipment slated for installation must be on-site during the cutover. A set of manuals for the equipment slated for removal should be on-site. They can be useful if it is necessary to return to the old system.

Several telephone numbers can be helpful if complications occur during a cutover. The numbers should be researched in advance so that time is not wasted when the customer is without communications.

Some of these telephone numbers represent contacts for the following:

- Internet access to download files from the manufacturer
- Manufacturer's technical assistance
- Local central office
- Long-distance providers
- Special circuit providers (e.g., T-1s, optical fiber, wide area network [WAN])

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Overview, continued

Make a list of every circuit number entering the facility so that they may be given to SPs to provide assistance.

Most ITS installers think of a cutover occurring on the weekend or in the middle of the night. These may not be the best times for the customer or the local SPs (e.g., the customer may download files from around the world between the hours of midnight and 4 a.m. each day). Technical assistance from the SPs after hours may be a problem. Most SPs use a reduced staff after normal working hours.

If a problem is experienced with the new system, it may be difficult to receive technical assistance from the manufacturer after hours. Contact the manufacturer ahead of time and ask about its after-hours assistance policy. If required, establishing an account with the vendor for technical assistance may be beneficial.

NOTE: Many manufacturers now charge for technical assistance. Most require a technician's certification number prior to giving assistance.

Performing a cutover on the weekend requires a great deal of coordination. Notify the users of the pending cutover, and provide initial training on the new system.

When installing a new PBX, the ITS installer should:

- Deactivate and remove the existing system.
- Install the new system.
- Cross-connect the backbone and horizontal cables to the new system.
- Transfer the entrance trunks and tie lines to the new system.
- Install, test, and label new user instruments.
- Perform acceptance testing of the entire system.

When installing a new data network, the ITS installer should:

- Install the new cabling system.
- Install and configure the new system electronics.
- Install and configure the new network interface card (NIC) and existing NIC card in each device.
- Cross-connect the backbone and horizontal cables to the new system.
- Test each network device's ability to log onto the network.
- Install, test, and label peripheral devices (e.g., printers, modems).
- Transfer any entrance tie lines to the new system.
- Perform acceptance testing of the entire system.
- Deactivate and remove the existing system.

Overview, continued

The new system should be ready for the users when they arrive. No matter how thoroughly the system is tested, problems may occur. When the users start loading the system with full-scale usage, trouble reports will be received.

A crew should be on-site and a notice explaining how to use the system and listing one telephone number to report troubles should be placed on every user's telephone. The users should be informed that the ITS installers are on-site and ready to fix any errors or provide training.

Steps—Cutover

Step	Cutover
1	Follow a method of implementation. • Confirm whether work will be performed after or during normal business hours. • Identify cables to be removed prior to the completion of the project. • Remove all cables and cross-connects that are not supporting active circuits and are scheduled for removal. • Develop cutover sheets. • Install temporary cabling if required. • Float backboards, racks, and equipment as required. • Install new cabling. • Install and configure new equipment. • Confirm the cutover time with the customer. • Notify the users of the cutover, and provide training on the new system. • Verify who is responsible for the interconnection of voice and data systems to the new cabling system. • Decide whether the system will be cut over under a flash-cut scenario or phased in over a period of time in preplanned stages. • Install, label, and configure telephone as required. • Install and configure the NICs at each network device as required. • Test each component within each system. • Provide on-site support both during and after the cutover. • Firestop all penetrations not being used to remove the abandoned cables.
2	Perform testing. • Perform balanced twisted-pair testing of all new cables for either link or channel tests, as determined by the customer. • Perform optical fiber testing using either an optical power meter or an optical time domain reflectometer (OTDR), as determined by the customer.

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Steps—Cutover, continued

Step	Cutover
3	Prepare documentation. • Label all equipment, pathways, and cabling as appropriate. • Update blueprints for as-built documentation. • Provide updated cross-connect records. • Provide interconnection drawings. • Provide equipment rack layout drawings. • Compile all test results in both hard copy and electronic media for the customer and the installation company's records.

Removing Abandoned Cable and Equipment

Cables may be removed only after they have been checked to verify that they do not support active circuits. Active cables must not be removed until the cutover is completed and the system has been accepted.

NOTE: During a retrofit installation, it is required by code that all abandoned cable be removed. The definition of abandoned telecommunications cable is installed telecommunications cable that is not terminated at both ends at the connector or other equipment and not identified for future use with a tag. This is considered a life/safety issue.

The removal of abandoned cable requires patience and an organized method of removal. It is easy to cut the wrong cable or damage the active remaining cables.

Cables in conduits can be difficult, if not impossible, to remove without damage to the other cables in the conduit. Cables often become twisted together as they are installed in conduits.

If pulled too hard, the abandoned cable may damage the active remaining cables and become even tighter around the other cables.

Cables may be freed by:

- Gently pulling as a helper pushes from the other end.
- Gently pulling all the cables back and forth a few millimeters (inches) while gently pulling the abandoned cable out.
- Pulling all the cables out together with a pull string attached. Discard the abandoned cables, and pull the good cables back and reterminate.
- Using an appropriate lubricant.

Removing Abandoned Cable and Equipment, continued

Cables above a suspended ceiling can present problems. When pulling a cable at one end, an assistant at the other end might mistake a moving cable as the correct one. Just as in the conduits, cables get wrapped around each other in cable trays and other support hardware. As it is pulled, the cable may actually be moving separate cables heading in different directions.

Cables in open ceilings are often bundled using cable ties. They are tie-wrapped to cable ladders and other supports. These fasteners must be removed prior to pulling the cables out.

Remove any equipment or cross-connects from both ends of a cable prior to cutting the cable. When the cable is cut, all conductors are momentarily shorted together. This can cause severe damage to electronic equipment.

Remove any cable-supporting hardware that will not be used. Abandoned hardware clutters the spaces and could possibly be reused on another job. Recycle hardware that is in good condition wherever possible.

Remove all trash and debris above the ceiling tiles, attics, and under the crawl spaces. For safety reasons, piles of cable ties, chunks of cable, coring debris, and the ITS installer's tools should be removed.

Dispose of the trash in a responsible manner. Scrap cable can be recycled. On large projects, a salvage yard may leave a dumpster for usable scrap materials. At the end of the project, the salvage yard will pick up the scrap and pay the company for the materials.

Recycle the cardboard containers that come with the new systems, user instruments, and cable reels.

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Steps—Postcutover Removal

Step	Postcutover Cable Removal
1	Identify cables to be removed. • Confirm that the cable is not in use by testing with a wand and tone generator. • Check identification labels on both ends of the cable. • Never start by cutting in the middle and working toward the ends.
2	Remove cable support hardware. • Disconnect all fasteners from the cable bundles to be removed (e.g., D-rings, grommets). • Dismantle all tie wraps from the cables to be removed.
3	Remove cable terminations. • Disconnect all cables from the work area outlets being removed. • Remove all terminations in the TR.
4	Remove cables.
5	Carefully retrieve the cables for disposal.
6	Install a firestopping system with all penetrations that cables were removed from and any penetrations for which the installation company is responsible.
7	Remove all trash and debris from above the ceiling tiles.
8	Recycle appropriate materials.

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National Fire Protection Association. NFPA 70. *National Electrical Code®*. Quincy, MA: National Fire Protection Association, 2011.

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Chapter 12
Specific Applications

Chapter 12 contains information related to installing security and fire alarm systems, wireless systems, paging systems, sound masking systems, and clock systems. This chapter provides information about special circuits extensions and building automation systems (BASs).

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Introduction

Information technology systems (ITS) are found in every branch of economy throughout the world. ITS professionals often specialize in a specific technology applicable in several different industrial areas, including health and safety technologies.

This chapter focuses on some of the most critical considerations related to:

- Security and fire alarm systems installation.
- Wireless systems installation.
- Paging systems installation.
- Sound masking systems installation.
- Clock systems installation.
- Special circuits extensions.
- Building automation systems (BASs).

Installing Security and Fire Alarm Systems

Overview

Unlike the ITS infrastructure, security and alarm infrastructure systems are commonly proprietary. Both of these systems have specific licensing requirements and should be verified with the authority having jurisdiction (AHJ). Follow manufacturer's installation guidelines and BICSI® best practices in all cable installation.

Security

Three major areas in security may be part of an ITS installer's work:

- Intrusion detection system (IDS)
- Access control system (ACS)
- Video surveillance (e.g., closed-circuit TV [CCTV])

NOTE: For additional information, refer to the current edition of BICSI's *Electronic Safety and Security Design Reference Manual (ESSDRM)*.

Fire Alarm

A fire alarm system should be designed by a licensed fire protection engineer to ensure proper coverage and code compliance. Before the ITS installers begin any fire alarm installation, they should check with the local AHJ for proper licensing requirements.

Directions on how to install wiring and equipment for fire alarm systems, including information regarding all circuits these devices control and provide power to, can be found in the manufacturer's documentation. BICSI best practices are applicable in the cable and equipment installation. Also, fire alarm circuits need to be installed in separate pathways from other ITS because of electromagnetic interference (EMI) considerations.

IMPORTANT: When a fire alarm system is designed and installed, it should be tested with a monitoring service, if applicable, and the local fire department to ensure that the system fire notifications were received.

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Installing Wireless Systems

Overview

This section provides an overview of the materials and installation practices necessary to support a wireless local area network (WLAN) infrastructure and a distributed antenna system (DAS). The WLAN is an extension of a facility's data network, and a DAS is typically deployed into areas where cellular or other radio frequencies (RFs) cannot reach or may interfere with existing devices.

A DAS retransmits and receives these frequencies within a building or complex by means of antennas that are distributed throughout to provide even and usable coverage.

A DAS consists of an infrastructure of electronic devices, including:

- Amplifiers.
- Cabling.
- Connectors.
- Antennas.

The ITS installer should take into consideration that antenna installation may be in an indoor or an outdoor location. This section covers antenna selection, antenna installation, access point (AP) selection, AP installation, antenna-to-AP connection, AP-to-switch connection, and DAS installation fundamentals.

The DAS distributes antennas at strategic locations in an outdoor setting, within a building, or in other RF-obstructed environments. The distributed antennas are interconnected by a system of cabling, connectors, and, where necessary, RF amplifiers.

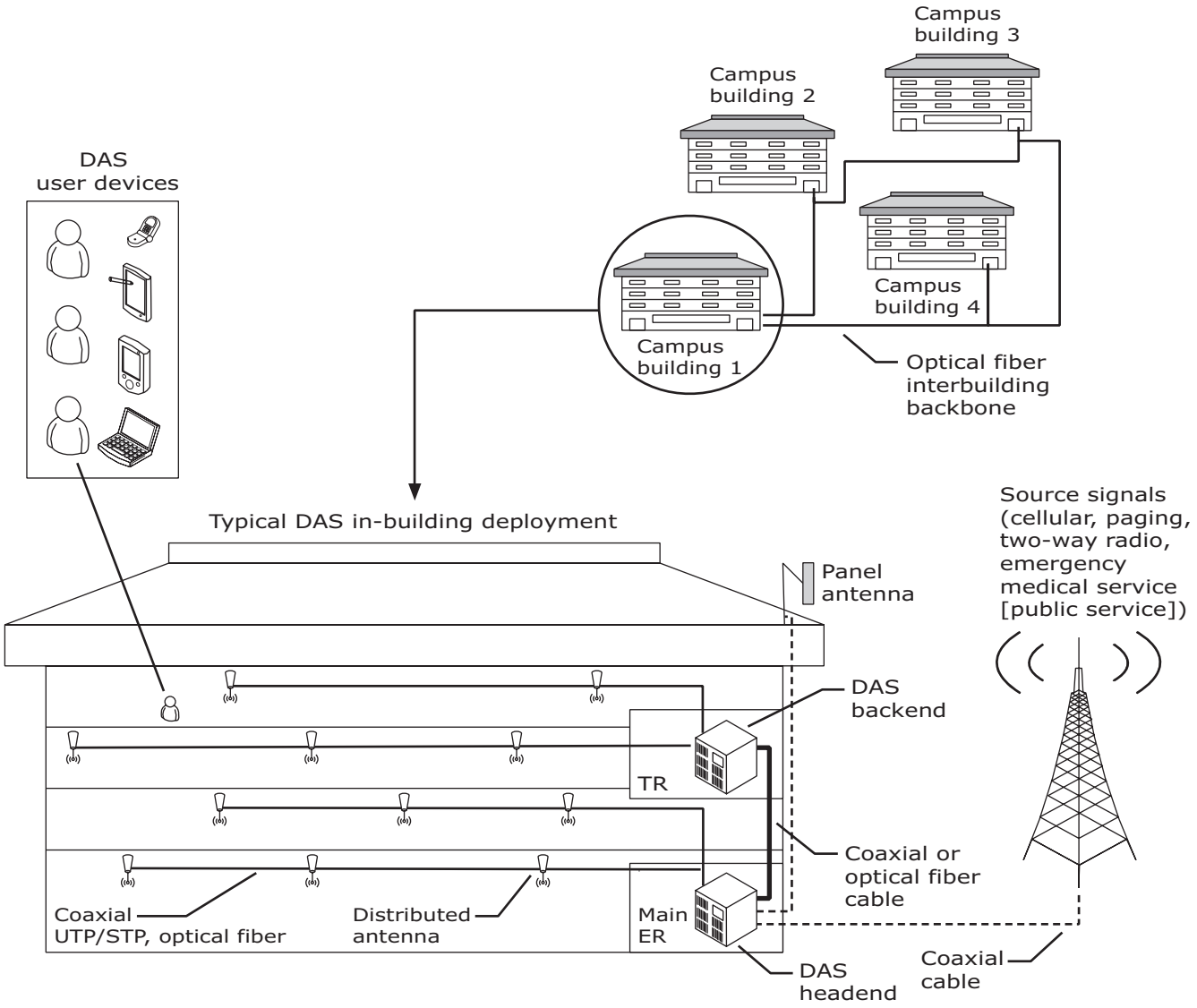
At the root of the system is a radio transceiver that either relays wireless transmissions to a broader outdoor network (e.g., cellular/personal communications system [PCS] repeater) or connects directly to the landline ITS network (indoor base station or WLAN AP).

The transceiver supplies radio signals into the distribution system that ultimately are transmitted to one antenna, multiple antennas, or all the antennas in the system. By increasing the number of broadcasting antennas and distributing them across the coverage area, a DAS provides coverage in areas that would not have service because of poor signal reception. A DAS also enhances network performance and offers a means to improve spectral efficiencies. At the same time, lower power output at each individual antenna results in more even coverage and improves RF safety (see Figure 12.1).

NOTE: A DAS may be active or passive. If installing an active system, additional equipment space may be required in the telecommunications room (TR).

Overview, continued

Figure 12.1
Typical distributed antenna system environments



DAS = Distributed antenna system
ER = Equipment room
STP = Shielded twisted-pair
TR = Telecommunications room
UTP = Unshielded twisted-pair

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Antenna Selection

Overview

Various types of antennas can be used in a DAS and WLAN application. The ITS installer should consider the antenna:

- Purpose and characteristics.
- Selection parameters.
- Types.

Purpose and Characteristics of Antennas

An antenna is a device that transmits and receives electromagnetic (EM) waves. EM waves are often referred to as radio waves. Most antennas are resonant devices, which operate efficiently over a relatively narrow frequency band.

An antenna must be tuned (matched) to the same frequency band as the radio system to which it is connected; otherwise, the reception and transmission will be impaired. Therefore, careful consideration must be taken when selecting an antenna.

Antenna gain is another issue an ITS installer must consider. Gain describes an increase in an RF signal's power and can affect an antenna's coverage zone. Gain is a power measurement in decibels (dB). A 6 dB rule is used to calculate an antenna's gain.

This rule states that:

- Each 6 dB increase in an antenna equals the doubling of the possible range.
- Each 6 dB decrease in an antenna equals the cutting of the possible range in half.

The ITS installer should ensure that the selected antenna has the proper gain for the application.

Antenna Selection Parameters

Some parameters to consider when selecting the type of antenna are the:

- Services to be supported (e.g., cellular, public safety).
- Antenna placement.
- Operating distance and transmitter power.
- Desired qualities (e.g., size, gain characteristics, omnidirectional or directional radiation pattern, aesthetics).

Antenna Selection, continued

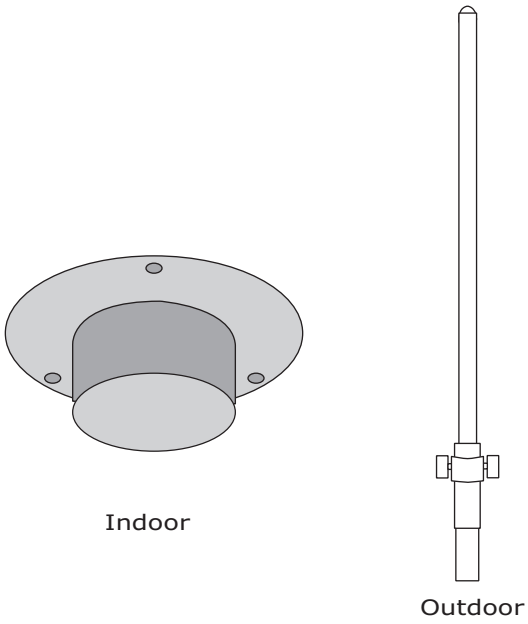
Antenna Types

Several types of antennas may be used for various applications, including:

- Omnidirectional antennas.
- Semidirectional antennas.
- Directional antennas.
- Radiation cabling.
- A combination of the above.

Omnidirectional antennas propagate or broadcast in a 360-degree pattern. They are perfect for broadcasting from the center of a room in all directions (see Figure 12.2). This can be useful for small rooms where one antenna can provide coverage for the entire room. For larger rooms (e.g., conference rooms, classrooms), more than one antenna may be needed. Omnidirectional antennas can also be used to create wireless fidelity (Wi-Fi) hot spots in outdoor and atrium locations. These are excellent point-to-multipoint configurations.

Figure 12.2
Omnidirectional antennas



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Antenna Selection, continued

Semidirectional antennas (e.g., panel antennas) propagate in a semidirectional pattern up to 180 degrees (see Figure 12.3). These antennas work well in hallways and in rooms where it might be desirable to control the dispersion of an antenna's signal within a room. Semidirectional antennas can also be used outdoors to provide directional coverage for Wi-Fi hot spots.

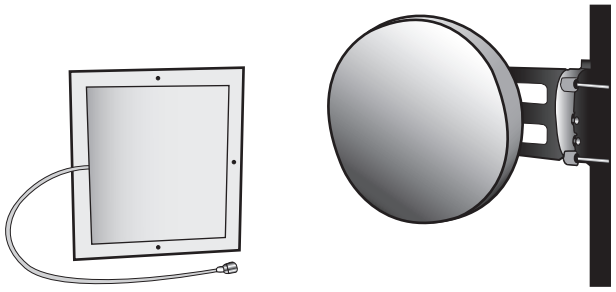
Figure 12.3
Semidirectional antennas



Directional antennas (e.g., Yagi, parabolic antennas) work well in outdoor environments for connection buildings or towers in a point-to-point (PTP) configuration (see Figure 12.4).

Antenna Selection, continued

Figure 12.4
Directional antennas



Radiation cabling technology allows a single length (run) of coaxial cable to be the radiating (transmit) and receive antenna. The coaxial cable has closely spaced slots in the outer conductor. Radiating cable is useful in combined systems because of its wide bandwidth, allowing operation from 74 megahertz (MHz) to more than 2.4 gigahertz (GHz [with some limitations]).

Antenna Installation

Overview

Antennas should always be installed according to the owner's construction documents and the manufacturer's instructions. Following are brief instructions for specific antenna installations.

Steps—Omnidirectional Antenna

The antenna's location can be flush with the drop ceiling or on a mast outside the facility. The following are general guidelines for each:

Step	Flush with the Drop Ceiling
1	Locate the exact antenna mounting position. This should be as near to the center of the tile as possible.
2	Remove the ceiling tile, and place it on a level working surface.
3	Ensure that the antenna is mounted on the finished side of the ceiling tile.
4	Using the manufacturer's hardware, follow the manufacturer's installation instructions to install the antenna.
5	Replace the ceiling tile to its position.

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Antenna Installation, continued

Step	Outside Mast Installation
1	Locate the exact antenna mounting position. There should be a clear view in all directions of the area to which the antenna is to provide coverage.
2	Install antenna mount to a mast or wall following the manufacturer's instructions.
3	Install antenna to mount following manufacturer's instructions. NOTE: Ensure that the antenna is as perpendicular to the ground as possible to maintain polarity.
4	When possible, use vertical wall penetrations to enter the building. If penetrating the roof, use manufacturer-supplied penetrating devices.
5	Ensure that all penetrations are waterproof. For vertical wall penetrations, create a drip loop for the cable.
6	Always ensure that the ITS installer does not exceed the manufacturer's cable bend radius when installing the antenna cable.
7	Lightning protection should be installed on the antenna cable before the cable enters the building.
8	Ensure that all masts and mounts are securely grounded.

Steps—Semidirectional (Panel) Antenna

The antenna's location can be flush with the indoor vertical wall or on a mast outside the facility. The following are general guidelines for each:

Step	Flush with the Indoor Vertical Wall
1	Locate the exact antenna mounting position. Use a stud finder to ensure that no wall or ceiling studs are behind the antenna.
2	Ensure that the antenna is correctly oriented.
3	Using the manufacturer's hardware, follow the manufacturer's instructions to create the proper wall penetration and install the antenna.

Antenna Installation, continued

Step	Outside on a Mast
1	Locate the exact antenna mounting position. There should be a clear view in all directions of the area to which the antenna is to provide coverage.
2	Install the antenna mount to a mast or wall following the manufacturer's instructions.
3	Install antenna to mount following the manufacturer's instructions. NOTE: Verify if the antenna is to be vertically or horizontally polarized There are swivel mounts that will allow adjusting of the polarization and azimuth of the antenna.
4	When possible, use vertical wall penetrations to enter the building. If penetrating the roof, use manufacturer-supplied penetrating devices.
5	Ensure that all penetrations are waterproof. For vertical wall penetrations, create a drip loop for the cable.
6	Always ensure that the manufacturer's cable bend radius is not exceeded when installing the antenna cable.
7	Lighting protection should be installed on the antenna cable before the cable enters the building.
8	Ensure that all masts and mounts are securely grounded.

Steps—Directional Antenna

The antenna's location can be on a vertical wall or on a mast outside the facility. The following are general guidelines for each:

Step	Flush with the Outdoor Vertical Wall
1	Locate the exact antenna mounting position. Verify the antenna is at the proper azimuth to provide maximum signal.
2	Ensure that the antenna is correctly oriented.
3	Using the manufacturer's hardware, follow the manufacturer's instructions to create the proper wall penetration and install the antenna. NOTE: For some campus PTP configurations, it may be necessary to perform a line-of-sight (LoS) verification to ensure that the wireless link can be obtained.

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Antenna Installation, continued

Step	Outside on a Mast
1	Locate the exact antenna mounting position. Verify the antenna is at the proper azimuth to provide maximum signal.
2	Ensure the antenna is correctly oriented.
3	Install the antenna mount to a mast or wall following manufacturer's instructions.
4	Install the antenna to mount following manufacturer's instructions.
	NOTE: Verify if the antenna is to be vertically or horizontally polarized. There are swivel mounts that will allow adjusting the polarization and azimuth of the antenna. For some campus PTP configurations, it may be necessary to perform a LoS verification to ensure that the wireless link can be obtained.
5	When possible, use vertical wall penetrations to enter the building. If penetrating the roof, use manufacturer-supplied penetrating devices.
6	Ensure that all penetrations are waterproof. For vertical wall penetrations, create a drip loop for the cable.
7	Always ensure that the manufacturer's cable bend radius is not exceeded when installing the antenna cable.
8	Lightning protection should be installed on the antenna cable before the cable enters the building.
9	Ensure that all masts and mounts are securely grounded.

Step	Radiating Cabling
1	Radiating cabling can be installed in cable tray systems or as a stand-alone.
2	Install standoffs into existing cable tray, if available, or install standoffs alone on existing structure.
	NOTE: Standoffs should be a minimum of 77 millimeters (mm [3 inches (in)]) below the cable tray.
3	Lay cable into the standoffs, maintaining either vertical or horizontal polarity.
4	Install connecting hardware in accordance with supplied drawings or manufacturer's instructions.
5	Connect radiation cabling to proper bidirectional amplifier as specified in drawings.

Access Point (AP) Selection

When selecting an AP, consider the following:

- Environment—Indoor or outdoor application.
- If the APs will have a wireless control system—Wireless control systems automatically monitor the APs and will control items (e.g., power levels, channel selection, network interfacing, troubleshooting).

NOTES: Channel and power selection may need to be set for APs that do not have a wireless control system.

When establishing an AP's power level, consider the gain of the device. Increasing or decreasing an AP's power level will affect coverage and throughput. In cases with many users, an ITS installer may have to install multiple APs but decrease the gain of each to prevent interference with one another. In cases with few users, an ITS installer may install the minimum amount of APs needed but use maximum power to ensure coverage.

- Frequency—2.4 GHz or 5.8 GHz (IEEE 802.11) application.
- Internal antenna or external antenna.
- PTP service—Wireless bridge.
- Point-to-multipoint service—WLAN or Wi-Fi.
- Mesh wireless systems—WLAN or Wi-Fi.

Access Point (AP) Installation

Because an AP is a radio device, it is susceptible to interference that can reduce throughput and range. Follow these basic guidelines to ensure the best possible performance:

- Ensure that a site survey has been performed to determine the optimum placement of APs. Review the AP locations, and identify the specific mounting methods required for each location.
- Mount APs at least 1 meter (m [3.28 feet (ft)]) away from metal obstructions, especially when using the antennas directly attached to the AP.
- Do not mount APs outside unless they are in a manufacturer-approved enclosure.
- Mount the AP at the specified location using the manufacturer-specified mounting instructions. APs can be installed in the following configurations:
  - Above the drop ceiling
  - Flush with the drop ceiling
  - Wall mounted
  - Stand-alone on a desktop

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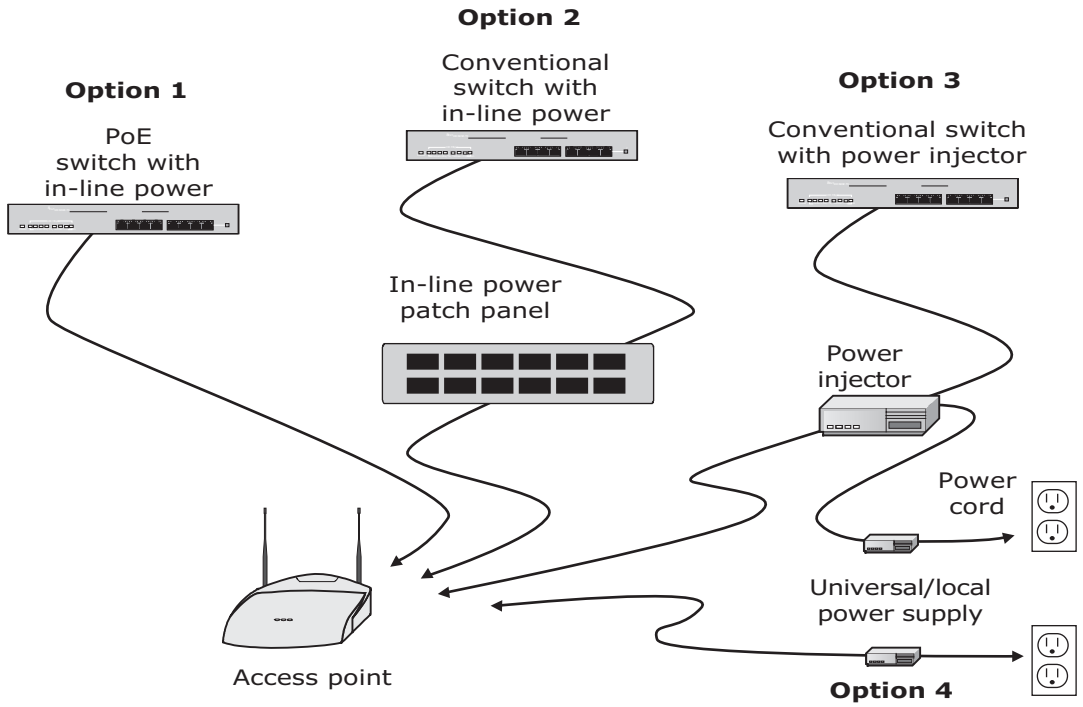
Access Point (AP) Installation, continued

- Record the AP serial number and medium access control (MAC) address if visible. This will assist the network integrator in configuring and testing the AP after the installation.
- APs will need a power source. The power may come from two sources:
  - Power that is provided by an electrical outlet installed on the wall, in an external enclosure, or in a ceiling enclosure.
  - Power over Ethernet (PoE). This power is provided by a PoE switch or power injector. In this case, the power is delivered via an unshielded twisted-pair (UTP) cable.

NOTE: Electrical power can include one multiple source power source (supply) within a common area with individual power cables placed to an AP. The designer must know the distance between the AP and the power supply before designing this type of power application.

Figure 12.5 shows an example of the various methods by which an AP can be powered. Option 1 shows a PoE switch with inline power. Option 2 shows a conventional switch that uses an inline power patch panel. Option 3 shows a conventional switch that uses a power injector. Option 4 shows an AP being supplied with local power.

Figure 12.5
Powering an access point



PoE = Power over Ethernet

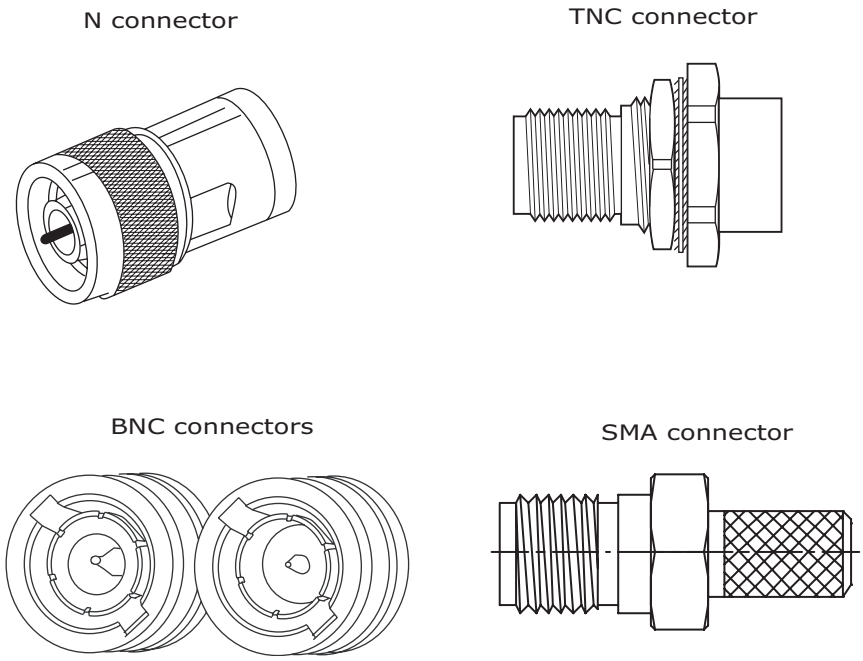
Antenna-to-Access Point (AP) Connection

Most antennas used with APs indoors come with a 0.91 m (3 ft) cable, commonly known as a pigtail. Special-length pigtails can be ordered from the antenna manufacturer.

Connect the pigtail to the AP following the manufacturer's instructions. Most pigtails consist of a Series-58 cable connected to a subminiature version A (SMA)-type connector or a Series-316 cable connected to a multimedia communications exchange (MMCX) connector.

For external antenna connections, normally APs will be connecting to the antenna via a Series-58 cable with loose connectors. In this case, the ITS installer will have to install the proper connector to the Series-58 cable on both ends following the manufacturer's instructions. Figure 12.6 is a sample of the various types of connectors that an ITS installer may need to use.

Figure 12.6
Connector types



BNC = Bayonet Neill-Concelman
SMA = Subminiature version A
TNC = Threaded Neill-Concelman

Access Point (AP)-to-Switch Connection

APs will be connected to a switch located in the supporting TR. APs are connected to the switch via category 6/class E cabling. Normal data connection installation procedure will apply. The ITS installer will install UTP cabling from the TR and install the proper 8-position, 8-contact (8P8C) connectors to connect the AP and the supporting switch. Cables should be routed as recommended for data cables.

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Distributed Antenna System (DAS) Installation Fundamentals

Distributed Antenna System (DAS) Antenna Parameters

Some parameters to consider when installing DAS antennas are the:

- Interior or exterior physical placement of the antenna (e.g., wall, ceiling, mast, interior, exterior, aesthetics).
- Location of the antenna.
- Desired qualities such as omnidirectional, semidirectional, directional, or radiation cabling.

NOTE: Care must be taken to ensure that radiating cable is properly polarized for the application for which it is intended. Changing the polarization of the cable run can cause distortion and loss of the signal.

Mounting Methods for Distributed Antenna System (DAS)

Equipment and Antennas

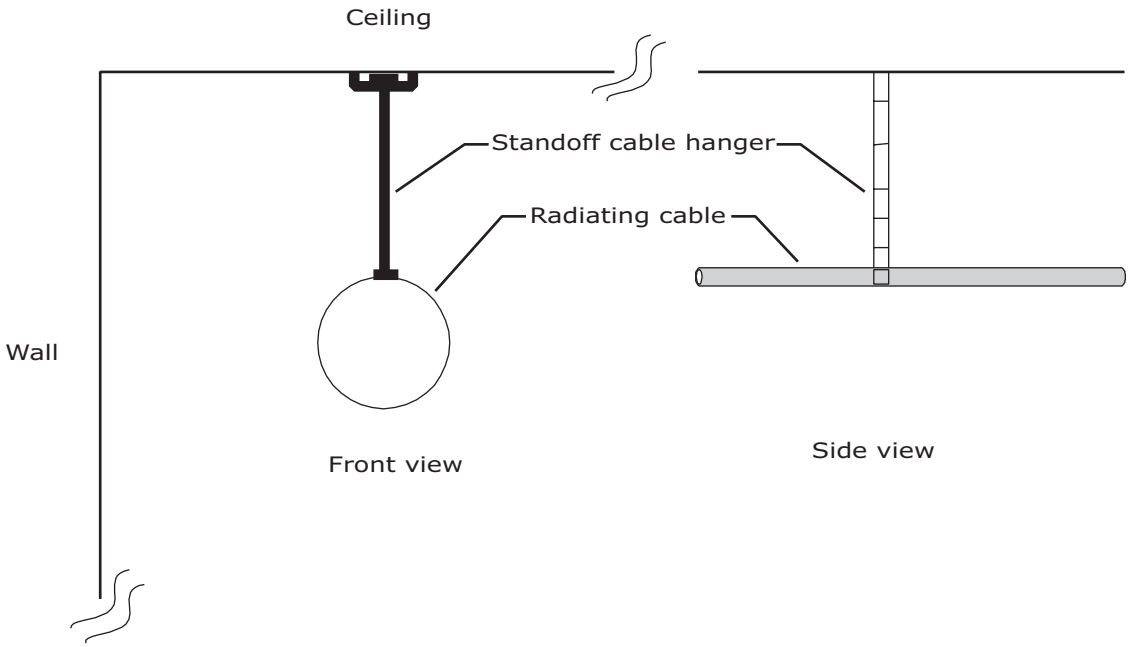
Mounting methods for DAS equipment and antennas vary based on the type of system (e.g., manufacturer, model) being installed and the location and environment where the various components are deployed. The mounting methods referenced in this section are the common methods.

The ITS installer should recognize that specialized applications and requirements might mandate the fabrication of mounting devices and methods. In all cases, compliance with local codes and standards is mandatory.

Radiating cable is typically mounted with standoff cable that keep the radiating cable a set distance away from the nearest physical obstacle to preserve the uniformity of the radiation pattern hangers (see Figure 12.7).

Mounting Methods for Distributed Antenna System (DAS), continued

Figure 12.7
Radiating cable standoff mount



Distributed Antenna System (DAS) Equipment

In indoor applications, rack- or wall-mounted methods are commonly used. Wall-mounted methods may be accomplished as freestanding (equipment directly mounted to the backboard) or enclosed in cabinets.

Indoor applications include:

- Direct wall mounted—Directly fixed to a backboard with screws or other fasteners.
- Cabinet wall mounted—Installed into a specialized or commonly available cabinet.
- Rack mounted—Installed in open or enclosed rack assemblies.

In outdoor applications, the roof, building enclosures, and tower-mounted equipment are common methods for equipment mounting.

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Mounting Methods for Distributed Antenna System (DAS), continued

Outdoor applications include:

- Wall mounted—Directly mounted to an outdoor wall with screws and fasteners.
- Cabinet wall or pedestal mounted—Installed in a protected or environmentally controlled cabinet, typically using rack rails.
- Pole mounted—Installed on a power distribution pole, light pole, traffic light, or auxiliary fixture using through bolts or straps.

NOTE: The installer should have personal protective equipment (PPE). Refer to Chapter 2: Safety Procedures for information on the available equipment and safety considerations.

Rooftop Installation Considerations

When installing on a rooftop, the installer will need to consider the follow items:

- Penetrations:
  - Roof
  - Wall
  - Nonpenetration mounts
- Presence of a lightning protection system

Site Survey

A site survey should be conducted, when possible, before installing a DAS. The following items should be noted and recorded to aid in planning and installing the DAS:

- Building configurations:
  - Single story or multistory
  - Single or multiple building campuses
  - Single tenant or multi-tenant
- System orientation:
  - Above ground
  - Below ground
  - Vertical or horizontal orientation (tunnel or high-rise)
- Composition of construction materials:
  - Concrete, masonry, brick, or stone outer walls
  - Wood floors, studs, or roof
  - Framed wall, plaster, or masonry inner walls
  - Metal studs, floors, or roof

Installing Paging Systems

Overview

When installing an overhead voice paging system, the ITS installer should be familiar with the overall intent of the design. This will assist the ITS installer in the proper installation of the system.

A typical installation consists of:

- A headend.
- Cabling.
- Speakers.

The cabling will be placed first in the construction process. Two basic types of voice paging systems are:

- Centrally amplified systems (25/70/100 volt [V]).
- Distributed amplifier systems (24 volt direct current [Vdc]).

The various components for these two types are interchangeable only within each system type. That is, centrally amplified components from one manufacturer may be used with those of another manufacturer of centrally amplified components, and distributed amplifier components from one manufacturer may be used with those of another manufacturer of distributed amplifier components.

Overhead Paging Systems

Loudspeaker Cabling

Loudspeaker cable for a 70 V centrally amplified system typically consists of two stranded, twisted, and unshielded conductors. The length of the cable and the total loudspeaker wattage on the cable determines the cable gauge. For 24 Vdc distributed amplifier systems, a 2-pair balanced twisted-pair is required, but typically a 4-pair cable is used. Cable-jacket ratings are dictated by the space in which the cable is located.

Loudspeaker cables should be separated from other low-voltage cables. This is especially true for centrally amplified systems.

The design provided to the ITS installer will determine whether the cable should be home run or looped for either type of system.

Often the cable will be installed before the project is ready for loudspeakers. Enough cable slack should be provided and secured in place to facilitate easy installation of the loudspeaker at a later date.

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Overhead Paging Systems, continued

Loudspeaker Installation

Loudspeakers to be mounted in a suspended ceiling should be installed soon after the grid is in place. The ITS installer should always follow the manufacturer's recommendations when installing loudspeakers. Failure to do so may result in the loudspeaker's fall from the ceiling. Codes may require support brackets and fire-resistant back boxes.

Horn loudspeakers are typically used in environments where no suspended ceiling exists. Horn loudspeakers need to be securely mounted, typically on a wall and using the building structural steel. These may be a vertical I-beam or horizontal roof-support structure.

Connecting Cabling to Loudspeakers

For centrally amplified systems, the cable will typically have two conductors. Ceiling loudspeakers will have several connections. As a rule, there will be a common connection and several wattage connections, including 0.125 watt (W), 0.25 W, 0.5 W, 1 W, 2 W, and 4 W. The ITS installer should connect one conductor to the common and the other conductor to the wattage tap designated in the design. Polarity should be observed when connecting the loudspeakers. If one conductor is black, it should always be connected to the common connection. If the loudspeakers are looped, the cable feeding the next loudspeaker will be connected to these same terminals.

Horn loudspeakers may have only two connections points. In this case, a knob or a screw will adjust the wattage. Polarity still needs to be observed.

For distributed amplifier systems, the loudspeakers will have four connections. Two connections will be for the 24 Vdc power, and two connections will be for the audio feeding the loudspeaker. Polarity and feeds must be observed. The audio must not be mixed with power, and the 24 Vdc power must be connected in the same polarity with the same conductors. Distributed amplifier horn loudspeakers will have four connection points just as the ceiling loudspeakers do.

Distributed amplifier systems will sometimes have remote power supplies. The cable connecting these systems will sometimes need to be routed to these power supplies. The power supplies will only power a certain number of loudspeakers.

Overhead Paging Systems, continued

Headend

Headend equipment may include amplifiers, zone paging devices, tone generators, message devices, telephone system interfaces, and other devices as required. The ITS installer should become familiar with the devices and their interconnection. Audio levels vary greatly in the headend of a paging system. Cables carrying the signal to the loudspeakers in a centrally amplified system carry relatively high signal levels. The cables should be kept physically separate from the signals connected to the inputs of the amplifiers. This separation is not critical in distributed amplifier systems. Headend equipment may be mounted in a rack or on a wall. If mounted on a wall, sufficient support is required. Typically, plywood is affixed to the wall as a support structure for the equipment.

NOTE: For further information, refer to BICSI's current *Telecommunications Distribution Methods Manual* (*TDMM*) and *AV Design Reference Manual* (*AVDRM*).

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Installing Sound Masking Systems

Overview

With the trend toward open office space planning and a reduction of cubicle size, the increased employee density has significantly elevated noise levels, causing distraction, increasing employee stress, and decreasing employee productivity.

The American Society of Testing and Materials (ASTM) has set a privacy index (PI) for the amount of privacy from one cubicle to another in open office configurations. PI ranges from 0 to 100 with 0 being no acoustical privacy, and 100 being complete acoustical privacy. PI is not a percentage; rather, it is an exponential ratio. A PI of 50 does not equal 50 percent privacy. The target rate for PI is between 80 and 90 percent. Table 12.1 shows the relative acoustical privacy according to the ASTM index.

Table 12.1
Privacy index

Privacy Index	Privacy
0–69	No privacy
70–79	Transitional privacy
80–94	Normal privacy
95–100	Confidentiality

NOTE: Additional information on the design of sound masking systems can be found in BICSI's current *AVDRM*.

Three ways to control noise within an office environment, often referenced as the ABCs of sound masking, are to:

- Absorb sound.
- Block sound.
- Cover up sound.

Ceiling tiles and carpets perform sound absorption. Cubicle partitions and walls block the sound. Sound masking effectively covers up the noise that cannot be absorbed or blocked.

Basic Installation Practices

Sound masking systems are proprietary systems that involve multiple methods of obtaining the desired effect of covering the noise levels within open office areas. Each consists of the following basic components:

- Masking generator
- Equalizer
- Amplifiers
- Loudspeakers
- Volume controls

Most sound masking systems are centrally amplified systems. However, there are also systems that can be installed utilizing balanced twisted-pair cable for distributed amplifier cables. Some systems use 18 AWG [1.0 mm (0.039 in)] 5-conductor plenum-rated cable.

Types of Sound Masking Systems

Two types of sound masking systems are:

- In-plenum.
- Direct-field.

In-Plenum Systems

In-plenum systems utilize loudspeaker assemblies installed above the ceiling tiles. ITS installers need to consider several factors during the installation:

- The sound reverberates in the plenum area through the ceiling tiles into the workspace below. The ideal installation is to locate the loudspeakers just above the ceiling tiles and direct the loudspeakers upward to the surface above in the plenum space (e.g., roof structure, floor above).
- If sound-absorbing insulation is applied to the underside of the structural decking, loudspeakers should be aimed downward or sideways.
- Some manufacturers use loudspeaker enclosures to reflect sound downward.

Direct-Field Systems

Direct-field systems are installed directly in the workspace and may result in a quieter, less obtrusive sound that masks speech. Direct-field systems are easier to install and require much less tuning than in-plenum systems. In addition, direct-field systems can work in environments that do not have ceiling tiles in place. Direct-field systems use loudspeakers/emitters that can be installed in furniture, ceiling tiles, or other fixtures.

Regardless of the system, ITS installers must follow the installation instructions of the specific sound masking system manufacturer. An acoustical consultant should perform the tuning of the installed system.

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Installing Clock Systems

Many types of clock systems are currently in use. A clock system utilizes some type of control device, which is sometimes called a master clock. The clocks, called secondary clocks, are installed for personnel to read throughout the facility.

Controls signals may be transmitted through dedicated copper cabling, over the building power system, or via wireless signals.

Wireless systems typically use a proprietary signal structure or terrestrial satellite signals. The signal for either one of these systems may need to be amplified to effectively reach all of the secondary clocks in the facility.

Wired secondary clocks may use several types of correction. These are minute impulse or 59th minute correction. Minute-impulse clocks receive a pulse each minute. The clocks that employ 59th minute correction use a motor that normally runs the hands.

EXAMPLE: At the 59th minute, the master clock sends a pulse that adjusts the secondary clocks to the correct minute. At 6 p.m. each day, the master clock sends a longer pulse that corrects all of the secondary clocks to the correct hour.

Extending Special Circuits

Overview

Alternative solutions for allowing a circuit to reach its destination are important. Standards for equipment, circuit service, and cabling requirements are the key components for transmitting voice, data, and video users.

NOTE: Refer to BICSI's *TDMM* Chapter 1: Principles of Transmission, which gives detailed information on what makes a circuit. Standards, applications, and performance information are provided using both copper and optical fiber cabling mediums.

Typical Circuit

A typical circuit uses an electrical or optical conductor to carry current or light from one point to another. Metallic conductors (e.g., copper, copper-covered steel, high-strength copper alloys, aluminum, silver, gold) are used to carry electrical signals. Silver and gold are typically not used because of high costs of the metals. Singlemode or multimode graded glass is used to carry signals optically.

The common factor among the two conductor mediums is that they both must transport a circuit within the bandwidth range and dB loss requirements of the circuits' standard. Standards-making bodies write the performance standards for a circuit so that it can be transported to the user without error.

Principles of Transmission

Analog signals are in the form of a wave that uses continuous variations in time in order to transmit information. The fundamental example of an analog signal is the sinusoid, which is an oscillating, periodic signal that is described by amplitude, frequency, and phase. Amplitude is the amount of amplification. Hz is the standard unit for frequency measurement. Phase is the description for the reference of time.

Decibel levels are used to express power ratios of all types of analog and digital signals regardless of the transport medium. Echo and delay occur when a signal encounters a discontinuity in the medium carrying the signal, causing some of the signal power to be reflected back to the transmitter. The reflected signal appears as a delayed version or echo.

Echoing in voice circuits is occurring all of the time but is usually returning so fast that it is not noticeable from the original sound. For an echo to occur, there has to be enough delay for the echo to be distinguishable from the original source of sound.

Phase and delay can be expressed as a phase shift or time delay. More complex signals are composed of many sinusoidal components. A delay is expressed only in time, not in phase.

These simple descriptions for transmitting a signal are important to understand so that the signal can be transported without problems.

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Principles of Transmission, continued

Analog Telephone Transmission

The telephone, from which a voice signal originates, can be considered a signal generator that is connected to a load. This is a combination of the connecting cables and the other telephone. The cables are the transmission line.

The maximum transmission of electrical power occurs when the transmitting device and the receiving device have the same load resistance or impedance. Impedance is a parameter that applies to alternating current (ac) signals. Like resistance, impedance is expressed in ohms and has both a magnitude and a phase component.

The source or load impedance connected to line must be matched in the best way possible for maximum efficiency. In voice-band applications, a typical impedance of 600 or 900 ohms is used to match the cable pairs. The impedance of 600 ohms is used for private line circuits and trunks, and 900 ohms is used for central office (CO) switching system line circuits.

At voice frequencies, the principal elements contributing to loss and phase distortion are the conductor resistance and the mutual capacitance of the cable pair in the field. Increasing the frequency increases the speed of the transmission through the cable pairs.

Telephone Company Pair Loading

Common telephone practices use a higher gauge wire to increase the frequency over longer distances. Typically, a telephone plant will use 24 AWG [0.51 mm (0.020 in)] wire for service to subscribers. Using 22 AWG [0.64 mm (0.025 in)] or 19 AWG [0.91 mm (0.036 in)] wire will increase the frequency over the longer distance of a cable pair.

Telephone companies apply inductors or loading coils placed at intervals along a cable route to improve speech transmission quality. These load coils compensate for the capacitance of a cable pair and reduce the capacitive current loading in the range of audio frequencies.

The most common distances for loading coils is 1.37 kilometer (km [4500 ft]) for D-loading and 1.8 km (5900 ft) for H-loading. It is important to understand that without the load coils, a voice signal transmitted from the central switching office will leave as a strong signal and eventually will weaken and disappear as the distance from the CO increases.

Load coils by design cut off frequencies above the voice range. The shorter the distance between the coils, the higher the cutoff frequency. Load coils will block analog high-fidelity and digital signals.

Telephony engineers design the last load coil on the cable pair to the subscriber to allow for cabling within the structure past the lightning protector.

Principles of Transmission, continued

Cable TV Systems

Cable service providers transport cable TV, voice, and data via their coaxial or optical fiber network cabling. The coaxial plant uses a trunk coaxial cable, which travels over a great distance to amplifiers and taps. The engineer uses a formula to ensure that the signal is not degraded between the amplifiers and taps. The number of subscribers and the distance of the cable are important elements for consideration. This is a dB loss measurement.

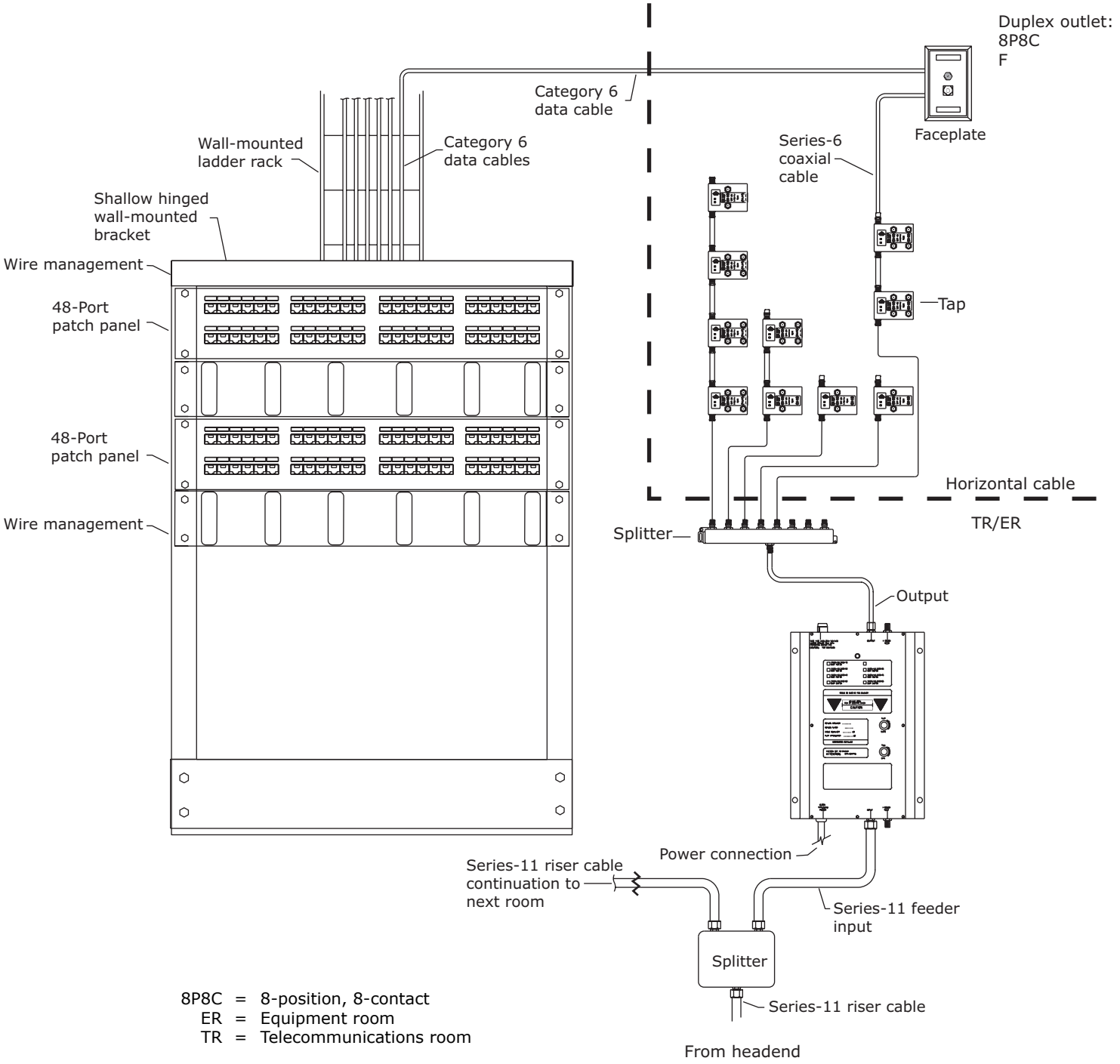
The more modern system uses singlemode optical fiber cable from the headend to the nodes distributed to serve a particular area. Nodes are used to branch off with additional optical fiber cable to the next node or to transport the signal to a more traditional coaxial plant. Optical fiber equipment is used to regenerate the signal to the optical fiber and coaxial cable plants.

Figure 12.8 is an example of a coaxial TV distribution network. Figure 12.9 is an example of an optical fiber distribution network.

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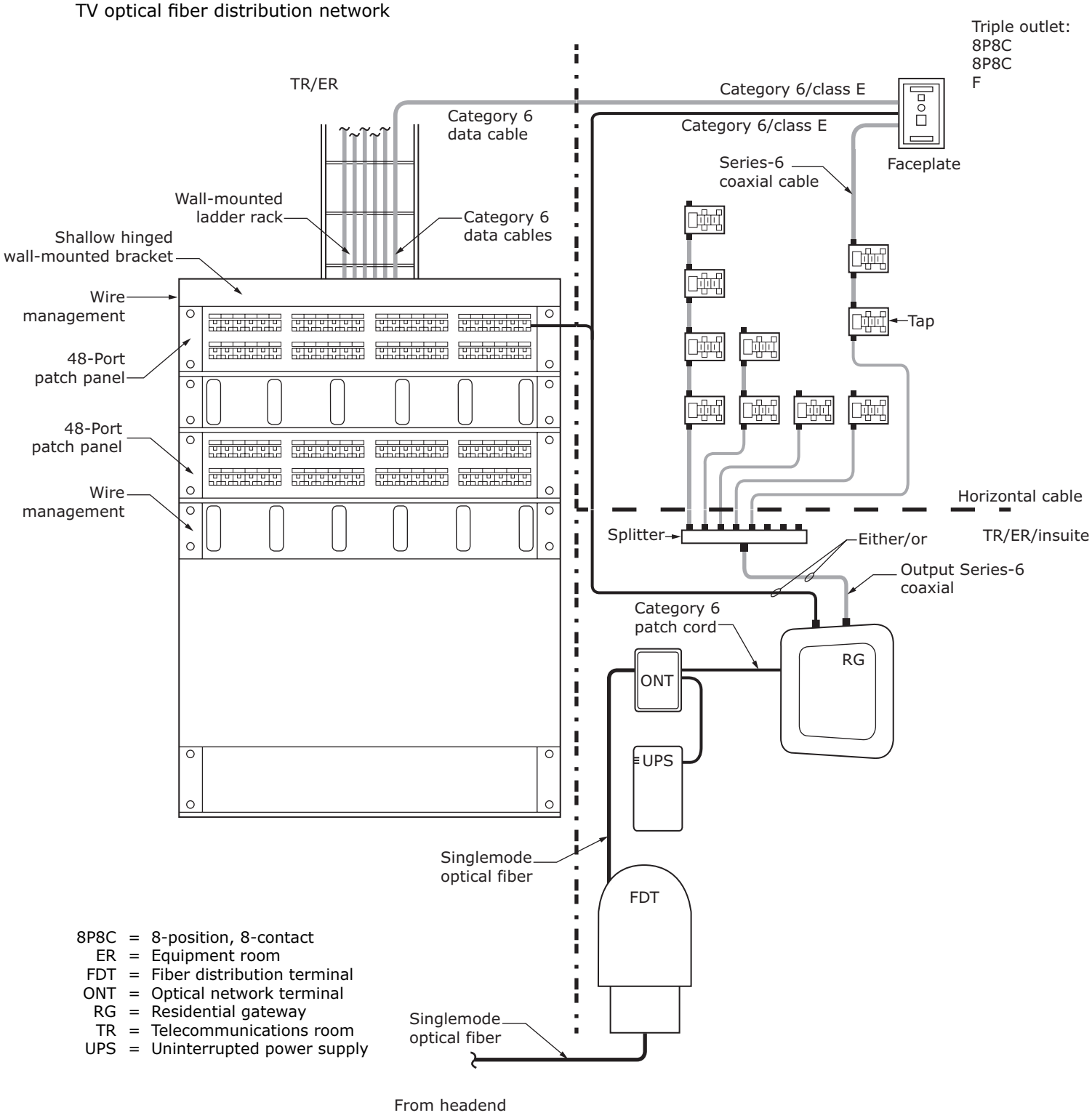
Principles of Transmission, continued

Figure 12.8
TV coaxial distribution network



Principles of Transmission, continued

Figure 12.9
TV optical fiber distribution network



8P8C = 8-position, 8-contact
ER = Equipment room
FDT = Fiber distribution terminal
ONT = Optical network terminal
RG = Residential gateway
TR = Telecommunications room
UPS = Uninterrupted power supply

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Principles of Transmission, continued

Transporting Digital Signals

Information transmitted by a telecommunications system can originate as analog or digital. Digital data is represented by a string of bits, whereas analog data is represented by the continuous variation of the data.

Sending digital data has a major advantage over sending analog data. If the digital signal is recovered before attenuation and added channel noise becomes so large that bit errors occur, then the signal can be recovered exactly. Thus, digital signals can be transmitted noise free over essentially unlimited distances if the digital data is recovered and regenerated at intervals before it is degraded by added noise.

Digital transmission systems can transmit analog data by first converting it to equivalent digital data, but a transmission system that is designed to transmit analog data cannot efficiently handle digital data.

Equipment determines whether a digital signal is transmitted as an asynchronous or synchronous transmission signal. Asynchronous transmission occurs without a precise time relationship in the signal characters or the bits that represent them. Synchronous transmission is performed by synchronizing the data bits in phase or in unison with equally spaced clock signals or pulses. Both the sender and receiver must have timing and synchronization capabilities.

Synchronous transmission is more efficient than asynchronous transmission because no start and stop bits are required. It is used for digital baseband transmission systems.

Digital signal transmission signals are transported using time division multiplexing (TDM). The levels of multiplexing are DS0, DS1, DS2, and DS3. The levels in Europe are E1, E2, E3, and E4.

DS0 signals are the lowest hierarchy and are typically groomed down from a T1 within a building it is serving.

The DS1 or E1 signal can operate over standard balanced twisted-pair cable within specific distance limits and design conditions. It is widely used for short haul distances up to 320 km (200 mile [mi]).

The DS2 or E2 signals over 305 m (1001 ft) require special balanced twisted-pair cable (e.g., low capacitance) that has special crosstalk and attenuation characteristics. This signal is seldom used except in low-speed optical fiber systems that carry these signals.

The DS3 and DS4 or E3 and E4 signals are used between customer locations and between customer and main entrance facility locations. They are carried over short distances or several kilometers (miles) through optical fiber systems.

Premises Signal Cabling

Twisted-Pair Premises Signal Cabling

At the premises location, analog or digital signals are handed off through balanced twisted-pair, coaxial, or optical fiber cables.

Voice-grade signals can be delivered through the lightning protection copper cable pair, a port of a piece of equipment, or a cross-connect panel. Standard voice signals are typically delivered to the telephone or a telephone system with a jumper wire cross-connected from the pair of copper conductors of the lightning protector.

These signals can travel between buildings and multiple cross-connects. Analog voice signals can also be looped together so that multiple locations can have the same telephone number.

Voice signals can be transported via a T1 and then groomed with a channel bank. A typical channel bank will groom out 64 voice-grade lines. The lines are then cross-connected to equipment twisted-pair cables, lightning protection, another building, house vertical or horizontal cables, or directly to a station cable.

T1s can be extended within a building by a smart jack card with a longer dB loss range. When a T1 is tested and the loss factor appears to be out of range because of distance, the card extends the signal by applying a small amount of voltage on the signal to carry it farther than a normal card.

Optical Fiber Premises Signal Cabling

Distance limitation plays a major role in transporting Ethernet, T1, and T3 signals to their destinations. Cabling standards for transporting these signals must be adhered to, or the signal will degrade and not reach its destination.

Telephone companies, hospitals, high-rise buildings, and campuses use equipment and optical fiber cable to extend the service to its destination. This is called PTP optical fiber extension equipment.

The equipment at the main equipment end is typically a multicard port system. Typically, it has 14 ports, depending on the manufacturer. This allows the engineer to purchase the right card needed to extend the Ethernet, T1, or T3 signal to its destination. The equipment can be powered by either ac or direct current (dc) voltage.

At the destination end, another multicard port piece of equipment is installed. Typically, it is placed in a TR within the customer's computer room or in a room where multiple signals can be served. Equipment at the user end is typically 2 to 14 ports, depending on the manufacturer's and the designer's requirements. The equipment can be powered by either ac or dc voltage.

The in port of the equipment is a dual optical fiber connector. The out port is an RJ-45 for Ethernet, RJ-48 for a T1, and coaxial for a T3.

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Premises Signal Cabling, continued

Singlemode or multimode optical fiber cable is placed between the main equipment end and the destination end. The cable can be terminated into an optical fiber patch panel and cross-connected through an optical fiber jumper cable to the equipment or directly terminated and plugged into the equipment. Optical fiber cables serving multiple buildings and floors with various optical fiber panels can also be used to connect the equipment. It is not a requirement to make the main optical fiber cabling always end at one equipment point.

Dual-position pieces of equipment at the destination end can be placed at several premises locations. This is done by the branching of the optical fiber panel with additional optical fiber cable to the piece of equipment.

Engineers have to ensure that they do not extend the dB loss factor between the main equipment light source and the extended equipment's light receiver. This test is performed with a light source and meter. The meter can also be placed at the end of the optical fiber cable or jumper where it plugs into the extension equipment. This helps the technician to know what the light source's loss factor is before it is plugged into the equipment.

Because most systems use two optical fiber strands per circuit, the engineer must calculate how much main optical fiber cable is required for the cable network to serve the extension equipment or multiple extension equipment points.

The extension equipment must also be placed in a location so that the Ethernet, T1, or T3 signal is within the limits of the standard. If the equipment is placed out of bounds of the standard, the signal can be degraded or not work properly.

The approximate cabling distance limitation for a T1 is 366 m (1201 ft). Ethernet is 100 m (328 ft). A T3 coaxial cable is 122 m (400 ft).

Native LAN Presence in Remote Locations

An Ethernet extension system can be installed as an Ethernet extension for remote locations beyond a typical large campus environment (e.g., railway yards, military bases) where a single Internet protocol (IP) segment network is necessary. This configuration extends carrier or enterprise LANs by connecting separate LANs via the device's Ethernet interface then connecting back-to-back (origination device to destination device) via the TDM-based T1 circuit or digital subscriber line (DSL)-based wide area network (WAN) circuit.

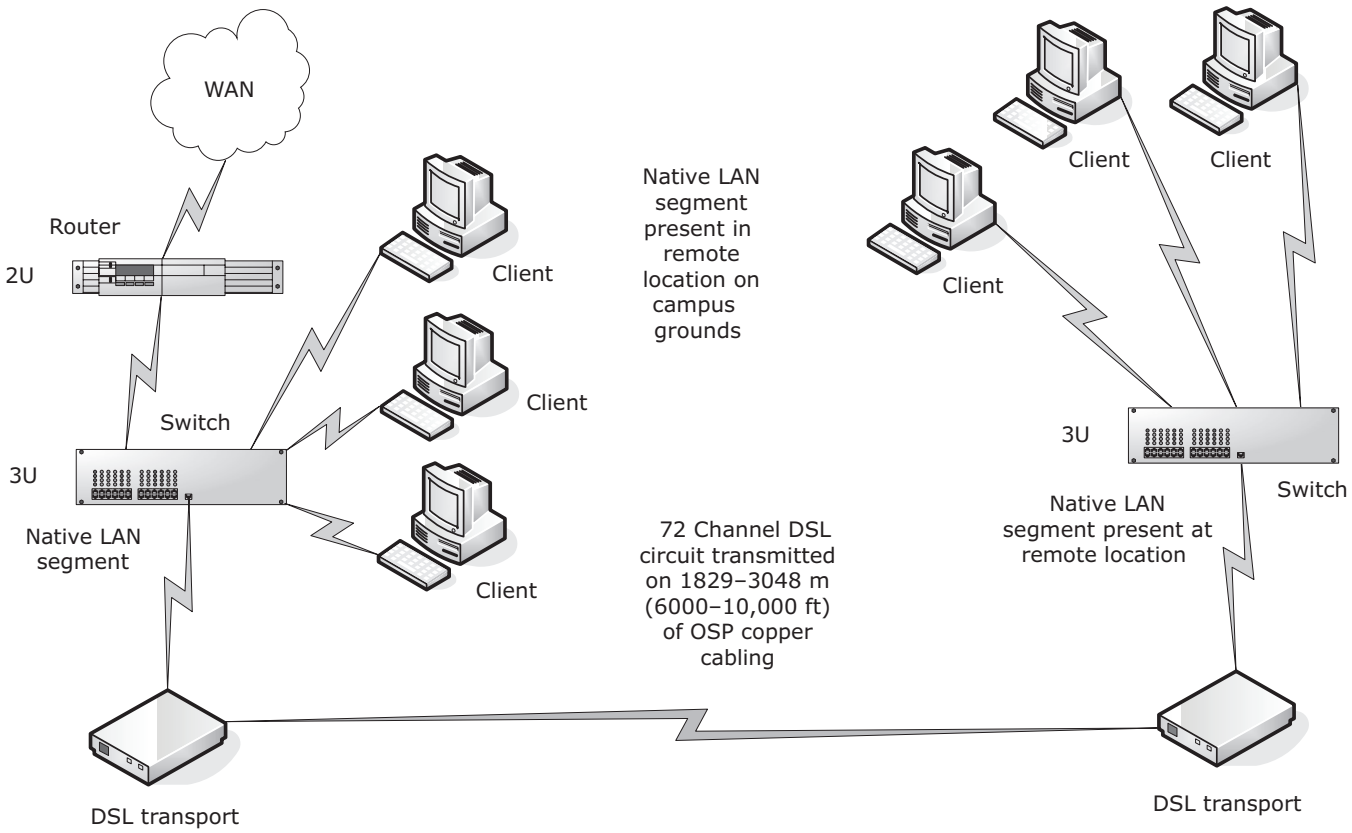
The DSL devices are managed through the command line interface (CLI) or through the graphical user interface (GUI) screens such as a standard web browser.

The operating distance up to 3048 m (10,000 ft) for the LAN extension system can be affected by the type of cable (including gauge of copper wire 24-26 AWG) and manufacturer of equipment along with other limitations such as outside environment issues.

This solution can be deployed in large single-tenant or single-user campus environments utilizing already-installed outside plant (OSP) cabling infrastructure (see Figure 12.10).

Premises Signal Cabling, continued

Figure 12.10
Native LAN segmentation present at remote site



DSL = Digital subscriber line
ft = Foot
m = Meter
OSP = Outside plant
U = Unit
WAN = Wide area network

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Cable TV Premises Cabling

Cable TV companies deliver their signal to the premises as close to zero dB loss as possible at the grounded connection. Loss for premises cabling, including the taps, should not exceed 7 to 8 dB of loss. Exceeding this loss can cause distortion of signals, especially digital and high-definition TV (HDTV).

When loss is apparent within premises, amplification equipment can be installed before the first tap within the building. The equipment can also be installed on a particular cable run that will cause the signal to exceed the loss factor.

NOTE: ITS installers must understand what the standard and loss factor is of an analog or digital signal.

Building Automation System (BAS)

Overview

The objective of a BAS is to centralize and simplify the monitoring, control operation, and management of a building. The purpose is to achieve an improved building operation, reduce energy costs, and provide a safe and comfortable working environment for the building occupants.

A BAS within an intelligent building (IB) can be categorized as energy management systems or safety/security systems.

Energy management systems reduce costs by controlling electricity expenditures for lighting and heating, ventilating, and air-conditioning (HVAC) systems and monitoring maintenance requirements.

Safety systems consist of fire alarm systems and security and access control systems.

Most BASs are vendor-specific, and the ITS installer must follow the manufacturer's specific installation procedures to ensure a proper operating system.

NOTE: The design of a BAS is covered in detail in BICSI's *TDMM,* which should be used as a reference when making such installations.

Building Automation Cabling

The horizontal cabling of a BAS shall be in a star topology consisting of any of the following media approved by the standards:

- 100-Ohm balanced twisted-pair cable
- Multimode 62.5/125 or 50/125 micrometer (µm) optical fiber cable
- Singlemode optical fiber cable

The cable is connected to a BAS outlet/connector, a horizontal connection point (HCP), or both.

The system can be configured as a:

- Centralized BAS.
- Distributed BAS.

A centralized BAS must comply with the distance requirements specified for centralized optical fiber cabling. Distributed BAS links shall be no more than 90 m (295 ft) independent of the media chosen.

A minimum of one dedicated horizontal cabling link shall be provided for each distinct BAS service. Although some BAS applications allow multiple channels within the same cable, the ITS installer should consult with the BAS equipment manufacturer prior to installing BASs sharing the same cable. Local codes or the AHJ may restrict sheath sharing.

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Appendix A
Codes, Standards, Regulations, and Organizations

Appendix A describes the codes and standards that an information technology systems (ITS) designer and installer must be aware of for the design and construction process of the ITS system. Appendix A details the sources of codes and standards and lists important international, multinational/regional, and country-specific codes and standards.

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Introduction

Nothing impacts the design and construction of a telecommunication network more than codes, standards, and regulatory acts. The information technology systems (ITS) designer and installer must be familiar with the electrical, communications, safety and building codes, standards, directives, and regulations for the nation, region, and municipality in which the design and installation work is performed. The ITS designer and installer must be aware of the critical importance of compliance with codes and standards.

In recent years, national, regional, and international standards-making bodies have joined efforts to harmonize the standards affecting information communication systems. These harmonization efforts, along with the technological developments that impact standards, codes, and regulations, maintain the dynamic nature of the documents.

Codes and standards are considered living documents because they are continually reviewed and revised. Codes such as the *National Electrical Code*® (*NEC*®) in the United States are typically revised every three years, and standards are revised every four to seven years, depending on the technology. The ITS designer must follow the changes in these dynamic processes.

The continuous standards harmonization efforts do not guarantee that all of the unique requirements for a specific design work area are covered. Since other disciplines (e.g., data processing, telephony, construction, architecture) are involved in the telecommunications design, the ITS designer should also be knowledgeable about these related codes, standards, and local and national regulations.

Therefore, the ITS designer must follow the rules that govern:

- Local carriers.
- Access providers (APs) and service providers (SPs).
- Telecommunications industry.
- Postal, telegraph, and telephone (PTT).

To aid ITS designers and installers, this appendix provides information on the critical codes, standards, and regulations encountered routinely in performing their duties. Information is also provided on standards that may be encountered for specific applications (e.g., outside plant, wireless), which are not necessarily included in all projects.

Construction

In the United States, Canada, and many other countries, building codes and standards regulate the construction industry. The local authority having jurisdiction (AHJ) normally enforces the codes, standards, and the legal regulations for the jurisdiction.

Codes and standards encompass most, if not all, aspects of the construction industry. Installation methods and products must conform to local regulatory, code, and standards requirements.

ITS designers and installers must have a thorough knowledge of the applicable sections of these codes that affect telecommunications. Because this topic is complex, a separate section in this appendix details the various code authorities, standards committees, and reference sources.

Be aware that these codes and standards are updated regularly. It is the responsibility of the ITS designer and installer to follow the changes.

Codes, Regulations, and Directives

Codes pertain to:

- Electricity.
- Building.
- Fire.
- Other safety issues.

The purpose of codes is to ensure the:

- Practical safeguarding of persons and property from hazards.
- Quality of construction.

The *NEC*® in the United States and the *Canadian Electrical Code (CECode)* in Canada are issued to provide the criteria for minimizing the risk of electrical shock, fires, and explosions from electrical installations. Codes, when adopted by an AHJ, have the force of law and regulatory powers.

An AHJ may be a specific code authority (e.g., electrical inspector, building inspector, fire marshal). Typically, more than one AHJ will be invoved on the project site because of different aspects requiring review and approval. The ITS designer and installer must meet with and comply with their specific concerns.

State, provincial, municipal, and local codes may be more restrictive than national codes and regulations and, therefore, take precedence. The order or hierarchy of code compliance should be in full conformance to local, state, and national codes.

In the European Union (EU), a set of regulations titled "Directives," take precedence. Some examples of such regulations are *Construction Products Directive* and *Electromagnetic Compatibility Directive*.

Within each country, building regulations and other government-mandated regulations are enforced.

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Standards

A standard is a document, developed and approved by consensus, that establishes requirements for processes, procedures, practices, or methods. Additionally, standards may be established for the selection, application, and design of materials, equipment, products, and services.

One of the purposes of a standard is to ensure a minimal level of acceptable performance. While codes and safety standards address the safety of persons and property in the installation or use of a telecommunications or other system, codes do not ensure the system functionality. Codes often reference numerous standards to ensure the minimum functional requirements of a given material or component.

Safety standards provide the criteria for safety testing of a component or system. Performance and safety standards are typically test standards. Test standards provide uniform rules for the object, methods, and acceptable results of testing. For example, in the United States, the *NEC*® requires that a cable placed in space and defined as a plenum or other air-handling space must be listed for that purpose.

This listing is given to the material that meets a specific safety test standard of minimum acceptable requirements for:

- Flammability.
- Smoke generation.
- Smoke density.
- Amount of toxic gasses generated under flame.

Standards, continued

Other standards are not written for safety requirements, but they are written for product performance or conformance.

Standards are established as a basis to quantify, compare, measure, or specify:

- Capacity.
- Quantity.
- Content.
- Extent.
- Value.
- Quality.

As with most standards, telecommunications standards are typically voluntarily adopted. They represent industry consensus on requirements and best practices. A significant benefit of standards in the telecommunications industry is the ensured interoperability of components and systems by multiple manufacturers.

For example, if a manufacturer of network interface cards (NICs) does not adhere to standards such as IEEE 802.3, then the product may not properly function with other standards-compliant products.

Standardization Efforts

United States (U.S.) Standards Development

In 1985, the U.S. Computer Communications Industry Association (CCIA) asked the Electronic Industries Association (EIA) to develop standards for telecommunications cabling. EIA accepted the task, and the project was assigned to the Engineering Committee (TR) 42 (formerly TR 41.8).

In 1988, the telecommunications sector of the EIA (specifically the TR and Fiber Optics [FO] committees and subcommittees) became the Telecommunications Industry Association (TIA) under the TIA technical council. TIA conducted the standards activities through EIA until it no longer needed its sponsorship for National Standard recognition.

Many TIA standards that govern telecommunications cabling infrastructure are accredited through the American National Standards Institute (ANSI). As such, they have a broad industry acceptance throughout the United States.

Associations, such as the Alliance for Telecommunication Industry Solutions (ATIS), BICSI®, and the Society for Cable Telecommunications Engineers (SCTE), have developed standards that further define aspects of telecommunications cabling, cabling design, and cabling installation.

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Standardization Efforts, continued

International Standards Development

The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) jointly oversee international standardization of telecommunications cabling. These organizations form a specialized system for worldwide standardization.

National bodies that are members of ISO or IEC participate in the development of international standards through committees that deal with specific technical fields. ISO and IEC committees collaborate with other international governmental and nongovernmental organizations to develop harmonized international requirements.

In the field of information technology, ISO and IEC have established a joint technical committee, which is known as JSO/JEC JTC 1.

Independent Standards-Setting Organizations

A number of independent organizations specialize in establishing, certifying, and maintaining standards. Many industry trade organizations and national and international standards-setting bodies develop standards. Some of these organizations are listed in this appendix.

International Codes and Standards

International Code Council (ICC)

The ICC was established in 1994 as a nonprofit organization committed to developing a single set of all-inclusive and coordinated national model construction codes. The ICC was founded by the International Conference of Building Officials (ICBO), Building Officials and Code Administrators International (BOCA), and Southern Building Code Congress International (SBCCI).

The mission of the ICC is to provide the highest quality codes, standards, products, and services for all concerned with the safety and performance of the built environment.

The ICC has developed and made available the following international codes:

- International Building Code®
- International Energy Conservation Code®
- International Existing Building Code®
- International Fire Code®
- International Fuel Gas Code®
- International Mechanical Code®
- ICC Performance Code™
- International Plumbing Code®
- International Private Sewage Disposal Code®
- International Property Maintenance Code®
- International Residential Code®
- International-Wildland Urban Interface Code™
- International Zoning Code®

International Organization for Standardization (ISO)

ISO has a membership of 163 national standards bodies from countries large and small, industrialized, developing, and in transition in all regions of the world.

ISO produces documents and standards that affect telecommunications and is responsible for the seven-layer Open Systems Interconnection (OSI) model. The OSI model provides criteria for product development that is interoperable. The ITS designer and installer should be familiar with the standardized signaling and connection interface for various network-accessing protocols.

International Electrotechnical Commission (IEC)

IEC is a leading global organization that prepares and publishes international standards for electrical, electronic, optical fiber, and related technologies. These standards serve as a basis for national standardization and as reference for drafting international tenders and contracts.

Through its members, IEC promotes international cooperation regarding electrotechnical standardization and related matters (e.g., standards, conformity assessment).

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International Organization for Standardization/International Electrotechnical Commission Joint Technical Committee 1 (ISO/IEC JTC1)

In 1988, the ISO and the IEC created a Joint Technical Committee on Information Technology (ISO/IEC JTC1). ISO/IEC JTC1 produces standards that affect telecommunications.

The most relevant are:

- ISO/IEC 11801 Ed 2:2002, *Information Technology—Generic Cabling for Customer Premises*.
- ISO/IEC 14763-1:1999, *Information Technology—Implementation and Operation of Customer Premises Cabling—Part 1: Administration*.
- ISO/IEC TR 14763-2:2000, *Information Technology—Implementation and Operation of Customer Premises Cabling—Part 2: Planning and Installation of Copper Cabling*.
- ISO/IEC 14763-3:2006, *Information Technology—Implementation and Operation of Customer Premises Cabling—Part 3: Testing of Optical Fibre Cabling*.
- ISO/IEC 15018:2004, *Information Technology—Generic Cabling for Homes*.
- ISO/IEC 18010:2002, *Information Technology—Pathways and Spaces for Customer Premises Cabling*.
- ISO/IEC 24702:2006, *Information Technology—Generic Cabling—Industrial Premises.*
- ISO/IEC 24764 Ed 1.0: 2010, *Information Technology—Generic Cabling Systems For Data Centres.*

Institute of Electrical and Electronics Engineers® (IEEE®)

IEEE® is a nonprofit, technical professional association with more than 350,000 individual members in 150 countries. IEEE is an authority in technical areas ranging from computer engineering and telecommunications to consumer electronics. IEEE has nearly 900 active standards and an additional 700 under development.

The IEEE publishes many documents that affect telecommunications. Some important standards are:

- IEEE C62.41.1:2002 (R2008), *IEEE Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits*.
- IEEE C62.41.2:2002, *IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits*.
- IEEE PC62.41.2:2002/Cor 1, *IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits—Corrigendum 1.*
- IEEE C62.43:2005, *Application of Surge Protectors Used in Low-Voltage (Equal to or Less than 1000 Voltage, rms, or 1200 V, DC) Data, Communications, and Signaling Circuits.*
- IEEE C62.45:2002 (R2008), *IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits*.
- IEEE 81:1983, *IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System—Part 1: Normal Measurements*.
- IEEE 142:2007, *IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems—Green Book™.*

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- IEEE 446:1995 (R2000), *IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications—Orange Book™*.
- IEEE 450:2002, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*.
- IEEE P450:2010, *IEEE Draft Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.*
- IEEE 1100:2005, *IEEE Recommended Practice for Powering and Grounding Electronic Equipment—Emerald Book*.
- IEEE 1184:2006, *IEEE Guide for the Selection and Sizing of Batteries for Uninterruptible Power Supply Systems*.
- IEEE 1187:2002, *IEEE Recommended Practice for Installation Design and Installation of Valve Regulated Lead-Acid Storage Batteries for Stationary Applications*.
- IEEE P1187:2007, *Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Batteries for Stationary Applications.*
- IEEE 1188:2005, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*.
- IEEE 1394:2008, *IEEE Standard for a High-Performance Serial Bus*.
- IEEE P1394d:2009, *IEEE Standard for a High-Performance Serial Bus—Amendment: IEEE 1394 Single-mode Fiber Physical Medium (PMD) Specification.*
- IEEE 1394.1:2004 (R2008), *IEEE Standard for High-Performance Serial Bus Bridges*.
- IEEE 1394.3™:2003 (R2008), *IEEE Standard for a High-Performance Serial Bus Peer-to-Peer Data Transport Protocol (PPDT)*.

Project 802

The ITS designer and installer should be familiar with the Physical Layer signaling and connectivity for LAN standards under the IEEE Project 802.

Project 802 was organized specifically for the development of LAN and metropolitan area network (MAN) standards. The Local and Metropolitan Area Network Standards Committee (LMSC) develops LAN and MAN standards, primarily for the lowest two layers of the OSI Reference Model. The LMSC coordinates with other national and international standards groups with some standards now published by ISO as international standards.The objective of the LMSC is to develop standards that will be accepted by organizations using LANs as well as LAN hardware and software vendors. This encourages customers to ask for and manufacturers to develop standardized products, ensuring interoperability among products obtained from different vendors.

The working groups under the LMSC are identified as:

- Active—Standards published, continuing work.
- Hibernating—Standards published, but inactive. (At the time of this revision, there are currently no hibernating groups.)
- Disbanded—Did not publish a standard.

The LMSC working groups and some of their respective standards (including drafts) within IEEE 802 are described in the following sections.

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802.1 *Local Area Network (LAN)/Metropolitan Area Network (MAN) Bridging and Management*

- IEEE 802.1AB:2005, *IEEE Standard for Local and Metropolitan Area Networks—Station and Media Access Control Connectivity Discovery*.
- IEEE 802.1D:2004, *IEEE Standard for Local and Metropolitan Area Networks: Media Access Control (MAC) Bridges*.
- IEEE 802.1H:1997 (ISO/IEC TR11802-5:1997), *IEEE Technical Reports and Guidelines—Part 5: Media Access Control (MAC) Bridging of Ethernet V2.0 in Local Area Networks*.
- IEEE 802.1Q:2005, *IEEE Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks*.
- IEEE 802.1Q:2005/Cor 1:2008, *IEEE Standard for Local and Metropolitan Area Networks-Virtual Bridged Local Area Networks—Amendment 07: Multiple Registration Protocol-Corrigendum 1: Corrections to the Multiple Registration Protocol*.
- IEEE 802.1Qau:2010, *IEEE Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks—Amendment 13: Congestion Notification.*
- IEEE 802.1Qav:2009, *IEEE Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks— Amendment 12: Forwarding and Queuing Enhancements for Time-Sensitive Streams.*
- IEEE 802.1Qaw:2009, *IEEE Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks—Amendment 9: Management of Data Driven and Data Dependent Connectivity Faults.*
- IEEE 802.1X:2004, *Standard for Local and Metropolitan Area Networks—Port-Based Network Access Control*.
- IEEE 802.1ad:2005, *IEEE Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks—Amendment 4: Provider Bridge*.
- IEEE 802.1AE:2006, *IEEE Standard for Local and Metropolitan Area Networks—Media Access Control (MAC) Security*.
- IEEE 802.1ag:2007, *IEEE Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks—Amendment 5: Connectivity Fault Management*.
- IEEE 802.1ah:2008, *IEEE Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks—Amendment 6: Provider Backbone Bridges*.
- IEEE P802.1aj:2009, *IEEE Draft Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks—Amendment 8: Two-Port Media Access Control (MAC) Relay.*
- IEEE 802.1ak:2007, *IEEE Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks—Amendment 7: Multiple Registration Protocol*.
- IEEE 802.1ap:2008, *IEEE Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks—Amendment 8: Management Information Base (MIB) Definitions for VLAN Bridges*.
- IEEE 802.1AR:2009, *IEEE Standard for Local and Metropolitan Area Networks—Secure Device Identity.*
- IEEE 802.1AX™:2008, *IEEE Standard for Local and Metropolitan Area Networks—Link Aggregation.*

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802.1 Working Projects

The 802.1 working group has two active groups, Internetworking and Security, which are responsible for the following projects:

- IEEE P802.1Q:2008, *IEEE Draft Standard for Local and Metropolitan Area Networks—Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks.*
- IEEE P802.1Qat:2006, *IEEE Draft Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks Amendment 9: Stream Reservation Protocol (SRP).*
- IEEE P802.1Qaz:2009, *Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks Amendment: Enhanced Transmission Selection for Bandwidth Sharing Between Traffic Classes.*
- IEEE P802.1Qbb:2008, *IEEE Draft Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks Amendment: Priority-based Flow Control.*
- IEEE P802.1Qbc:2009, *IEEE Draft Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks Amendment: Provider Bridging—Remote Customer Service Interfaces.*
- IEEE P802.1Qbe:2009, *IEEE Draft Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks Amendment: Multiple Backbone Service Instance Identifier (I-SID) Registration Protocol (MIRP).*
- IEEE P802.1Qbf:2009, *IEEE Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks Amendment: Provider Backbone Bridge Traffic Engineering (PBB-TE) Infrastructure Segment Protection.*
- IEEE P802.1Qbg:2009, *Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks Amendment: Edge Virtual Bridging.*
- IEEE P802.1Qbh:2009, *Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks Amendment: Bridge Port Extension.*
- IEEE P802.1AC:2006, *Standard for Media Access Control (MAC) Service Definition*.
- IEEE P802.1AS:2006, *IEEE Draft Standard for Local and Metropolitan Area Networks—Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks.*
- IEEE 802.1aq:2005, *Standard for Local and Metropolitan Area Networks—Virtual Bridged Local Area Networks—Amendment 8: Shortest Path Bridging.*
- IEEE P802.1AXbk:2010, *IEEE Standard for Local and Metropolitan Area Networks—Link Aggregation Amendment: Protocol Addressing.*
- IEEE P802.1BA:2008, *Standard for Local and Metropolitan Area Networks—Audio Video Bridging (AVB) Systems*.

802.3 *Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*

- IEEE 802.3:2008, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements—Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*.

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- IEEE 802.3:2008/Cor 1:2009, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks— Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Corrigendum 1: Timing Considerations for PAUSE Operation.*

The IEEE 802.3 working group is responsible for developing standards and recommended practices for access control and physical signaling in the carrier sense multiple access with collision detection (CSMA/CD) form of network communications. This group specifies the Physical and Data Link Layer standards for LANs using a CSMA/CD access method and a bus topology. Such LANs include Ethernet, Fast Ethernet, Gigabit Ethernet, and 10 Gigabit Ethernet.

The 802.3 standard defines the Physical Layer implementations among a variety of physical media.

It incorporates the following previously published standards:

- IEEE 802.3x—*Specification for Full-Duplex Operation.*
- IEEE 802.3y—*Physical Layer Specifications for 100 Mb/s Operation Over Two Pairs of Category 3 or Higher Twisted-Pair Cable.*
- IEEE 802.3z—*Specification for 1000 Mb/s (Gigabit Ethernet) Operation Over Optical Fiber Cable.*
- IEEE 802.3ab—*Specification for 1000 Mb/s (Gigabit Ethernet) Operation Over Four Pairs of Category 5 or Higher Twisted-Pair Cable, Type 100BASE-T.*
- IEEE 802.3ac—*Ethernet Frame Extensions for Virtual Local Area Networks (VLANs) and Tagging On 802.3 Networks.*
- IEEE 802.3ad—*Aggregation of Multiple Link Segments.*
- IEEE 802.3ae—*10 Gb/s Operation.*
- IEEE 802.3af—*Data Terminal Equipment (DTE) Power Via Media Dependent Interface (MDI).*
- IEEE 802.3ah—*Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks (such as Ethernet Passive Optical Network [EPON] and Ethernet over DSL).*
- IEEE 802.3ak—*Physical Layer and Management Parameters for 10 Gb/s Operation, Type 10GBASE-CX4.*
- IEEE 802.3an—*Amendment 1: Physical Layer and Management Parameters for10 Gb/s Operation, Type 10GBASE-T.*
- IEEE 802.3ap—*Amendment 4: Ethernet Operation over Electrical Backplanes.*
- IEEE 802.3aq—*Amendment 2: Physical Layer and Management Parameters for10 Gb/s Operation, Type 10GBASE-LRM.*
- IEEE 802.3as—*Amendment 3: Frame Format Extensions.*
- IEEE 802.3at—*Data Terminal Equipment (DTE) Power Via Media Dependent Interface (MDI) Enhancements.*

Institute of Electrical and Electronics Engineers® (IEEE®), continued

The 802.3 working group is also responsible for the following initiatives:

- IEEE 802.3av:2009, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks-Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment 1: Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks.*
- IEEE 802.3at:2009, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications—Amendment: Data Terminal Equipment (DTE) Power Via Media Dependent Interface (MDI) Enhancements).*
- IEEE 802.3ba:2010, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment 4: Media Access Control Parameters, Physical Layers, and Management Parameters for 40 Gb/s and 100 Gb/s Operation.*
- IEEE 802.3bc:2009, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks-Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment 2: Ethernet Organizationally Specific Type, Length, Value (TLVs).*

802.3 Working Projects

The 802.3 working group is also responsible for the following initiatives:

- IEEE P802.3.1:2009, *IEEE Draft Standard for Management Information Base (MIB) Definitions for Ethernet.*
- IEEE P802.3az:2007, *IEEE Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment: Media Access Control Parameters, Physical Layers and Management Parameters for Energy-Efficient Ethernet.*
- IEEE P802.3bd:2009, *IEEE Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications—Amendment: MAC Control Frame for Priority-based Flow Control.*
- IEEE P802.3bf:2009, *IEEE Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment: Media Access Control (MAC) Service Interface and Management Parameters to Support Time Synchronization Protocols.*

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- IEEE P802.3bg–2010:*IEEE Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment: Physical Layer and Management Parameters for Serial 40 Gb/s Ethernet Operation Over Single Mode Fiber.*

802.11 *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*

- IEEE 802.11:2009 (ISO/IEC 8802–11:1999*), Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.*

This standard incorporates the following previously published amendments:

- IEEE 802.11b:1999, *Higher Speed Physical Layer (PHY) Extension in the 2.4 GHz Band.*
- IEEE 802.11d:2001 (R2003), *Amendment 3: Specifications for Operation in Additional Regulatory Domains*.
- IEEE 802.11e:2005, *Amendment 8: Medium Access Method (MAC) Quality of Service Enhancements.*

802.11e is a standard that defines quality of service enhancements for LAN applications. The standard is considered of critical importance for delay-sensitive applications, (e.g., voice over Internet protocol [VoIP] and streaming multimedia). The standard assigns priorities to these types of data.

- IEEE P802.11g:2003*, Further Higher-Speed Physical Layer Extension in the 2.4 GHz Band.*
- IEEE 802.11h:2004, *IEEE Standard for Information Technology— Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Spectrum and Transmit Power Management Extensions in the 5 GHz Band in Europe.*

IEEE 802.11h is a standard that enables WLANs that operate in the 5-gigahertz (GHz) range to comply with European RF regulations.

- IEEE 802.11i:2004, *Amendment 6: Medium Access Control (MAC) Security Enhancements.*

The specification for WiFi protected access (WPA) and robust security network (RSN), IEEE 802.11i is built on the 802.1x port-based authentication scheme. The standard will cover user and device authentication. It replaces Wireless Encryption Protocol (WEP) with a stronger, more secure encryption standard.

- IEEE 802.11j:2004, *Amendment 7: 4.9 GHz-5 GHz Operation in Japan.*
- IEEE 802.11k:2008, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between System—Local and Metropolitan Area Networks—Specific Requirement Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 1: Radio Resource Measurement of Wireless LANs.*

Institute of Electrical and Electronics Engineers® (IEEE®), continued

IEEE 802.11k is a standard for radio resource measurement. It will increase the manageability of WLANs by measuring radio and network information, which can be used by network management applications.

- IEEE 802.11n:2009, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 5: Enhancements for Higher Throughput.*

IEEE 802.11n is the next step in WLAN standards. The 802.11a and 802.11g standards both deliver a maximum 54 megabits per second (Mb/s). The proposed 802.11n specification, which will use the same 5 GHz frequency range as 802.11a, will raise the maximum throughput to 100 Mb/s or higher. This will improve the speed of wireless multimedia applications.

- IEEE 802.11p:2010, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 7: Wireless Access in Vehicular Environments.*
- IEEE 802.11r™:2008, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 2: Fast BSS Transition.*
- IEEE 802.11w:2009, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 4: Protected Management Frames.*
- IEEE 802.11y:2008, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 3: 3650-3700 MHz Operation in USA.*

802.11 Working Projects

The 802.11 working group is also responsible for the following initiatives:

- IEEE P802.11:2008, *IEEE Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*.
- IEEE P802.11s:2009, *IEEE Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 10: Mesh Networking.*

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- IEEE P802.11u–2009, *IEEE Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 7: Interworking with External Networks.*
- IEEE P802.11v:2009, *IEEE Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks— Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 8: Wireless Network Management.*
- IEEE P802.11z:2007, *IEEE Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 7: Extensions to Direct Link Setup (DLS).*
- IEEE P802.11aa:2008, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment: MAC Enhancements for Robust Audio Video Streaming.*
- IEEE P802.11ac:2008, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment: Enhancements for Very High Throughput for Operation in Bands Below 6GHz.*
- IEEE P802.11ad:2008, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment: Enhancements for Very High Throughput in the 60 GHz Band.*
- IEEE P802.11ae:2009, *Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment: Prioritization of Management Frames.*
- IEEE P802.11af:2009, *Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment: TV White Spaces Operation*.
- IEEE P802.11mb:2007, *Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment: Accumulated Maintenance Changes.*

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802.15 *Wireless Personal Area Networks (WPANs)*

- IEEE 802.15.1:2005, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.1: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Wireless Personal Area Networks (WPANs).*
- IEEE 802.15.2:2003 (R2009), *IEEE Recommended Practice for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.2: Coexistence of Wireless Personal Area Networks With Other Wireless Devices Operating in Unlicensed Frequency Bands.*
- IEEE 802.15.3:2003 (R2008), *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.3: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for High Rate Wireless Personal Area Networks (WPANs).*
- IEEE 802.15.3b:2005 (R2008), *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.3: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for High Rate Wireless Personal Area Networks (WPANs)—Amendment 1: MAC Sublayer.*
- IEEE 802.15.3c:2009, *IEEE Amendment to IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.3: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for High Rate Wireless Personal Area Networks (WPANs)—Amendment 2: Millimeter Wave Based Alternative Physical Layer Extension.*
- IEEE 802.15.4:2006, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs).*
- IEEE 802.15.4a:2007, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs)—Amendment 1: Add Alternate PHYs.*
- IEEE 802.15.4c:2009, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs)—Amendment 2: Alternative Physical Layer Extension to Support One or More of the Chinese 314-316 MHz, 430-434 MHz, and 779-787 MHz Bands.*

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- IEEE 802.15.4d:2009, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs)—Amendment 3: Alternative Physical Layer Extension to Support the Japanese 950 MHz Bands.*
- IEEE 802.15.5:2009, *IEEE Recommended Practice for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.5: Mesh Topology Capability in Wireless Personal Area Networks.*

The 802.15 working group is also responsible for the following initiatives:

- IEEE P802.15.4:2006/Cor 1, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs)—Corrigendum 1.*
- IEEE P802.15.4e:2007, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs)—Amendment: Amendment to the MAC Sub-layer.*
- IEEE P802.15.4f:2008, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs)—Amendment: Active Radio Frequency Identification (RFID) System Physical Layer (PHY).*
- IEEE P802.15.4g:2008, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs)—Amendment: Physical Layer (PHY) Specifications for Low Data Rate Wireless Smart Metering Utility Networks.*
- IEEE P802.15.6:2007, *Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 15.6: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Wireless Personal Area Networks (WPANs)—Used in or around a Body.*
- IEEE P802.15.7:2008, *Physical (PHY) and Medium Access Control (MAC) Layer Standard for Short-Range Wireless Optical Communication Using Visible Light.*

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802.16 *Broadband Wireless Metropolitan Area Networks (WMANs)*

- IEEE 802.16:2009, *IEEE Standard for Local and Metropolitan Area Networks—Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems*.
- IEEE 802.16.2:2004, *IEEE Recommended Practice for Local and Metropolitan Area Networks—Coexistence of Fixed Broadband Wireless Access Systems*.
- IEEE 802.16/Conformance04:2006, *IEEE Standard for Conformance to IEEE 802.16 Part 4: Protocol Implementation Conformance Statement (PICS) Proforma for Frequencies below 11 GHz.*

The downside of 802.16a (commonly referred to as worldwide interoperability for microwave access [WiMAX]) is that it is a fixed access system, meaning that users must mount a dish-like antenna outside their home or office to access it. To circumvent this issue, IEEE formed a study group to develop an extension to WiMAX called 802.16e. This extension introduces nomadic capabilities that allow users to connect to a wireless Internet SP (WISP), even when they roam outside their home or business.

- IEEE P802.16h:2010, *IEEE Amendment to IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems—Improved Coexistence Mechanisms for License-Exempt Operation.*
- IEEE 802.16j:2009, *IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Broadband Wireless Access Systems—Amendment 1: Multihop Relay Specification.*
- IEEE 802.16k:2007, *IEEE Standard for Local and Metropolitan Area Networks: Media Access Control (MAC) Bridges—Amendment 2: Bridging of IEEE 802.16.*

The 802.16 working group is also responsible for the following initiatives:

- IEEE P802.16m:2006, *IEEE Draft Amendment Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Broadband Wireless Access Systems—Advanced Air Interface.*
- IEEE P802.16n:2010, *IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Broadband Wireless Access Systems Amendment: Higher Reliability Networks.*

802.17 Resilient Packet Ring Working Group (RPRWG)

The IEEE 802.17 Resilient Packet Ring Working Group (RPRWG) defines a resilient packet ring access protocol for use in local, metropolitan, and wide area networks for transfer of data packets at rates scalable to many gigabit per second (Gb/s). The new standard will use the existing Physical Layer specifications and develop new specifications where appropriate.

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In MANs and WANs, optical fiber rings are widely deployed. These rings are currently using protocols that are neither optimized nor scalable to the demands of packet networks, including speed of deployment, bandwidth allocation and throughput, resiliency to faults, and reduced equipment and operational costs.

- IEEE 802.17:2004, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 17: Resilient Packet Ring (RPR) Access Method and Physical Layer Specifications*.
- IEEE 802.17a:2004, *IEEE Standard for Local and Metropolitan Area Networks—Media Access Control (MAC) Bridges—Amendment 1: Bridging of IEEE 802.17*.
- IEEE 802.17b:2007, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 17: Resilient Packet Ring (RPR) Access Method and Physical Layer Specifications—Amendment 1: Spatially Aware Sublayer*.
- IEEE 802.17c:2010, *IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 17: Resilient Packet Ring (RPR) Access Method and Physical Layer Specifications—Amendment 2: Protected Inter-ring Connection.*

The 802.17 working group is also responsible for the following initiative:

- IEEE P802.17:2009, *Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 17: Resilient Packet Ring (RPR) Access Method and Physical Layer Specifications.*

802.18 Radio Regulatory Technical Advisory Group (RR-TAG)

IEEE 802 LMSC currently has six working groups with projects on standards for radio-based systems: 802.11 (WLANs), 802.15 (WPANs), 802.16 (WMANs), 802.20 (wireless mobility), 802.21 (handoff/interoperability between networks), and 802.22 (WRANs). The task of the Radio Regulatory Technical Advisary Group (RR-TAG) is to monitor and participate in the activities of these groups.

802.19 Coexistence Technical Advisory Group (TAG)

The IEEE 802.19 Coexistence Technical Advisary Group (TAG) develops and maintains policies defining the responsibilities of 802 standards developers to address the issues of coexistence with the existing standards and other standards under development. When required, the TAG offers assessments to the Sponsor Executive Committee (SEC) regarding the degree to which standards developers have conformed to those conventions. In addition, the TAG may develop coexistence documentation of interest to the technical community outside 802.

The following is a new standard project initiated by the Mobile Broadband Wireless Access (MBWA) working group:

- IEEE P802.19.1:2009, *Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 19: TV White Space Coexistence Methods.*

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802.20: Mobile Broadband Wireless Access (MBWA) Working Group

On December 11, 2002, the IEEE Standards Board approved the establishment of IEEE 802.20, the MBWA Working Group.

The mission of IEEE 802.20 is to develop the specification for an efficient packet-based air interface optimized for the transport of IP-based services. The goal is to enable worldwide deployment of affordable, ubiquitous, always on, and interoperable multi-vendor mobile broadband wireless access networks that meet the needs of business and residential end-user markets.

The project scope is the specification of Physical and media access control (MAC) Layers of an air interface for
interoperable mobile broadband wireless access systems, operating in licensed bands below 3.5 GHz, optimized Internet protocol (IP) data transport, with peak data rates per user in excess of 1 Mb/s.

It supports various vehicular mobility classes up to 250 kilometers per hour (km/h) in a MAN environment and targets spectral efficiencies, sustained user data rates, and a number of active users that are all significantly higher than achieved by existing mobile systems.

The following are new standard projects initiated by the MBWA working group:

- IEEE 802.20:2008, *IEEE Standard for Local and Metropolitan Area Networks—Part 20: Air Interface for Mobile Broadband Wireless Access Systems Supporting Vehicular Mobility—Physical and Media Access Control Layer Specification*.
- IEEE 802.20.2:2010, *IEEE Standard for Conformance to IEEE 802.20 Systems—Protocol Implementation Conformance Statement (PICS) Proforma.*
- IEEE 802.20.3:2010, *IEEE Standard for Minimum Performance Characteristics of IEEE 802.20 Terminals and Base Stations/Access Nodes.*

The 802.20 working group is also responsible for the following initiatives:

- IEEE P802.20a:2008, *IEEE Draft Standard for Local and Metropolitan Area Networks–Part 20: Air Interface for Mobile Broadband Wireless Access Systems Supporting Vehicular Mobility–Physical and Media Access Control Layer Specification–Amendment 1: MIB Enhancements and Corrigenda Items.*
- IEEE P802.20b:2009, *IEEE Draft Standard for Local and Metropolitan Area Networks–Virtual Bridged Local Area Networks—Amendment: Bridging of 802.20.*

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802.21 Handoff/Handover Working Group

An 802-handover standard would be applicable to 802 wired and wireless media types. For example, a handover between 802.3 and 802.11 within a single mobile station is a plausible application of such a standard.

This standard defines extensible 802 media access independent mechanisms that enable the optimization of handover between heterogeneous 802 systems and may facilitate handover between 802 systems and non-802 (cellular) systems.

The following is a new standard project initiated by the Handoff/Handover Working Group:

- IEEE 802.21:2008, *IEEE Standard for Local and Metropolitan Area Networks—Part 21: Media Independent Handover Services.*

The 802.21 working group is responsible for the following initiatives:

- IEEE P802.21a:2008, S*tandard for Local and Metropolitan Area Networks: Media Independent Handover Services—Amendment for Security Extensions to Media Independent Handover Services and Protocol.*
- IEEE P802.21b:2009, *Standard for Media Independent Handover Services—Amendment: Handovers with Downlink Only Technologies.*
- IEEE P802.21c:2009, *Standard for Local and Metropolitan Area Networks—Part 21: Media Independent Handover Services Amendment: Optimized Single Radio Handovers.*

802.22 Wireless Regional Area Networks (WRAN) Working Group

The Wireless Regional Area Network (WRAN) working group is responsible for policies and procedures for operation in the TV bands. WRAN will specify a cognitive air interface for fixed point-to-multipoint wireless local area networks (WLANs) that operate on unused channels in the very high frequency (VHF)/ultrahigh frequency (UHF) TV bands between 54 and 862 megahertz (MHz).

The following are new projects initiated by the WRAN group:

- IEEE P802.22:2009, *IEEE Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 22.1: Standard to Enhance Harmful Interference Protection for Low Power Licensed Devices Operating in the TV Broadcast Bands.*
- IEEE P802.22.1:2006, *IEEE Draft Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 22.1: Standard to Enhance Harmful Interference Protection for Low Power Licensed Devices Operating in TV Broadcast Bands.*
- IEEE P802.22.2:2006, *Recommended Practice for Information Technology—Telecommunications and Information Exchange Between Systems—Wireless Regional Area Networks (WRAN)—Specific Requirements Part 22.2: Recommended Practice for the Installation and Deployment of IEEE 802.22 Systems.*

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802.23 Emergency Services Working Group

This standard defines a media independent structure within IEEE 802 to present consistent access and data that aid in compliance to civil authority needs (e.g., VoIP 911 calls) for communications systems that include IEEE 802 networks. This standard includes a data link layer interface that provides IP-based networks citizen-to-authority emergency services capabilities using Emergency Context Resolution with Internet Technologies (ECRIT).

- IEEE P802.23:2010, *Standard for Local and Metropolitan Area Networks—Emergency Services for Internet Protocol (IP) Based Citizen to Authority Communications Status: New Standard Project.*

P802 Handoff Executive Committee Study Group

On March 14, 2003, the IEEE 802 Executive Committee approved the Handoff Executive Committee Study Group (ECSG) with a charter to:

- Consider the possibility of developing a standard specifying a common handoff framework applicable to 802 standards, wired and wireless.
- Develop a project authorization request (PAR) and five criteria for a new standard for link security that can be applied to IEEE 802 networks.
- Make a recommendation on the placement of the project within IEEE 802 and the existing working groups.

P802 Link Security Executive Committee Study Group

On November 15, 2002, the IEEE 802 Executive Committee approved the Link Security ECSG with the scope to develop link security requirements for IEEE 802 networks and a charter to:

- Evaluate link security architecture issues with the objective of identifying the broader scope that can be common to all MAC solutions.
- Develop a PAR and five criteria for a new standard for link security that can be applied to IEEE 802 networks and, in particular, to 802.3 networks.
- Make a recommendation on the placement of the project within IEEE 802 and the existing working groups.

This group is now a Study Group of the IEEE 802.1 Working Group, allowing closer cooperation between security experts in IEEE 802.

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Regional Codes and Standards

Australia/New Zealand Codes and Standards

The following standards are published by Australia/New Zealand standards (AS/NZS) and are relevant to an ITS designer and installer:

- AS/NZS 3080:2003, *Telecommunications Installations—Generic Cabling for Commercial Premises.*
- AS/NZS 3084:2003, *Telecommunications Installations—Telecommunications Pathways and Spaces for Commercial Buildings*.
- AS/NZS 3085.1:2004, *Telecommunications Installations—Administration of Communications Cabling Systems—Basic Requirements*.
- AS/NZS ISO/IEC 15018:2005, *Information Technology—Generic Cabling for Homes*.
- AS/NZS 3087.1:2003, *Telecommunications Installations—Generic Cabling Systems—Specification for the Testing of Balanced Communication Cabling*.
- AS/NZS 3087.2:2003*, Telecommunications Installations—Generic Cabling Systems—Specification for the Testing of Patch Cords in Accordance with AS/NZS 3080*.

Countries of the Americas Codes and Standards

The Inter-American Telecommunication Commission (CITEL)

The Inter-American Telecommunication Commission (CITEL) was established under the auspices of the Organization of American States (OAS). It has 35 member states and over 200 associate members. It has been entrusted by the heads of state at the Summits of the Americas with specific mandates. CITEL has technical autonomy to perform its functions within the limits prescribed by the OAS Charter, its statutes, and the mandates of the General Assembly. Its objectives include facilitating and promoting the continuous development of telecommunications.

CITEL has a permanent executive committee, which consists of eleven members, three Permanent Consultative committees, and one working group:

- Permanent Consultative Committee I (PCC I), which addresses telecommunication standardization
- Permanent Consultative Committee II (PCC II), which addresses radio communications, including broadcasting
- A steering committee
- Conference preparatory working group, whose members are all member states of the organization and associate members that represent various private telecommunication associations or companies, and permanent observers and regional and international organizations

European Codes and Standards

Comité Européen de Normalisation Electrotechnique (CENELEC)

While every country in the European Union has adopted the Comité Européen de Normalisation Electrotechnique (CENELEC) standards, there may be local standards that provide guidance or are specific to a country application for the CENELEC standards.

The organization of the CENELEC cabling-related standards is shown in Table A.1.

Table A.1
Relationship between series EN 50174 and other design standards

Building Design Phase	Cabling Design Phase	Planning Phase	Implementation Phase	Operation Phase
EN[1] 50310	**EN 50173**	**EN 50174-1**	**EN 50174-1**	**EN 50174-1**
5.2: Common bonding network (CBN) within a building **6.3:** ac distribution system and bonding of the protective conductor (TN-S)	**or (and)** **EN 50098-1** **or (and)** **EN-50098-2** **or (and)** Other application standards	**4:** Specification considerations **5:** Quality assurance **7:** Cabling administration **and** **EN 50174-2** **4:** Safety requirements **5:** General installation practices for metallic and optical fiber cabling **6:** Additional installation practice for metallic cabling **7:** Additional installation practice for optical fiber cabling **and** **EN 50174-3** (for equipotential bonding)	**6:** Documentation **7:** Cabling administration **and** **EN 50174-2** **4:** Safety requirements **5:** General installation practices for metallic and optical fiber cabling **6:** Additional installation practice for metallic cabling **7:** Additional installation practice for optical fiber cabling **and** **EN 50174-3** (for equipotential bonding)	**5:** Quality assurance **7:** Cabling administration **8:** Repair and maintenance

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European Codes and Standards, continued

Table A.1, continued
Relationship between series EN 50174 and other design standards

Building Design Phase	Cabling Design Phase	Planning Phase	Implementation Phase	Operation Phase
		EN 50310	**EN 50310**	
		5.2: Common bonding network (CBN) within a building **6.3:** ac distribution system and bonding of the protective conductor (TN-S)	**5.2:** Common bonding network (CBN) within a building **6.3:** ac distribution system and bonding of the protective conductor (TN-S)	

[1] European Norm (EN) is sometimes preceded by "pr," meaning preliminary.

ac = Alternating current
CBN = Common bonding network
EN = European norm

European Codes and Standards, continued

CENELEC EN 50098-1:1998 ***Customer Premises Cabling for Information Technology—Part 1: ISDN Basic Access***

This European standard defines the requirements for the design and configuration of customer premises cabling for the connection of basic access integrated services digital network (ISDN) equipment.

It also defines:

- Design requirements for ISDN basic access with point-to-point and point-to-multipoint cabling configurations.
- Minimum cabling requirements for the installation of new cabling.
- Criteria for the use of generic cabling.
- Criteria for the use of existing cabling.

This standard applies to the customer premises cabling. It describes the cabling requirements needed to transmit ISDN basic access signals as defined by ITU-T Recommendation I.430. The requirements placed on the customer premises cabling are solely those necessary to enable terminal equipment conforming to ETS 300 012-1 to operate into the network termination (NT) via configurations defined in this standard.

CENELEC EN 50098-2:1996 ***Customer Premises Cabling for Information Technology—Part 2: 2048 kb/s ISDN Primary Access and Leased Line Network Interface***

This European standard specifies the design and configuration of customer premises cabling for the connection of primary access ISDN equipment.

It includes:

- Design requirements for ISDN primary access point-to-point configuration.
- Cabling requirements for the installation of new cabling.
- Criteria for the use of existing cabling.
- Implementation of ISDN primary access on generic cabling systems according to EN 50173.

This standard applies to the customer premises cabling for the transmission of ISDN primary access signals as defined by ETS 300 011. The requirements in this standard also apply to the cabling between Open Network Provision 2048 kb/s Network Interfaces and terminal equipment conforming to ETS 300 248.

CENELEC EN 50173 Series

CENELEC EN 50173 is a series of standards detailing general cabling systems for general practice and office, industrial, residential, and data centers applications.

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European Codes and Standards, continued

CENELEC EN 50173-1:2007 +A1:2009, +A2:2010 *Information Technology—Generic Cabling Systems—Part 1: General Requirements*

CENELEC EN 50173-1 contains those specifications that are common to generic cabling systems irrespective of the type of premises. It specifies generic balanced twisted-pair, unbalanced coaxial, singlemode, multimode, and plastic optical fiber cabling components for use within premises, which may comprise single or multiple buildings on a campus.

This European standard is optimized for premises where the maximum distance over which telecommunications services have to be distributed is 10,000 m (32,809 ft). The principles of this standard may also be applied to larger installations.

Cabling defined by this standard supports a wide range of services, including voice, data, text, image, and video. This standard specifies the:

- Structure and configuration for generic cabling.
- Cabling performance requirements.
- Implementation options.
- Applications supported by application and by media type.

Safety (e.g., electrical safety and protection, optical power, fire) and electromagnetic compatibility (EMC) requirements are outside the scope of this European standard and are covered by other standards and regulations. However, information given in this standard may be of assistance in meeting these standards and regulations or determining which cabling components are best suited for the environment in which they are to be installed.

EN 50173-2+A1:2010 *Information Technology—Generic Cabling Systems—Part 2: Office Premises*

This European standard is based upon and references the requirements of EN 50173-1. This European standard contains additional requirements that are appropriate to office premises in which the maximum distance over which communications services have to be distributed is 2000 m (6562 ft). The principles of this European standard may also be applied to installations that do not fall within this range.

In addition to the requirements of EN 50173-1, this European standard specifies:

- An extended structure and configuration for generic cabling within office premises in support of a wide range of services, including voice, data, text, image, and video.
- Implementation options.

European Codes and Standards, continued

EN 50173-3 ***Information Technology—Generic Cabling Systems—Part 3: Industrial Premises***

This European standard, EN 50173-3, recognizes the benefit of generic cabling to interconnect several pieces of apparatus within industrial premises (within and between structures and buildings) and is to be read in conjunction with EN 50173-1.

This European standard provides for industrial premises:

- Users with an application-independent generic cabling system and an open market for cabling components.
- Requirements for infrastructures that support critical automation, process control, and monitoring applications in a range of industrial environments.
- Users with a flexible cabling scheme such that modifications are both easy and economical.
- Building professionals (e.g., architects) and production and control engineers with guidance, allowing the accommodation of cabling both before specific requirements are known (i.e., in the initial planning either for construction or refurbishment) and for further deployment as the requirements of specific industrial areas are defined.
- Industry and standardisation bodies with a cabling system that supports current products and provides a basis for future product development and applications standardisation.

EN 50173-4 ***Information Technology—Generic Cabling Systems—Part 4: Residential Premises***

This European standard specifies generic cabling in homes, which are installed to support one or more of the following groups of applications and are based upon balanced and coaxial cabling as appropriate:

- Information and Communications Technologies (ICT)
- Broadcast and Communications Technologies (BCT)
- Commands, Controls and Communications in Buildings (CCCB)

Other cabling media, used for the above applications, are not covered in this standard. Backbone cabling connecting individual homes within single premises is built according to the relevant standard (e.g., EN 50173-1, EN 50083 series).

EN 50173-5 ***Information Technology—Generic Cabling Systems—Part 5: Data Centres***

The importance of the information technology cabling infrastructure is similar to that of other utilities such as heating, lighting, and electricity supplies. As with other utilities, interruptions to service can have a serious impact. Poor quality of service because of a lack of planning, use of inappropriate components, incorrect installation, poor administration, or inadequate support can threaten an organisation's effectiveness.

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European Codes and Standards, continued

Cabling within data centres comprises both application-specific and multipurpose networks that are mission critical to the enterprise. Generic cabling designs in accordance with the EN 50173 series have supported the development of high data rate applications based upon a defined cabling model. This European standard recognizes the benefit of generic cabling to provision multiple services and to connect large quantities of equipment within the limited space of data centre premises and is to be used in conjunction with EN 50173-1.

This European standard, EN 50173-5, provides:

- Users with an application-independent generic cabling system and an open market for cabling components.
- Requirements for infrastructures that support critical applications within data centres.
- A flexible cabling scheme such that modifications are both easy and economical.
- A scaleable structure to support expansion with minimum operational disruption.
- Building professionals (e.g., architects) with guidance allowing the accommodation of cabling before specific requirements are known (i.e., in the initial planning either for construction or refurbishment).
- Industry and standardisation bodies with a cabling system that supports current products and provides a basis for future product development and applications standardisation.

CENELEC EN 50174 Series

CENELEC EN 50174 series of standards specifies the basic requirements for the planning, implementation, and operation of information technology cabling using balanced twisted-pair cabling and optical fiber cabling.

This European standard is applicable to:

- Cabling designed to support particular analog and digital telecommunications services, including voice services.
- Generic cabling systems designed in accordance with EN 50173 and intended to support a wide range of telecommunications services.

Information in this standard is intended for those involved in the procurement, installation, and operation of information technology cabling.

This standard is addressed to:

- Architects, building designers, and builders.
- Main contractors.
- Designers, suppliers, installers, maintainers, and owners of information technology cabling.
- Public network providers and local service providers.
- End users.

EN 50174 is applicable to certain hazardous environments, but it does not exclude additional requirements, which are applicable in specific circumstances (e.g., those defined by electrical supply and electrified railways).

European Codes and Standards, continued

CENELEC EN 50174-1:2009 ***Information Technology—Cabling Installation—Part 1: Installation Specification and Quality Assurance***

This European standard provides guidance on the preparation and agreement of an installation specification covering the information technology cabling, its accommodation, and associated building services.

It also defines installation and acceptance testing practices, enabling the agreement of a quality plan used to demonstrate conformance with the installation specification.

The importance of services delivered by information technology cabling infrastructure is similar to that of utilities such as heating, lighting, and electricity supplies. As with those utilities, interruptions to service can have a serious impact. Poor quality of service because of a lack of planning, use of inappropriate components, incorrect installation, poor administration, or inadequate support can threaten an organisation's effectiveness.

There are four phases in the successful implementation of information technology cabling. These are:

- Design.
- Specification—The detailed requirement for the cabling, including the planning of its accommodation and associated building services addressing specific environments (e.g., electromagnetic) together with the quality assurance requirements to be applied.
- Installation—In accordance with the requirements of the specification.
- Operation—The management of connectivity and the maintenance of transmission performance during the life of the cabling.

This European standard is in three parts and addresses the specification, installation, and operational aspects. The EN 50173 series and other application standards cover design issues.

EN 50174-1 is used during the specification phase. It addresses the:

- Installation specification, quality assurance documentation, and procedures.
- Documentation and administration.
- Operation and maintenance.

EN 50174-2 and EN 50174-3 are intended to be used by the personnel directly involved in the planning aspects of the specification phase and the installation phase. EN 50174-2 is applicable inside buildings, and EN 50174-3 is applicable outside buildings.

This European standard is also relevant to:

- Architects, building designers, and builders.
- Main contractors.
- Designers, suppliers, installers, inspectors (auditors), maintainers, and owners of information technology cabling.
- Public network providers and local service providers.
- End users.

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European Codes and Standards, continued

The requirements and recommendations of Clause 4 are primarily for owners of premises housing information technology systems. The owners may delegate selected responsibilities to designers, specifiers, operators, and maintainers of installed information technology cabling.

The requirements and recommendations of Clause 5 are primarily for the installers of information technology cabling.

CENELEC EN 50174-2:2009 *Information Technology—Cabling Installation—Part 2: Installation Planning and Practices Inside Buildings*

EN 50174-2 is concerned with the planning and installation of information technology cabling using metallic cabling and optical fiber cabling inside buildings. It provides guidance as to the responsibilities of those involved and is intended to be referenced in relevant contracts.

EN 50174-2 contains requirements and recommendations relating to the installation planning and practices by defining:

- Planning strategy (road map) and guidance, depending on the application, electromagnetic environment, building infrastructure, facilities, etc.
- Planning and installation requirements for metallic and optical fiber information technology cabling, depending on the application, electromagnetic environment, building infrastructure, facilities, etc.
- The practices and procedures to be adopted to ensure that the cabling is installed in accordance with the specification.

The standard excludes specific requirements applicable to other cabling systems (e.g., power cabling, coaxial cabling); however, it takes into account the effects other cabling systems may have on the installation of information technology cabling (and vice versa) and gives general advice.

CENELEC EN 50174-3:2003 *Information Technology—Cabling Installation—Part 3: Installation Planning and Practices Outside Buildings*

This European standard establishes requirements for satisfactory installation and operation of information technology cabling outside buildings—it is not restricted to campus areas.

This standard excludes specific requirements applicable to other cabling systems (e.g., power cabling, coaxial cabling); however, it takes into account the effects that other cabling systems may have on the installation of information technology cabling (and vice versa) and gives general advice.

European Codes and Standards, continued

EN 50174-3 contains detailed requirements and guidance relating to the installation planning and practices by defining:

- Planning strategy (road map) and guidance, depending on the application and physical environment (e.g., climatic, mechanical, electromagnetic).
- Design and installation rules for metallic and optical fiber cabling, depending on the application, electromagnetic environment, and physical environment.
- Requirements on satisfactory operation of the cabling, depending on the application, electromagnetic environment, and physical environment.
- The practices and procedures to be adopted to ensure that the cabling is installed in accordance with the specification.

CENELEC EN 50310:2010 *Application of Equipotential Bonding and Earthing in Buildings with Information Technology Equipment*

This European standard outlines requirements for satisfactory installation and operation of information technology cabling outside buildings—it is not restricted to campus areas.

This standard excludes specific requirements applicable to other cabling systems (e.g., power cabling, coaxial cabling); however, it takes into account the effects that other cabling systems may have on the installation of information technology cabling (and vice versa) and gives general advice.

CENELEC EN 62305-1:2010 *Protection Against Lightning—Part 1 General Principles*

This part of IEC 62305 provides the general principles to be followed in the protection against lightning of:

- Structures, including their installations and contents as well as persons.
- Services connected to a structure.

The following cases are outside the scope of this standard:

- Railway systems
- Vehicles, ships, aircraft, and offshore installations
- Underground high pressure pipelines
- Pipe, power, and telecommunication lines not connected to a structure

The need for protection, the economic benefits of installing protection measures, and the selection of adequate protection measures should be determined in terms of risk management. Risk management is the subject of IEC 62305-2.

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European Codes and Standards, continued

The criteria for design, installation, and maintenance of lightning protection measures are considered in three separate groups:

- The first group concerns protection measures to reduce physical damage and life hazard in a structure is given in IEC 62305-3.
- The second group concerns protection measures to reduce failures of electrical and electronic systems in a structure is given in IEC 62305-4.
- The third group concerns protection measures to reduce physical damage and failures of services connected to a structure (mainly electrical and telecommunication lines) is given in IEC 62305-5.

National Codes and Standards

Australian Communications and Media Authority (ACMA)

The Australian Communications and Media Authority (ACMA) produces standards that affect telecommunications. Some of the most relevant are:

- AS/ACIF S008:2006, *Requirements for Authorised Cabling Products.*
- AS/ACIF S009:2006, *Installation Requirements for Customer Cabling (Wiring Rules).*
- HB 29:2007, *Communications Cabling Manual, Module 2: Communications Cabling Handbook.*

The handbook provides cabling installers with a practical field guide to allow them to cable premises for voice, data, and video. It guides them through appropriate standard requirements with cross-references to the actual standards—AS/ACIF S009:2006 and AS/NZS 3080:2003.

Brazilian Codes and Standards

The Associacão Brasileira de Normas Técnicas (ABNT) Brazil produces standards that affect telecommunications. Some of the most
relevant are:

- ABNT NBR 5410:2004, *Instalações elétricas de baixa tensão (Low Voltage Electrical Installations).*
- ABNT NBR 6814:2001, *Fios e cabos elétricos—Ensaio de resistência elétrica (Cables and Wires—Electrical Resistance Test and Measurement).*
- ABNT NBR 9130:2009, *Fios e cabos telefônicos—Ensaio de desequilíbrio resistivo (Telephone Cables and Wires—Resistance Unbalance Test).*
- ABNT NBR 9133:1999, *Cabos telefônicos—Ensaio de atenuação de sinal de transmissão—Método de ensaio (Telephone Cables—Signal Transmission Attenuation—Methods of Test).*
- ABNT NBR 13989:1997, *Cabo óptico subterrâneo—Determinação do desempenho quan do submetido ao ensaio de coeficiente de atrito estático—Método de ensaio (Underground Optical Cable—Performance Evaluation of Static Friction Coefficient—Method of Test).*
- ABNT NBR 13990:1997, *Cabo óptico subterrâneo—Determinação do desempenho quando submetido à vibração—Método de ensaio (Underground Optical Cable — Performance Evaluation under Vibration Conditions—Method of Test).*
- ABNT NBR 14103:2005, *Cabo óptico dielétrico para aplicação enterrada (Direct-buried Dielectric Optical Cable).*
- ABNT NBR 14159:1998, *Cabo óptico com núcleo geleado protegido por capa APL—Especificação (APL-insulated Optical Cable Loosy Tube Filled with Gel).*

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Brazilian Codes and Standards, continued

- ABNT NBR 14160:2005, *Cabo óptico aéreo dielétrico auto-sustentado (Aerial Selfsustained Dielectric Optical Cable).*
- ABNT NBR 14161:1998, *Cabo óptico dielétrico de emergência—Especificação (Emergency Dielecric Optical Cable—Specification).*
- ABNT NBR 14433:2000, *Conectores montados em cordões ou cabos de fibras ópticas e adaptadores—Especificação (Optical Connectors and Adapters Assembled in Patch Cords or Optical Fiber Cables—Specification).*
- ABNT NBR 14565:2007, *Cabeamento de telecomunicações para edifícios comerciais (Telecommunications Cabling for Commercial Buildings).*
- ABNT NBR 14566:2004, *Cabo óptico dielétrico para aplicação subterrânea em duto e aérea espinado (Spined Dielectric Optical Cable for Underground Duct Installation—Specification).*
- ABNT NBR 14584:2000, *Cabo óptico com proteção metálica para instalações subterrâneas—Verificação da suscetibilidade a danos provocados por descarga atmosférica—Método de ensaio (Optical Cable with Metallic Protection for Underground Installations—Evaluation of Damage Caused by Atmospheric Discharge—Method of Test).*
- ABNT NBR 14589:2000, *Cabo óptico com proteção metálica para instalações subterrâneas—Determinação da capacidade de drenagem de corrente—Método de ensaio (Optical Cable with Metallic Protection for Underground Installations—Evaluation of Current Flow—Method of Test).*
- ABNT NBR 14683:2001, *Sistemas de subdutos de polietileno para telecomunicações—Parte 1: Requisitos para subduto de parede lisa (Polyethylene Innerduct Systems for Telecommunications—Part 1: Innerducts Smooth Wall Requirements).*
- ABNT NBR 14702:2001, *Emenda 2004—Cabos coaxiais flexíveis com impedância de 75 ohms—especificação (75-ohm Flexible Coaxial Cables—Specifications).*
- ABNT NBR 14702:2004, *Cabos coaxiais flexíveis com impedância de 75 ohms para redes de banda larga—especificação (75-ohm Flexible Coaxial Cables for Broadband Applications—Specification).*
- ABNT NBR 14703:2005, *Cabos de telemática de 100 Ω para redes internas estruturadas —Especificação (Telecommunications Cable for Structured Cabling, 100-ohm—Specification).*
- ABNT NBR 14705:2010, *Cabos internos de telecomunicações—classificação quanto ao retardo à propagação de chamas (Indoor Telecommunications Cable—Fire Rating Classification).*
- ABNT NBR 14770:2004, *Cabos coaxiais rígidos com impedância de 75 ohms para redes de banda larga—especificação (75-ohm Rigid Coaxial Cables for Broadband Applications —Specification).*

Brazilian Codes and Standards, continued

- ABNT NBR 14771:2001, *Cabo óptico interno—Especificação (Indoor Optical Cable—Specification)*.
- ABNT NBR 14772:2006, *Cabo óptico de terminação—Especificação (Optical Cable for Connectors Termination—Specification)*.
- ABNT NBR 14773:2001, *Cabo óptico dielétrico protegido contra ataque de roedores para aplicação em linhas de dutos—Especificação (Corrugated-metal Sheath Dielectric Optical Cable for Duct Systems Distribution—Specification)*.
- ABNT NBR 14774:2001, *Cabo óptico dielétrico protegido contra ataque de roedores para aplicação enterrada—Especificação (Corrugated-metal Sheath Dielectric Optical Cable for Direct-buried Distribution—Specification)*.
- ABNT NBR 15108:2004, *Cabo óptico com núcleo dielétrico e proteção metálica para aplicação em linhas de dutos (Dielectric Optical Cable with Metallic Protection for Duct System Installation)*.
- ABNT NBR 15110:2004, *Cabo óptico com núcleo dielétrico e proteção metálica para aplicação enterrada (Optical Cable with Dielectric Core Protected by Metallic Insulated Sheath for Direct-buried Installations)*.

National Agency for Telecommunications (ANATEL [Agência Nacional de Telecomunicações]):

- Resolucao 242, *Regulamento para certificação e homologação de produtos para telecomunicações (Resolution 242, Regulation for Certification of Telecommunications Products)*.

Canadian Codes and Standards

Canadian Standards Association (CSA®)

The Canadian Standards Association (CSA®) produces several documents and standards that affect telecommunications. Among the most important are:

- CSA C22.1-09, *Canadian Electrical Code (CEC), Part I, Safety Standard for Electrical Installations*.
- CSA C22.1HB-09, *CEC Handbook, An Explanation of Rules of the Canadian Electrical Code*.
- CSA T568.1-05, *Commercial Building Telecommunications Cabling Standard—Part 1: General Requirements* (Adopted ANSI/TIA/EIA-568-B.1-2001).

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Canadian Codes and Standards, continued

Canadian Electrical Code (CECode)—Part I

The CSA sponsors, controls, and publishes the *Canadian Electrical Code, Part I*. The intent of this code is to establish safety standards for the installation and maintenance of electrical equipment, including telecommunications. Compliance with the requirements of this code and proper maintenance will ensure an essentially safe installation. The *Canadian Electrical Code, Part I* is a voluntary code for adoption and enforcement by the provincial and territorial regulatory authorities.

All provinces and local jurisdictions have adopted the *Canadian Electrical Code, Part I* as their standard, and some have introduced additional requirements.

The *Canadian Electrical Code, Part I* (e.g., revised every three years) is used by:

- Lawyers (barristers) and insurance companies to determine liability.
- Fire marshals and electrical inspectors in loss prevention and safety enforcement.

ITS designers and installers must be familiar with all sections of the *Canadian Electrical Code, Part I* when planning the installation of the telecommunications system within Canada and the Bahamas.

Table A.2 lists sections of the *Canadian Electrical Code, Part I* that are applicable to the telecommunications distribution design.

Canadian Codes and Standards, continued

Table A.2
Sections of the *Canadian Electrical Code*

Section	Title	Contents
2	General Rules	Provides information on: • Permits. • Marking of cables. • Flame spread requirements for electrical wiring and cables.
10	Grounding and Bonding	Contains detailed bonding and grounding (earthing) information and requirements for using and identifying bonding and ground (earth) conductors.
12	Wiring Methods	Involves the requirements for installing cabling systems. It outlines: • Raceway systems. • Boxes. • Other system elements.
54	Community Antenna Distribution and Radio and Television Installations	Applies to circuits employed to distribute video, radio, and other information frequency signals.
56	Optical Fiber Cables	Contains the requirements for installing optical fiber cables.
60	Electrical Communication Systems	Contains the requirements for installing communications circuits.
82	Closed-Loop and Preclosed-Loop Power Distribution	Contains the requirements for controlling the signal between the energy controlling equipment and the utilization equipment.

National Research Council of Canada, Institute for Research in Construction (NRC-IRC)

The National Research Council of Canada, Institute for Research in Construction (NRC-IRC) produces several documents and standards that affect telecommunications. Among the most important are:

- *NRC National Building Code of Canada 2005.*
- *NRC National Fire Code of Canada 2005.*

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French Codes and Standards

Electrical and Communications Technical Union (UTE [Union Technique de l'Ectricite et de la Communication])

The Electrical and Communications Technical Union (UTE) produces several documents and standards that affect telecommunications in France.

Among the most important are:

- UTE C 15-900:2006, *Guide Pratique—Cohabitation entre réseaux de communication et d'énergie—Installation des réseaux de communication (Coexistence Between Communication and Power Networks—Implementation of Communication Networks).*
- UTE C 90-480-1:2001 (NFEN 50174-1), *Technologies de l'information—Installation de câblage—Partie 1: Planification de l'assurance de la qualité (Information Technology —Cabling Installation—Part 1: Specification and Quality Assurance).*
- UTE C 90-480-2:2001 (NFEN 50174-2), *Technologies de l'information—Installation de câblage—Partie 2: Planification et pratiques d'installation à l'intérieur des bâtiments (Information Technology—Cabling Installation—Part 2: Installation Planning and Practices Inside Buildings)*.
- UTE C 90-470-2:1995, *Systèmes électroniques pour les foyers domestiques et les bâtiments, HBES—Rapport technique 2—Recommandations pour l'installation professionnelle des câbles à paires torsadées—Classe 1 (Home and Building Electronic Systems [HBES]—Technical Report 2: Guidelines for the Professional Installation of Twisted-Pair Cables—Class 1)*.

Japanese Codes and Standards

The specific standard for residential cabling in Japan is JIS X 5150:2004 (ISO/IEC 11801 Ed.2:2002), *Information Technology—Generic Cabling for Customer Premises.*

United Kingdom (UK) Codes and Standards

NOTE: See also European Codes and Standards for additional applicable standards within the United Kingdom (UK).

The United Kingdom produces standards relating to telecommunications. Some of the most relevant are:

BS 6701:2010 *Telecommunications Equipment and Telecommunications Cabling—Specification for Installation, Operation, and Maintenance*

This edition of BS 6701 extends the requirements of the BS EN 50174 series of standards to the installation, operation, administration, and maintenance of telecommunications equipment and telecommunications cabling other than cabling within the scope of the BS EN 50174 series of standards. It also specifies requirements beyond the scope of the BS EN 50174 series of standards for telecommunications equipment and all types of telecommunications cabling.

United Kingdom (UK) Codes and Standards, continued

The requirements contained within Clause 4 are primarily for the installers of telecommunications equipment and telecommunications cabling.

The requirements contained within Clause 5 are primarily for owners of premises housing telecommunications systems. These owners may delegate selected responsibilities to designers, specifiers, operators, and maintainers of installed telecommunications equipment and telecommunications cabling.

BS 7671:2008 *Requirements for Electrical Installations—IEE Wiring Regulations,* 17th Edition

In Great Britain, electrical installations are required to comply with Statutory Regulations such as *The Electricity Safety, Quality and Continuity Regulations* 2002 (and amendments) and *The Electricity at Work Regulations* 1989 (and amendments). The regulations represent the principal legal requirements. BS 7671 (and amendments) is the national standard to which all domestic and industrial wiring must conform.

Amendment No. 2 primarily concerns a fundamental change to the colors of fixed wiring cables along with some changes because of the introduction of the *Electricity Supply Quality and Continuity Regulations* and some certificate changes. The regulations are to be applied generally to electrical installations. However, in certain circumstances, these regulations may need to be supplemented by the requirements or regulations of other British or European standards.

BS 8300:2009 *Design of Buildings and Their Approaches to Meet the Needs of Disabled People—Code of Practice*

This British standard gives recommendations for the design of new buildings and their approaches to meet the needs of disabled people. This standard explains how the built environment can be designed to anticipate and overcome restrictions that prevent disabled people from making full use of premises and their surroundings. An accessible environment is one in which a disabled person can enter and make use of independently or with help from a partner or assistant.

Some facilities may be designed in such a way as to incorporate access for disabled people. In other situations, additional features such as grab rails, touch legible signs, and hearing enhancement systems may be needed. The guidance in this standard covers a wide range of impairments and the use of the built environment by disabled people who may be residents, visitors, spectators, customers, employees, or participants in sports events, performances, and conferences.

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United Kingdom (UK) Codes and Standards, continued

This British standard does not apply to dwellings or residential buildings designed exclusively for use by disabled people nor does it make specific recommendations relating to the use of buildings by children.

This document should be read in conjunction with building design and requirement documents and local authority guidelines.

BS 8492:2009 *Telecommunications Equipment and Telecommunications Cabling—Code Of Practice For Fire Performance and Protection*

This British standard gives recommendations for fire performance and fire protection of all types of telecommunications equipment and telecommunications cabling. It covers:

- Designing and implementing cabling infrastructures.
- Selecting products, including materials and construction.
- Minimizing fire spread.
- Increasing safety levels for personnel and property.

This British standard details the relationship between its recommendations, the usage of premises, and fire protection measures. It is applicable to certain hazardous environments, but it does not exclude additional requirements that are applicable in particular circumstances (e.g., electrified railways, petrochemical sites, intrinsically safe areas, explosive ordnance storage facilities [bomb dumps]).

NOTE: Annex A considers the fire hazard posed by the installation of telecommunications equipment and telecommunications cabling infrastructure within premises.

United States (U.S.) Codes and Standards

American National Standards Institute (ANSI)

ANSI is a private, not-for-profit organization that serves as the administrator and coordinator of the United States' private sector voluntary standardization system. ANSI's mission is to promote and facilitate voluntary consensus standards and conformity assessment systems.

Americans with Disabilities Act (ADA)

The Americans with Disabilities Act (ADA) of 1992 as it relates to telecommunications is covered in:

- Title IV: Telecommunications of the *Telecommunications Act*, which covers the functionality of devices for hearing and speech impaired individuals.
- Section 4.31: Telephones of the Americans with Disabilities Act (ADA) Accessibility Guidelines (ADAAG). "Accessibility Guidelines for Buildings and Facilities" covers accessibility to telephones and communications devices by the physically impaired.

Additionally, as stated in Section 255 of the *Telecommunications Act,* the industry is obligated to ensure accessibility and usability.

United States (U.S.) Codes and Standards, continued

BICSI®

The BICSI® Standards program produces standards of interest to ITS designers and installers. Some of BICSI's notable standards include:

- ANSI/BICSI 001:2009, *Information Transport Systems Design Standard for K-12 Educational Institutions.*
- ANSI/BICSI 002:2011, *Data Center Design and Implementation Best Practices.*

Federal Communications Commission (FCC)

At the federal level in the United States, the Federal Communications Commission (FCC) publishes numerous reports and orders that deal with specific issues, some of which are listed in this appendix. Table A.3 lists important FCC documents.

Table A.3
Federal Communications Commission documents

Document	Subject Matter
CC Docket 88-57	Defines the location of the demarcation point. The third report and order (99-405) established category 3 UTP as the minimum cable standard for simple premises cabling.
CC Docket 99-216	*The Privatization and Streamlining of Part 68 of the Commission's Rules*. Effective July 23, 2001, the Administrative Council for Terminal Attachments (ACTA) assumed operational responsibility for Part 68. ACTA was established to assume relevant responsibilities privatized by the FCC.
Fact Sheet ICB-FC-011	Connection of 1- and 2-line terminal equipment to the telephone network and installation of premises cabling.
FCC Part 15	*Radiated Emission Limits* (revised 1998) addresses electromagnetic radiation.
FCC Part 22	*Public Mobile Services* (revised 1998).
FCC Part 68	*Connection of Terminal Equipment to the Telephone Network* (1998) provides regulations for connecting premises cabling and customer-provided equipment to the regulated networks. NOTE: This is currently specified within TIA 968.
FCC Part 76	*Cable Television Service*, revised 1998.
Telecommunications Act, 1996	Established new rules for provisioning and competition in telecommunications services.

ACTA = Administrative Council for Terminal Attachments
CC = Common carrier
FCC = Federal Communications Commission
TIA = Telecommunications Industry Association
UTP = Unshielded twisted-pair

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United States (U.S.) Codes and Standards, continued

IEEE C2-2007 *National Electrical Safety Code® (NESC®)*

Published by the IEEE, the *National Electrical Safety Code®* (*NESC®*) is the single most important document for safeguarding persons against electrical hazards during the installation, operation, and maintenance of electric supply and communication lines. The document contains extensive updates and critical revisions that directly impact the power utility industry.

Adopted into law by the majority of states and Public Service Commissions across the United States, *NESC®* is a performance code that has been considered the authoritative source on sound electrical engineering practice for nearly 90 years.

The *NESC®* covers basic provisions for the safeguarding of persons from the hazards arising from the installation, operation, or maintenance of outside plant (OSP) overhead and underground electrical supply and communication lines. It also includes work rules for the construction, maintenance, and operation of electric supply and communication lines and equipment.

The code is typically applicable to those systems and the equipment operated by utilities or similar systems and equipment of an industrial complex under the control of qualified persons. The *NESC®* is also applicable to privately owned or operated complexes. This can include campus environments such as hospitals, college campuses, or industrial complexes.

The *NESC®* is included in the National Institute for Standards and Technology (NIST). The *NESC®* code parts, sections, and rules applicable to telecommunications distribution requirements are listed in Table A.4.

United States (U.S.) Codes and Standards, continued

Table A.4
NESC® parts, sections, and rules applicable to telecommunications distribution requirements

NESC® Reference	Title
Section 1	Introduction to the *National Electrical Safety Code*®
Section 9	Grounding Methods for Electric Supply and Communications Facilities
Part 2	Safety Rules for the Installation and Maintenance of Electric Supply and Communication Lines
Section 20	Purpose, Scope, and Application of Rules
Section 21	General Requirements
Rule 215	Grounding of Circuits, Supporting Structures, and Equipment
Section 22	Relations Between Various Classes of Lines and Equipment
Rule 222	Joint Use of Structures
Rule 223	Communications Protective Requirements
Rule 224	Communication Circuits Located Within the Supply Space and Supply Circuits Located Within the Communication Space
Section 23	Clearances
Rule 230	General
Rule 230F	Fiber-Optic Cable
Rule 231	Clearances of Supporting Structures from Other Objects
Rule 232	Vertical Clearance of Wires, Conductors, Cables, and Equipment Above Ground, Roadway, Rail, or Water Surfaces
Rule 233	Clearances Between Wires, Conductors, and Cables Carried on Different Supporting Structures
Rule 234	Clearance of Wires, Conductors, Cables, and Equipment from Buildings, Bridges, Rail Cars, Swimming Pools, and Other Installations
Rule 235	Clearance for Wires, Conductors, or Cables Carried on the Same Supporting Structure
Rule 236	Climbing Space
Rule 237	Working Space
Rule 238	Vertical Clearance Between Certain Communications and Supply Facilities Located on the Same Structure
Rule 239	Clearances of Vertical and Lateral Facilities From Other Facilities and Surfaces on the Same Supporting Structure
Rule 239F	Requirements for Vertical and Lateral Communication Conductors on Communication Line Structures or Within the Communication Space on Jointly Used Structures
Rule 239H	Requirements for Vertical Communication Conductors Passing Through Supply Space on Jointly Used Structures

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United States (U.S.) Codes and Standards, continued

Insulated Cable Engineers Association (ICEA)

The Insulated Cable Engineers Association (ICEA) is a wire and cable manufacturers' organization that writes telecommunications specifications for the telephone and electrical power industries.

ICEA publications are:

- Adopted in the public interest.
- Designed to:
  - Eliminate misunderstanding between the manufacturer and the user.
  - Assist users in selecting and obtaining proper products for their particular need.

ICEA standards of interest are:

- ANSI/ICEA P-61-694-1999, *Coding Guide for Copper Outside Plant and Riser Telecommunications Cables*.
- ANSI/ICEA S-80-576-2002, *Category 1 and 2 Individually Unshielded Twisted-Pair Indoor Cables for Use in Communications Wiring Systems.*
- ANSI/ICEA S-83-596-2001, *Optical Fiber Premises Distribution Cable*.
- ANSI/ICEA S-84-608-2007, *Telecommunications Cable Filled, Polyolefin Insulated, Copper Conductor*.
- ANSI/ICEA S-85-625-2007, *Telecommunications Cable Aircore, Polyolefin Insulated, Copper Conductor Technical Requirements*.
- ANSI/ICEA S-86-634-2004, *Buried Telecommunications Wire-Filled, Polyolefin Insulated, Copper Conductor Technical Requirements*.
- ANSI/ICEA S-87-640-2006, *Optical Fiber Outside Plant Communications Cable.*
- ANSI/IEA S-89-648-2006, *Telecommunications Aerial Service Wire Technical Requirements.*
- ANSI/ICEA S-90-661-2002, *Category 3, 5, & 5e Individually Unshielded Twisted-Pair Indoor Cable for Use in General Purpose and LAN Communication Wiring Systems Technical Requirements.*
- ANSI/ICEA S-91-674-2006, *Coaxial and Coaxial/Twisted-Pair Composite Buried Service Wires Technical Requirements.*
- ANSI/ICEA S-98-688-2006, *Broadband Twisted-Pair Cable, Aircore, Polyolefin Insulated Copper Conductors Technical Requirements.*
- ANSI/ICEA S-99-689-2006, *Broadband Twisted-Pair, Cable Filled, Polyolefin Insulated Copper Conductors Technical Requirements.*

United States (U.S.) Codes and Standards, continued

- ANSI/ICEA S-101-699-2001, *Standard For Category 3 Individually Unshielded Twisted-Pair Indoor Cable For Use In General Purpose Non-LAN Telecommunications Wiring Systems Technical Requirements.*
- ICEA S-102-700-2004, *Category 6 Individually Unshielded Twisted-Pair Indoor Cables for Use in Communication Wiring Systems Technical Requirements.*
- ANSI/ICEA S-102-732-2009, *Standard for Category 6 and 6_A, 100 Ohm Individually Unshielded Twisted Pairs, Indoor Cables (With or Without an Overall Shield) for Use in LAN Communication Wiring Systems Technical Requirements.*
- ICEA S-103-701-2005, *Riser Cables Technical Requirements.*
- ICEA S-104-696-2001, *Indoor-Outdoor Optical Fiber Cable.*
- ICEA S-110-717-2003, *Optical Fiber Drop Cable.*

National Electrical Installation Standards (*NEIS*®)

The NEIS® develops and produces national installation standards. Standards of interest are:

- ANSI/NECA/BICSI-568, *Standard for Installing Commercial Building Telecommunications Cabling*, 2006.
- ANSI/NECA/BICSI-607, *Telecommunications Bonding and Grounding Planning and Installation Methods for Commercial Buildings,* 2010.

National Fire Protection Association® (NFPA®)

The NFPA® develops and produces fire and safety standards and codes. The following codes and standards are associated with telecommunications:

- NFPA 70®, *National Electrical Code® (NEC®)*, 2011.
- NFPA 70E, *Standard for Electrical Safety in the Workplace®*, 2009.
- NFPA 72®, *National Fire Alarm and Signaling Code®*, 2010.
- NFPA 75, *Standard for the Protection of Information Technology Equipment*, 2009.
- NFPA 76, *Standard for the Fire Protection of Telecommunications Facilities*, 2009.
- NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*, 2009.
- NFPA 99, *Standard For Health Care Facilities, 2005.*

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United States (U.S.) Codes and Standards, continued

- NFPA 101®, *Life Safety Code®*, 2009.
- NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, 2006.

  NOTE: NFPA 255 was withdrawn by NFPA in 2009.
- NFPA 262, *Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces*, 2011.
- NFPA 520, *Standard on Subterranean Spaces*, 2010.
- NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 2011.
- NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*, 2010.
- NFPA 5000®, *Building Construction and Safety Code®*, 2009.

National Electrical Code® (NEC®)

The NFPA sponsors, controls, and publishes the *NEC®* within the U.S. jurisdictional area. The *NEC®* is intended to protect people and property from electrical hazards. The *NEC®* specifies minimum provisions necessary to safeguard persons and property from electrical hazards.

In the United States, most federal, state, and local municipalities have adopted the *NEC®*, in whole or in part, as their legal electrical code. Some states or localities adopt the *NEC®* and add more stringent requirements. Local jurisdiction determines the current edition recognized and does not always adopt the latest edition.

The *NEC®*, which is revised every three years, is used by:

- Lawyers and insurance companies to determine liability.
- Fire marshals and electrical inspectors in loss prevention and safety enforcement.

In buildings that will contain the telecommunications systems, the *NEC®* requirements do not address the electrical environment for reliable and error-free operation of the installed equipment. Additional considerations beyond those necessary for safety are described in performance standards.

The following list of chapters, articles, and sections is not intended to be all-inclusive. They are a representation of those that may impact telecommunications installations. The reader is advised to read the code carefully and verify interpretations with local code enforcement officials since jurisdiction of codes is their responsibility.

The *NEC®* allows Chapter 8: Communications Systems to be separate and independent of the other chapters and articles of the code unless specifically referenced within Chapter 8. Although not all of the articles and sections listed in Table A.5 are referenced by Chapter 8, the information in these articles and sections apply to telecommunications.

United States (U.S.) Codes and Standards, continued

Table A.5
NEC® 2008 chapters, articles, and sections that impact telecommunications installation

NEC® Reference	Title
Section 90.1	Purpose
Section 90.2	Scope
Section 90.3	Code Arrangement
Section 90.4	Enforcement
Section 90.5	Mandatory Rules, Permissive Rules, and Explanatory Material
Section 90.7	Examination of Equipment for Safety
Section 90.8	Wiring Planning
Article 100	Definitions
Article 110	Requirements for Electrical Installations
Section 110.12	Mechanical Execution of Work
Section 110.26	Spaces About Electrical Equipment
Section 110.32	Work Space About Equipment
Section 110.33	Entrance to Enclosures and Access to Working Space
Section 110.34	Work Space and Guarding
Article 200	Use and Identification of Grounded Conductors
Article 210	Branch Circuits
Section 210.25	Branch Circuits in Buildings with More Than One Occupancy
Section 225.14	Open-Conductor Spacings
Article 250	Grounding and Bonding
Section 250.32	Buildings or Structures Supplied by a Feeder(s) or Branch Circuit(s)
Section 250.50	Grounding Electrode System
Section 250.52	Grounding Electrodes
Section 250.53	Grounding Electrode System Installation
Section 250.60	Use of Strike Termination Devices
Section 250.70	Methods of Grounding and Bonding Conductor Connection to Electrodes
Section 250.104	Bonding of Piping Systems and Exposed Structural Steel
Article 280	Surge Arresters, Over 1 kV
Article 285	Surge-Protective Devices (SPDs), 1 kV or Less

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United States (U.S.) Codes and Standards, continued

Table A.5, continued
NEC® 2011 chapters, articles, and sections that impact telecommunications installation

NEC® Reference	Title
Article 300	Wiring Methods
Section 300.1	Scope
Section 300.3	Conductors
Section 300.4	Protection Against Physical Damage
Section 300.11	Securing and Supporting
Section 300.21	Spread of Fire or Products of Combustion
Section 300.22	Wiring in Ducts Not Used for Air Handling, Fabricated Ducts for Environmental Air and Other Spaces for Environmental Air (Plenums)
Article 310	Conductors for General Wiring
Article 314	Outlet, Device, Pull, and Junction Boxes; Conduit Bodies; Fittings; and Handhole Enclosures
Article 324	Flat Conductor Cable: Type FCC
NOTE: The following Articles within Chapter 3 primarily address pathway considerations.	
Article 342	Intermediate Metal Conduit: Type IMC
Article 344	Rigid Metal Conduit: Type RMC
Article 348	Flexible Metal Conduit: Type FMC
Article 350	Liquidtight Flexible Metal Conduit: Type LFMC
Article 352	Rigid Polyvinyl Chloride Conduit: Type PVC
Article 356	Liquidtight Flexible Nonmetallic Conduit: Type LFNC
Article 358	Electrical Metallic Tubing: Type EMT
Article 360	Flexible Metallic Tubing: Type FMT
Article 362	Electrical Nonmetallic Tubing: Type ENT
Article 366	Auxiliary Gutters
Article 372	Cellular Concrete Floor Raceways
Article 374	Cellular Metal Floor Raceways
Article 376	Metal Wireways
Article 378	Nonmetallic Wireways
Article 386	Surface Metal Raceways
Article 388	Surface Nonmetallic Raceways
Article 390	Underfloor Raceways
Article 392	Cable Trays
Article 400	Flexible Cords and Cables
Article 500	Hazardous (Classified) Locations, Classes I, II, and III, Divisions 1 and 2

United States (U.S.) Codes and Standards, continued

Table A.5, continued
NEC® 2011 chapters, articles, and sections that impact telecommunications installation

NEC® Reference	Title
Article 605	Office Furnishings (Consisting of Lighting Accessories and Wired Partitions)
Article 640	Audio Signal Processing, Amplification, and Reproduction Equipment
Article 645	Information Technology Equipment
Article 647	Sensitive Electronic Equipment
Article 701	Legally Required Standby Systems
Article 720	Circuits and Equipment Operating at Less Than 50 Volts
Article 725	Class 1, Class 2, and Class 3 Remote-Control, Signaling, and Power-Limited Circuits
Article 760	Fire Alarm Systems
Article 770	Optical Fiber Cables and Raceways
Article 800	Communications Circuits
Article 810	Radio and Television Equipment
Article 820	Community Antenna Television and Radio Distribution Systems
Article 830	Network-Powered Broadband Communications Systems
Article 840	Premises-Powered Broadband Communications Systems

EMT = Electrical metallic tubing
ENT = Electrical nonmetallic tubing
FCC = Flat conductor cable
FMC = Flexible metal coduit
FMT = Flexible metallic tubing
IMC = Intermediate metal conduit
kV = Kilovolt
LFMC = Liquidtight flexible metal conduit
LFNC = Liquidtight flexible nonmetal conduit
PVC = Polyvinyl chloride
RMC = Rigid metal conduit
SPD = Surge-protective devices

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United States (U.S.) Codes and Standards, continued

Rural Utilities Service (RUS)

The Rural Utilities Service (RUS) is an agency of the United States Department of Agriculture, which provides documents and specifications for telecommunications within rural areas of the United States.

Some key documents include:

- Bulletin 1751F-630, *Design of Aerial Plant,* 1996.
- Bulletin 1751F-635, *Aerial Plant Construction*, 1995.
- Bulletin 1751F-640, *Design of Buried Plant-Physical Considerations,* 1995.
- Bulletin 1751F-641, *Construction of Buried Plant,* 1995.
- Bulletin 1751F-642, *Construction Route Planning of Buried Plant,* 1995.
- Bulletin 1751F-643, *Underground Plant Design,* 2002.
- Bulletin 1751F-644, *Underground Plant Construction,* 2002.
- Bulletin 1751F-650, *Aerial Plant Guying and Anchoring,* 1996.
- Bulletin 1751F-815, *Electrical Protection of Outside Plant,* 1995.
- Bulletin 1753F-204, *REA Specification for Aerial Service Wires (PE-7),* 1996.
- Bulletin 1753F-205, *REA Specification for Filled Telephone Cables (PE-39),* 1993.
- Bulletin 1753F-206, *REA Specification for Filled Buried Wire (PE-86),* 1993.
- Bulletin 1753F-208, *REA Specification for Filled Telephone Cables with Expanded Insulation (PE-89),* 1993.
- Bulletin 1753F-601a*, Minimum Performance Specification For Fiber Optic Cables (For Backbone, Feeder, and Distribution Plant) (PE-90a),* 2009.
- Bulletin 1753F-601b, *Minimum Performance Specification For Fiber Optic Minimum Performance Specification For Fiber Optic Cables (Subscriber Drop Cables),* 2009.

United States (U.S.) Codes and Standards, continued

Society of Cable Telecommunications Engineers (SCTE)

SCTE produces documents and standards relating to broadband telecommunication cable systems. Some important standards are:

- ANSI/SCTE 01-2006, *Specification for "F" Port, Female, Outdoor.*
- ANSI/SCTE 02-2006, *Specification for "F" Port, Female, Indoor.*
- ANSI/SCTE 15-2006, *Specification for Trunk, Feeder, and Distribution Coaxial Cable.*
- ANSI/SCTE 47-2007, *Test Method for Coaxial Cable Attenuation.*
- ANSI/SCTE 60-2010, *Test Method For Interface Moisture Migration Double Ended.*
- ANSI/SCTE 71-2008, *Specification for Braided, 75—Coaxial, Multi-Purpose Cable.*
- ANSI/SCTE 74-2003, *Specification for Braided 75—Flexible RF Coaxial Drop Cable.*
- ANSI/SCTE 92-2007, *Specification for 5/8-24 Plug (Male), Trunk and Distribution Connectors*.
- ANSI/SCTE 117-2006, *Specification for Braided 75—Mini-Series Broadband Coaxial Cable*.
- ANSI/SCTE 123-2006, *Specification for "F" Connector, Male, Feed-Through.*
- ANSI/SCTE 124-2006, *Specification for "F" Connector, Male, Pin Type.*
- ANSI/SCTE 129-2007, *Drop Passives: Bonding Blocks (without Surge Protection).*
- ANSI/SCTE 146-2008, *Outdoor "F" Female to "F" Female Inline Splice.*
- ANSI/SCTE 147-2008, *Specification for 75 Ohm, Inline Attenuators.*
- ANSI/SCTE 148-2008, *Specification for Male "F" Terminator, 75 Ohm.*
- ANSI/SCTE 151-2008, *Mechanical, Electrical, and Environmental Requirements for RF Traps and Filters.*
- ANSI/SCTE 153-2008, *Drop Passives: Splitters, Couplers and Power Inserters.*
- ANSI/SCTE 155-2008, *Indoor "F" Female to "F" Female Inline Splice.*
- ANSI/SCTE 161-2009, *Drop Amplifiers.*
- ANSI/SCTE 167-2010, *Recommended Practice for Headend Cable Color Coding.*

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United States (U.S.) Codes and Standards, continued

Telecommunications Industry Association (TIA)

TIA is accredited by ANSI to develop voluntary industry standards for a wide variety of telecommunications products.

The TIA Standards and Technology Department is composed of five divisions:

- Fiber Optics
- User Premises Equipment
- Network
- Wireless Communications
- Satellite Communications

TIA produces several documents and standards that affect telecommunications, notably the telecommunications building cabling standards, including the 568-C Series.

Among the most notable TIA documents and standards are:

- TIA-526-7 (OFSTP-7)-2002, *Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant*. This standard specifies single-mode optical loss measurement methods between two passively connected points using an optical source and power meter.
- TIA-526-14-B-2010 (OFSTP-14), *Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant; IEC 61280-4-1 Edition 2, Fibre-Optic Communications Subsystem Test Procedure- Part 4-1: Installed Cable Plant- Multimode Attenuation Measurement*. This standard is used to measure the optical loss between any two passively connected points, including end terminations, of a multimode optical fiber cable plant. The optical fiber cable plant, as the term is used here, may consist of optical fiber cables, connectors, mounting panels, jumper cables, and other passive components, but it may not include active components. This standard includes an encircled flux launch condition metric for measuring cable plant. Additionally, this standard includes the description of using an optical time domain reflectomer (OTDR) for total attenuation measurement and measurements of individual component loss.
- ANSI/TIA-568-C.0–2009, *Generic Telecommunications Cabling for Customer Premises.* This standard specifies requirements for generic telecommunications cabling. It specifies requirements for cabling system structure, topologies and distances, installation, performance, and testing. The purpose of this standard is to enable the planning and installation of a structured cabling system for all types of customer premises. This standard specifies a system that will support generic telecommunications cabling in a multi-product, multi-vendor environment.
- ANSI/TIA-568-C.0-1–2010, *Generic Telecommunications Cabling for Customer Premises—Addendum 1, Updated References for Balanced Twisted-Pair.* This addendum updates balanced twisted-pair references in ANSI/TIA-568-C.0 to the current balanced twisted-pair cabling standards of ANSI/TIA-568-C.2 and ANSI/TIA-1152.

United States (U.S.) Codes and Standards, continued

- ANSI/TIA-568-C.1–2009, *Commercial Building Telecommunications Cabling Standard.* This standard specifies requirements for telecommunications cabling within a commercial building and between commercial buildings in a campus environment. It defines terms, specifies cabling topology, lists cabling requirements, establishes cabling distances, sets telecommunications outlet/connector configurations, and provides additional useful information. The purpose of this standard is to enable the planning and installation of a structured cabling system for commercial buildings. This standard establishes performance and technical criteria for various cabling system configurations for accessing and connecting their respective elements.
- ANSI/TIA-568-C.2–2009, *Balanced Twisted-Pair Telecommunications Cabling and Components Standard.* This standard specifies minimum requirements for balanced twisted-pair telecommunications cabling (e.g., channels, permanent links) and components (e.g., cable, connectors, connecting hardware, patch cords, equipment cords, work area cords, jumpers) that are used up to and including the telecommunications outlet/connector and between buildings in a campus environment. This standard also specifies field test procedures and applicable laboratory reference measurement procedures for all transmission parameters.
- ANSI/TIA-568-C.3–2009, *Optical Fiber Cabling Components Standard.* This standard is applicable to premises optical fiber cabling components. Specified in this standard are requirements for components such as cable, connectors, connecting hardware, and patch cords. The purpose of this standard is to specify cable and component transmission performance requirements for premises optical fiber cabling. It is intended to be used by manufacturers; however, users, designers, and installers may also find this standard useful.
- TIA-569-B–2004, *Commercial Building Standard for Telecommunications Pathways and Spaces.* This standard is limited to the telecommunications aspect of commercial building design and construction, encompassing telecommunications pathways and spaces. Telecommunications pathways are designed for installation of telecommunications media, and telecommunications spaces are the rooms and areas where media is terminated and telecommunications equipment is installed. Both single- and multi-tenant buildings are recognized by this standard.
- ANSI/TIA-570-B–2004, *Residential Telecommunications Infrastructure Standard.* This document standardizes requirements for residential telecommunications cabling. These requirements are based on the facilities that are necessary for existing and emerging telecommunications services, including security, home audio, and building control cabling systems.
- ANSI/TIA/EIA-598-C–2005, *Optical Fiber Cable Color Coding*. This standard specifies the recommended identification for individual fibers, fiber units, and groups of fiber units within a cable structure. The methods contained may be used to identify and locate specific fibers for the purpose of connection, termination, or testing within a communication system or for the topography of long haul, feeder route, subscriber, or distribution applications for both on-premises and OSP use. This standard also specifies the optical fiber type identification for color-coding or marking jackets for premises cables used primarily indoors.

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United States (U.S.) Codes and Standards, continued

- ANSI/TIA/EIA-606-A–2002, *Administration Standard for Commercial Telecommunications Infrastructure*. This standard specifies administration systems for commercial telecommunications infrastructure with choices of classes of administration for maintaining telecommunications infrastructure. This infrastructure may range in size from a building requiring a single telecommunications space (TS) and associated elements to many TSs and associated elements in multiple campus locations. This standard applies to administration of telecommunications infrastructure in existing, renovated, and new buildings.
- ANSI/J-STD-607-B–2011, *Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications*. The purpose of this standard is to enable the planning, design, and installation of telecommunications bonding and grounding (earthing) systems within a building with or without prior knowledge of the telecommunications systems that will subsequently be installed. This standard also provides recommendations for grounding (earthing) and customer-owned towers and antennas. This telecommunications bonding and grounding (earthing) infrastructure supports a multi-vendor, multiproduct environment as well as various system installation practices.
- ANSI/TIA-758-B–2011, *Customer-Owned Outside Plant Telecommunications Infrastructure Standard*. This document provides requirements used in the design of the telecommunication pathways and spaces, and the cabling installed between buildings or points in a customer-owned campus environment. Customer-owned campus facilities are typically termed outside plant. For the purpose of this standard, they are termed "customer-owned OSP."
- ANSI/TIA/EIA-862-A–2011, *Building Automation Systems Cabling Standard.* This document specifies a generic cabling system for building automation systems (BAS) that will support a multiproduct, multi-vendor environment. It also provides information that may be used for the design of BAS products for commercial enterprises.
- ANSI/TIA-942–2005, *Telecommunications Infrastructure Standard for Data Centers.* This standard specifies the minimum requirements for telecommunications infrastructure of data centers and computer rooms, including single tenant enterprise data centers and multi-tenant Internet hosting data centers. The topology proposed in this document is intended to be applicable to any size data center.
- ANSI/TIA-1005–2009, *Telecommunications Infrastructure Standard for Industrial Premises.* This standard specifies telecommunications cabling to support industrial premises applications (e.g., voice, data, text, video, industrial and building controls, security, fire alarm, image) while allowing for exposures to wider ranges than most commercial environments (e.g., temperature, humidity, electrical noise, shock, vibration, corrosive gases, dust, liquids). This standard is to enable the planning and installation of the telecommunications cabling infrastructure within and between industrial buildings such as manufacturing facilities, laboratories, and refineries. In these industrial premises, the cabling infrastructure may be exposed to environments more hostile than in commercial buildings and where the cabling must support applications and topologies specific to industrial premises. It provides cabling requirements, cabling distances, telecommunications outlet/connector configurations, and topologies. It describes environmental classifications and provides information that is useful for designing an appropriate telecommunications infrastructure.

United States (U.S.) Codes and Standards, continued

- ANSI/TIA-1152–2009, *Requirements for Field Test Instruments and Measurements for Balanced Twisted-Pair Cabling.* This standard includes requirements for field test instruments that are used to test balanced twisted-pair cabling as specified in the ANSI/TIA-568-C series of structured cabling standards. This standard specifies the reporting and accuracy performance requirements of field testers for balanced twisted-pair cabling measurements. Level IIe, III, and IIIe field tester requirements are specified in this standard. This standard contains methods to compare the field instrument measurements against laboratory equipment measurement specified in ANSI/TIA-568-C.2. Measurement accuracy based upon the assumptions for key performance parameters is addressed.
- ANSI/TIA-1179–2010, *Healthcare Facility Telecommunications Infrastructure Standard.* This standard specifies requirements for telecommunications infrastructure for health care facilities (e.g., hospitals, clinics). It specifies cabling, cabling topologies, and cabling distances. Additionally, pathways and spaces (e.g., sizing, location) and ancillary requirements are addressed. Telecommunications cabling specified by this standard is intended to support a wide range of health care facilities and systems. In addition to telecommunication systems, the telecommunications cabling specified by this standard is intended to support a wide range of clinical and non-clinical systems (e.g., radio frequency interference [RFID], BAS, nurse call, security, access control, pharmaceutical inventory), particularly those which utilize or can utilize IP-based infrastructure.

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Enforcement of United States Building Codes, Standards, and Regulations

Overview

Generally, codes of state or federal regulations are enforced by the same local agency responsible for issuing building permits. In almost all communities, the local government produces ordinances establishing building codes and standards for that jurisdiction.

Some states established statutory regulations that are the minimum conditions under which any local government may permit construction to occur.

In many areas, it is the responsibility of the local fire marshal to:

- Establish local codes.
- Enforce the codes for fire protection in buildings.

Double Requirements

In some areas, compliance with more than one set of codes or regulations is required such as obtaining city and county construction permits.

Local Applications of National Standards

In almost all areas of the United States, local and state governments adopt all or major portions of the building codes. In most cases, local code-making bodies make editorial and technical modifications to the major code they adopt.

In almost all cases, a significant portion of the U.S. national fire codes is either adopted or used as a pattern by local government agencies. Significant in this standardization within the United States is the *NEC*®, produced as NFPA 70.

Military Construction

Construction for branches of the U.S. military:

- Must comply with standards established by those service branches.
- Normally is not subject to local government jurisdiction.

However, most military branch standards:

- Follow the guidelines of national codes.
- Adopt the national codes in their own standards.

Federal Safety Health Standards

The federal government, through the Occupational Safety and Health Act (OSHA), enforces the safety aspects of codes and standards as they apply to employee working conditions. The following construction-related regulations are specific to safety requirements that would apply for installation of telecommunications systems are shown in Table A.6.

Table A.6
Federal safety health standards

Specification/ Standard Number	Title	Date
29CFR1910	*Code of Federal Regulations Title 29, Labor— Part 1910: Occupational Safety and Health Standards*	2008
29CFR1910.146	*Code of Federal Regulations Title 29, Labor— Part 1910.146: Permit-Required Confined Spaces*	2008
29CFR1910.1001	*Code of Federal Regulations Title 29, Labor— Part 1910.1001: Asbestos*	2008
29CFR1910.1926	*Code of Federal Regulations Title 29, Labor— Part 1910; 1926: Safety Standards for Fall Protection in the Construction Industry*	2008
47CFR22	*Code of Federal Regulations Title 47, Telecommunications—Part 22: Public Mobile Services*	2008
47CFR42-69	*Code of Federal Regulations Title 47, Telecommunications—Parts 42–69*	2008
47CFR68	*Code of Federal Regulations Title 47, Telecommunications—Part 68: Connection of Terminal Equipment to the Telephone Network*	2008
47CFR76	*Code of Federal Regulations Title 47, Telecommunications—Part 76: Multichannel Video and Cable Television Service*	2008
47CFR76.605	*Code of Federal Regulations Title 47, Telecommunications—Part 76.605: Technical Standards*	2008

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State Regulations

At the state level in the United States, many public utility/service commissions issue their own rules in addition to monitoring tariffs. State rules are generally in accordance with FCC regulations.

The state commissions' rules and SP tariffs are available to the public. Certain sections of these rules and tariffs deal with installing telecommunications cabling and cable facilities on private and public property.

Municipal/Local Regulations

Other regulations that may affect the installation of the ITS designer's and installer's work include:

- Licensing.
- Permitting.

These may involve additional costs or fees within the state or municipality in order to meet the criteria for actual implementation of the project.

Special Applications

The ITS designer and installer must be aware of any special restrictions or conditions in specialized environments such as:

- Health care facilities.
- Manufacturing facilities.
- Chemical and industrial areas:
  - Explosion proofing.
- Emergency management areas (911).
- Earthquake prone areas:
  - Seismic restraint criteria.
  - Earthquake zone categories.

Regulations and Standards for Wireless Transmission

Wireless Regulations, Standards, Codes, and Organizations

Wireless communications has existed for slightly over 100 years. For that long, it has had an international quality, exemplified by Guglielmo Marconi's demonstration of a transatlantic radiotelegraphy link in 1901. A number of international and regional standards and regulations in the wireless arena have been adopted since then.

On the following pages, the major standards, regulations, and codes that influence the installation and operation of communications devices utilizing the radio spectrum are listed. The role of various organizations in the wireless space and the synergies between them are also provided.

The major areas covered include:

- Wireless standards development organizations.
- Wireless standards and technologies in the following areas:
  - Personal area network (PAN).
  - Local area network (LAN).
  - Metropolitan area network (MAN).
  - Wide area network (WAN).
  - Global area network (GAN).
- Emerging wireless technologies and related standards.
- Codes and regulations.

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Wireless Standards Development Organizations

Several organizations are charged with writing and setting the standards used in the various wireless technologies.

The following are the most prominent:

- Association of Radio Industries and Businesses (ARIB).
- European Telecommunications Standards Institute (ETSI).
- Federal Aviation Administration (FAA).
- Federal Communications Commission (FCC).
- Institute of Electrical and Electronics Engineers® (IEEE®).
- International Civil Aviation Organization (ICAO).
- International Electrotechnical Commission (IEC).
- International Organization for Standardization (ISO).
- Occupational Safety and Health Administration (OSHA).
- Telecommunications Industry Association (TIA).
- Telecommunications Technology Association (TTA).
- Telecommunication Technology Committee (TTC).

Association of Radio Industries and Businesses (ARIB)

ARIB is based in Japan and conducts investigations, research and development, and consultation, and it establishes standards for the utilization of radio waves from the view of developing radio industries.

ARIB promotes the realization and popularization of new radio systems in the field of telecommunications and broadcasting.

European Telecommunications Standards Institute (ETSI)

ETSI is a nonprofit organization with a mission to produce telecommunications standards for use in Europe and beyond. ETSI unites 786 members from 56 countries and represents administrations, network operators, manufacturers, SPs, research organizations, and users.

ETSI plays a major role in developing a wide range of standards and other technical documentation as Europe's contribution to worldwide standardization in telecommunications, broadcasting, and information technology (IT).

The prime objective of ETSI is to support global harmonization by providing a forum in which all of the key players can contribute actively.

European Telecommunications Standards Institute (ETSI), continued

ETSI is actively involved in developing standards for over 30 key technical areas, including:

- Third generation (3G) global system for mobile communications (GSM).
- High-performance radio LAN type 1 (HiperLAN/1).
- HiperLAN/2.
- Digital enhanced cordless telecommunications (DECT).
- Mobility for emergency and safety applications.
- Radio spectrum.
- Short-range devices.

Federal Aviation Administration (FAA)

The FAA cannot enforce telecommunications tower regulations as this authority lies solely with the FCC. However, to help ensure aviation safety, the FCC requires that the FAA be notified of any proposed construction or modification to a tower above 61 m (200 ft). Tower installation companies must submit their proposed projects to the FAA and request a "determination of no hazard to air navigation" in return.

Federal Communications Commission (FCC)

The FCC regulates the towers with antennas through the antenna structure registration (ASR) program. All applicable equipment must have an FCC authorization. The requirements for equipment authorization are found in Title 47 of the *Code of Federal Regulations (CFR)*. The rules cover a diverse range of subjects from FCC organization to requirements for different radio services and maximum permissible heights for antennas located near airports.

Institute of Electrical and Electronics Engineers® (IEEE®)

The work of the IEEE 802 LMSC is of particular interest to wireless practitioners.

See the IEEE section in this appendix.

International Civil Aviation Organization (ICAO)

ICAO, an agency of the United Nations, develops the principles and techniques of international air navigation and fosters the international air transport planning and development to ensure a safe and orderly growth.

The ICAO Council adopts standards and recommended practices concerning air navigation, prevention of unlawful interference, and facilitation of border-crossing procedures for international civil aviation.

In addition, it defines the protocols for air accident investigation for the transport safety authorities of the Chicago Convention signatories. The ICAO rules that impact the wireless design include the heights and markings of structures around airports required for a smooth flight operation and accident prevention.

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International Electrotechnical Commission (IEC)

See the section on IEC in this appendix.

International Organization for Standardization (ISO)

See the section on ISO in this appendix.

Occupational Safety and Health Administration (OSHA)

OSHA is an agency of the U.S. Department of Labor. OSHA specifies regulations for the protection of workers who build, service, or operate wireless infrastructure towers.

Telecommunications Industry Association (TIA)

See the section on TIA in this appendix.

Telecommunications Technology Association (TTA)

TTA is an IT standards organization in Korea that develops new standards and provides services for the establishment of IT standards as well as testing and certification for IT products.

The scope of TTA activities includes telecommunications, IT, radio communications, and broadcasting. TTA has been working on over 2000 standards.

Telecommunication Technology Committee (TTC)

The purpose of this Japanese committee is to contribute to standardization efforts in the field of telecommunications by establishing protocols and standards for telecommunications networks and terminal equipment.

United States (U.S.) Approval of Electrical Products and Equipment

Product Certification

Most states or localities accept certification of electrical products by a national testing laboratory as evidence that products and materials are safe for use in that jurisdiction.

Some agencies may perform their own tests to determine acceptability for installation in their jurisdiction.

Some examples of performed tests from Underwriters Laboratories® (UL®) Inc. are:

- UL 1666, *Standard for Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts*, 2007.
- UL 1685, *Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables*, 2007.

Product Ratings

The categories used within the United States to rate products are:

- Listed.
- Classified.
- Recognized.
- Verified.

Listed

A product is listed after it successfully completes a series of mechanical, electrical, and thermal characteristics tests that simulate all reasonable, foreseeable hazards.

The listed classification is exclusive to the product for the specific applications for which it was tested and is not valid for other applications.

Classified

A product is classified after it is evaluated and passes tests for one or more of the following:

- Specific hazards only
- Performance under specified conditions
- Regulatory codes
- Other standards, including international standards

The classified rating is generally restricted to industrial or commercial products.

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Product Ratings, continued

Recognized

A product is recognized after it is tested for use as a component in a listed package and passes. These component products are tested for electrical, mechanical, and thermal characteristics.

The recognized classification is a more general-purpose approval than listed because it allows a product to be certified for a category of equipment uses.

An example is insulated wire, which is recognized as appliance wiring material, a category of uses that includes:

- Data communications.
- Telecommunications.
- Instrumentation.

Verified

UL® also produces a performance verification of communications cabling with the classification of verified. Cabling manufacturers and their cabling types are listed in the UL® publication, *Performance Levels Certification Program*, for meeting the base performance criteria for the product such as category 3, 5e, and 6.

A performance verification mark allows manufacturers to demonstrate that telecommunications cabling products are certified for both safety and performance, and they comply with industry performance standards and draft standards.

The UL® performance verification mark also signifies the testing of copper and optical fiber cabling products to industry performance standards such as ANSI/TIA/EIA, ISO/IEC 11801Ed.2:2002, NEMA, and Telcordia.

It can also be applied to UL®-listed optical fiber cable verified to Telcordia specifications. The verification mark may also be applied to data transmission or optical fiber cable verified to performance specifications only.

Test Standards

The following standards, though not directly or indirectly related to cabling or transmission systems, are applicable to telecommunications:

- ASTM E84-2010, *Standard Test Method for Surface Burning Characteristics of Building Materials*.
- Ceilings and Interior Systems Construction Association (CISCA)-2007, *Recommended Test Procedures for Access Floors*.
- NFPA 255-2006, *Standard Method of Test of Surface Burning Characteristics of Building Materials*.
  NOTE: This was withdrawn by the NFPA in 2009.
- UL 13-2007, *Power-Limited Circuit Cables*.
- UL 444-2008, *Communications Cables*.

Canadian Approval of Electrical Products and Equipment

Product Certification

All provinces or territories accept certification of electrical products by a recognized (the Standards Council of Canada) testing laboratory to the applicable CEC Part II standard as evidence that products and materials are safe for use in that jurisdiction.

Some agencies may perform their own tests to determine acceptability for installation in their jurisdiction per CSA SPE-1000, the standard for *Model Code for the Field Evaluation of Electrical Equipment*.

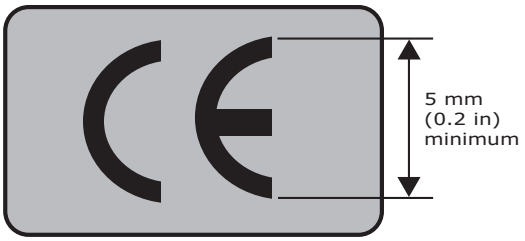
Some examples of performed tests from the CSA are:

- CSA C22.2 No. 0.3-01 (R2005), *Test Methods for Electrical Wires and Cables*.
- CSA C22.2 No. 214-08, *Communications Cables.*
- CSA C22.2 No. 232-M1998 (R2004), *Optical Fiber Cables*.

European Union CE (conformité européenne) Mark

For products placed on the single market in the European Economic Area (EEA), they are required to meet the applicable EU consumer safety, health, or environmental requirements. For electronic products and equipment to show that a product conforms to the EU's EMC Directive (and all applicable directives), the product must be labeled with the conformité européenne (CE) mark as shown in Figure A.1.

Figure A.1
Conformité européenne (CE) mark



The CE mark may be placed on the:

- Equipment.
- Equipment packaging.
- Instructions for use guidelines.
- Guarantee certificate.

For information technology equipment (e.g., computers, computer peripherals), the requirements of the CENELEC EN 55022 standard are similar to the FCC EMI requirements. CENELEC EN 55022 and its companion document, IEC CISPR-22, describe test procedures and limits similar to, but not identical to, the FCC Part 15 requirements and the ANSI/IEEE C63.4 test procedures.

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Glossary

This Glossary provides concise and up-to-date terminology that reflects the information transport systems installation industry worldwide. It includes specific definitions from standards bodies where appropriate, in an effort to harmonize terms within the industry. Symbols have also been updated.

Terms

A

ablative — The development of a hard char that resists the erosion of fire and flames; a characteristic of a firestop when exposed to fire.*

accelerator — A chemical agent used to cause a chemical reaction for setting permanent bonds on epoxy glues.

acceptance angle — Half-angle of the cone within which incident light is totally internally reflected within the optical fiber core. Light within this cone is coupled into reflected modes of the optical fiber.

acceptance plans — A facilitating agreement between parties (e.g., contractor and client or client representative) that defines satisfactory completion of a project task or complete project. It may include items on which the client's acceptance is dependent (e.g., delivery of as-built drawings, test certification).

acceptance test — Test or set of tests performed to demonstrate satisfactory completion of a predetermined task or group of tasks on which acceptance is dependent.

access — The process of connecting to a network.

access floor — A system consisting of completely removable and interchangeable floor panels that are supported on adjustable pedestals or stringers (or both) to allow access to the area beneath.*

access point (AP) — The central or control point in a wireless cell that acts as a link for traffic to and from wireless devices in the cell. The AP also connects wireless devices to the wired portion of the network.

accreditation — Formal process by which an agency or organization evaluates and recognizes an institution or program of study as meeting certain predetermined criteria or standards.

active circuit — A voice/data/video channel connected to a circuit.

acute care — A pattern of health care, which may involve an illness that is of short duration, rapidly progressive, and in need of urgent care.

addendum — Normative document used to provide additional requirements and recommendations to a published document (e.g., standards, contracts). When published, an addendum effectively becomes part of the document that it supports.

aerial cable	Telecommunications cable installed on aerial supporting structures (e.g., poles, sides of buildings, and other structures).*
aerial plant	An overhead infrastructure (e.g., pathway, cable) to provide telecommunications services between facilities.
air bottle	Compressed air source that can be used to propel a foam ball or other object through conduit for the purpose of placing a pull string.
air terminal	A strike termination device that is a point receptor for attachment of flashes to the lightning protection system and is listed for the purpose. Typical air terminals are formed of a tube or solid rod. Also called a lightning rod.
alien crosstalk	Unwanted coupling of signals into a balanced twisted-pair in a given cable from one or more balanced twisted-pair(s) external to the given cable.
all-threaded-rod (ATR)	Straight section of round rod stock that has threads installed over its entire length. Also called a threaded rod.
alternating current (ac)	**1.** Current flow that alternates periodically (usually sinusoidal) in magnitude and direction. **2.** The letters ac are used generically to refer to any periodically alternating (e.g., a sinusoid) waveform or signal (e.g., a line voltage of 115 Vac). Contrast with direct current (dc).
alternating current equipment ground (ACEG)	A conductor installed from the equipment grounding busbar inside electrical panel to a telecommunications grounding busbar or telecommunications main grounding busbar.
ambulatory care	The examination, diagnosis, treatment, and proper disposition of all categories of eligible inpatients and outpatients presenting themselves to the various ambulatory care specialty and/or subspecialty clinics.
ambulatory care clinic	An entity or unit of a medical or dental treatment facility that is organized and staffed to provide medical treatment in a particular specialty and/or subspecialty and holds regular hours in a designated place.
American Institute of Architects (AIA)	Organization that provides resources, continuing education, and networking for architects.
American National Standards Institute (ANSI)	A private, nonprofit membership organization focused on meeting the standards and conformity assessment requirements of its diverse constituency. It provides a neutral forum for the development of consensus agreements on issues relevant to voluntary standardization. The United States (U.S.) representative to the International Organization for Standardization, and through the U.S. National Committee, to the International Electrotechnical Commission (IEC).

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American wire gauge (AWG)	A system used to specify wire size. The greater the wire diameter, the smaller the AWG value. Historically, the AWG number has represented the number of drawing processes applied to a given wire.
ampere (A)	A unit of measurement of electric current. One ampere is equal to the current produced by one volt flowing through a resistance of one ohm.
analog	See analog signal.
analog input (AI)	A device (e.g., a temperature sensor) that sends a continuously variable signal to a building automation system controller.
analog output (AO)	A device (e.g., damper actuator) that receives a continuously variable signal from a building automation system controller.
analog signal	A signal in the form of a wave that uses continuous physical variables (e.g., voltage amplitude or frequency variations) to transmit information. Contrast with digital signal.
anchor	**1.** A fastening device. **2.** In an outside plant environment, a device made up of a single plate or series of flat plates, and combined with a rod having a connecting eye.
angle physical connector (APC)	Optical fiber connector that is polished at an angle of 8 to 10 degrees to reduce the back-reflection of the signal. Some high-performance singlemode systems (e.g., high bandwidth analog video systems) require a very low level of back-reflection (-55 dB or better) to perform correctly.
annular space	The ring of space outside of a pipe or cable penetrating a fire-rated barrier, but inside the hole or sleeve in the barrier.
apparatus	A finished combination of devices (or equipment) intended to be placed on the market as a single commercial unit.
approved ground	A grounding (earthing) source that has been approved for use by the authority having jurisdiction. See also earth ground and ground.
aramid	A material with exceptional tensile strength and coefficient of thermal expansion near that of glass. Widely used as a strength member in optical fiber cables. See aramid yarn.
aramid yarn	A strength element used in cable to provide support and additional protection of the fiber bundles. See aramid.

architectural drawing	A two-dimensional graphical representation of a building, space, or object prepared with adequate detail to convey design information in a manner to serve as a guide for construction thereof.
architectural, mechanical, electrical, structural (AMES)	Drawings or blueprints that include architectural, mechanical, electrical, and structural designs.
asbestos	Potentially hazardous, fibrous mineral substance used in buildings as insulation between the mid-1940s and 1978.
as-built	See record drawing.
asynchronous transfer mode (ATM)	A high-speed packet switching protocol that utilizes fixed-size packets, called cells, to carry all types of traffic (e.g., voice, data, still image, or audio/video).
attenuation	The decrease in magnitude of transmission signal strength between points, expressed in decibel as the ratio of output to input signal level.* See also insertion loss.
attenuation-to-crosstalk ratio (ACR)	The ratio obtained by subtracting insertion loss (attenuation [dB]) from near-end crosstalk (dB). ACR is normally stated at a given frequency. See bit error rate and signal-to-noise ratio.
aught	The arithmetical symbol 0 that is used in the numbering scheme for conductors larger than 0 AWG [8.3 mm (0.33 in)], (e.g., 2/0 AWG [13.41 mm (0.528 in)]). The term aught does not apply to conductors sized in thousand circular mils (MCM [e.g., 250 MCM, 300 MCM]).
aural ear protector	Resembles ear muffs; available in passive or active models. See also ear protector.
authority having jurisdiction (AHJ)	The building official, electrical inspector, fire marshal, or other individuals or entities responsible for interpretation and enforcement of local building and electrical codes.
autorange	Automatic ranging by an optical time domain reflectometer.
autotest	A function used by field test instruments to run all the required tests in a sequential manner without operator intervention.
average power (P_A)	Sustainable or usable portion of electrical energy in an alternating current. For sinusoidal signal, it is the peak power (P_P) multiplied by 0.707 (e.g., 100 watts of P_P is approximately equal to 71 watts of P_A). See also power and peak power.

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B

backboard — A panel (e.g., wood or metal) used for mounting connecting hardware and equipment.

backbone — A facility (e.g., pathway, cable, or conductors) between any of the following spaces: telecommunications rooms, common telecommunications rooms, telecommunications enclosures, common telecommunications rooms, floor-serving terminals, entrance facilities, equipment rooms, and common equipment rooms.*

backbone cable — See backbone.*

backbone cabling — Cable and connecting hardware that provides interconnections between telecommunications rooms, equipment rooms, and entrance facilities. See also backbone.

backbone pathway — The portion of the pathway system that permits the placing of main and high-volume cables between the entrance location and all cross-connect points within a building and between buildings.

backscatter — The scattering of light into a direction opposite to the original direction.

backscatter coefficient — The ratio of backscattered light to transmitted light. The backscatter is a fixed percentage of the transmitted light.

badge reader — A security system device that reads coded cards or badges. Synonym: card reader.

balanced cable — Two or more insulated pairs of wires—identical in composition, size, and length—uniformly twisted together.

balanced copper cable — A cable consisting of one or more copper symmetrical cable elements (twisted-pairs or quads).

balanced twisted-pair cable — See backbone.

balun — A balanced-to-unbalanced circuit-coupling device used to convert from unbalanced to balanced transmission (e.g., impedance matching of twisted-pair to coaxial cabling).

bandwidth — **1.** A range of frequencies available for signaling expressed in hertz. **2.** The information handling capability of a medium, expressed in units of frequency (hertz).

barrel connector — A female-to-female adaptor used to join two connectorized segments of coaxial cable together.

baseband signaling — See baseband transmission.

baseband transmission — A transmission technique in which all of the available bandwidth is dedicated to a single communications channel. Only a single message transfer can occur at a given time.

basic link test configuration — Horizontal cable of up to 90 m (295 ft) plus up to 2 m (6.5 ft) of test equipment cord from the main unit of the tester to the local connection, and up to 2 m (6.5 ft) of test equipment cord from the remote connection to the remote unit of the tester. Maximum length is 94 m (308 ft). Contrast with permanent link test configuration.

baud — **1.** The signal-change rate on the line. **2.** The rate at which the signal changes from one state to the other.

Bayonet Neill-Concelman (BNC) — See BNC connector.

beam clamp — A device attached to a beam or other building structure above the ceiling to hold cable supports or equipment.

bel — A ratio of analog signal strength; named in honor of telephone pioneer Alexander Graham Bell.

bend radius — **1.** The maximum radius that a cable can be bent to avoid physical or electrical damage to cause adverse transmission performance. **2.** Radius of curvature that a media can bend without signal degradation.

bending radius — **1.** For fibers, the bend radius that causes excess attenuation due to light leaking from the core. **2.** Smallest permitted bend in a cable; determined by the construction. Influences the design of cable pathways and installation practices.

biconic — Type of optical fiber connector.

BICSI® — An international telecommunications association offering training, conferences, publications, and registration programs for cabling distribution designers, as well as commercial and residential installers.

bidirectional signaling — Signals that pass in opposite directions between two transmitters. In a twisted-pair cable, this may be on the same or different pairs. Wireless and optical fiber systems also may operate in a bidirectional manner. Contrast with unidirectional signaling.

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bill of material (BOM) List of the quantity and specific types of materials to be utilized on a project. This list should also consider exempt materials (e.g., screws, bolts).

binary Describes an entity (e.g., signal or parameter) that has only two possible values, typically represented as on/off, open/closed, ground/open, high/low, yes/no, positive/negative, etc. When printed out, they are typically expressed as 1 and 0.

binary digit **1.** The smallest unit of information in digital systems. **2.** Zeros and ones used to represent data processed by digital devices.

binary digital system System in which the data rate is determined by the baud rate and the number of bits encoded per baud interval.

binder group One of two or more bound collections of pairs or fibers within a cable.*

bit **1.** The basic unit of digital information, used to indicate the existence of one of two binary states or conditions (e.g., current flow or no current flow, on or off). **2.** A digital pulse representing a one (1) or a zero (0); contracted from the phrase "binary digit." **3.** A binary digit; the smallest element of information in binary systems. It is either a logical one (1) or zero (0), also known as "an on or an off bit" of binary data.

bit error rate (BER) **1.** The ratio of incorrectly transmitted bits to total transmitted bits. A primary specification for all transmission systems, it is usually expressed as a power of 10. The number of errors made in a digital transmission as compared to complete accuracy. **2.** The fraction of bits transmitted incorrectly. See attenuation-to-crosstalk ratio and signal-to-noise ratio.

bit per second (b/s) A unit of measure used to express the data transfer rate. Commonly used rates include kilobit per second (kb/s), megabit per second (Mb/s), and gigabit per second (Gb/s). Also called bit rate.

block (connecting) See connecting hardware.

blueprint A reproduction of an architectural plan and/or technical drawing that provides details of a construction project or an existing structure.

BNC (Bayonet Neill-Concelman) connector A coaxial connector with twist-on bayonet locking coupling.

bond **1.** An electrical connection using a low-resistance path. **2.** A written obligation under seal to guarantee that specific documents are accurate or that the bonded party will meet specific requirements, in a specific way, within a specific time period.

bonding	The permanent joining of metallic parts to form an electrically conductive path that will assure electrical continuity and the capacity to conduct safely any current likely to be imposed.*
bonding conductor (BC)	A conductor used specifically for the purpose of bonding.
bonding conductor for telecommunications (BCT)	A conductor that interconnects the telecommunications bonding infrastructure to the building's service equipment (power) ground.*
branch splices	Splice in which one cable is spliced to multiple smaller pair-count cables.
bridging clip	Encased or bare metal clip utilized to couple cable conductors on a connecting block and provide a point of physical disconnection.
bridle ring	Ring that is circular in shape but is open rather than closed. It has a pointed shaft at its apex that is threaded for installation into wood or rethreaded devices.
broadband	Commonly used to refer to high-speed (over 100 Mb/s) digital circuits, where the communications channel is capable of transporting the data streams simultaneously generated by many devices.
bucket lift	Personnel lift composed of a large bucket mounted on the end of an extendable arm in which the user stands.
buffer coating	A protective thermoplastic material that is applied to the acrylate layer of the optical fiber to protect against environmental hazards. May be more than one layer.
buffer tube	A supplemental loose-fitting cover, which is applied over the primary coated optical fibers at time of installation.
building code	Construction requirements that are adjudicated into law by the authority having jurisdiction.
building entrance protector	Device or devices used to terminate cables entering or leaving buildings. It provides housing for the voltage and current-limiting modules to protect the cable pairs from lightning and foreign voltage.
building grounding electrode system	Network of grounded building components (e.g., metal underground piping, metal building frame, concrete-encased electrode, a ground ring and rod, pipe electrodes).

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bull line — A rope with limited stretch characteristics used for pulling high pair-count backbone cable.

bullwheel — Large wheel used to maintain an arc when feeding large cables into a backbone pathway.

bundle — **1.** Many individual optical fibers contained within a single jacket or buffer tube. Also, a group of buffered optical fibers distinguished in some fashion from another group in the same cable core. **2.** Used to indicate time and common handling of multiple cables routed together.

bundled cable — An assembly of two or more cables continuously bound together to form a single unit.* Contrast with hybrid cable.

bundled fiber — Group of buffered optical fibers distinguished in some fashion from other groups.

buried cable — A cable installed under the surface of the ground in such a manner that it cannot be removed without disturbing the soil.* See direct-buried cable and underground cable.

burn-in — Describes a test or continuous operation of a component or system before it is put into use.

bushing — An insulating lining for an aperture through which multiple conductors may pass.

bus topology — Each communications device or network has a single connection to a shared medium that serves as the communications channel. Also called a point-to-multipoint topology.

butt set — See telephone test set.

butt splice — A splice in which cables enter the same endcap of the splice closure.

C

cabinet — A container that may enclose connection devices, terminations, apparatus, wiring, and equipment.*

cabinet (telecommunications) — Enclosure used for terminating telecommunications cables, wiring, and connection devices with a hinged cover, usually flush-mounted in the wall.

cable (CA) — **1.** An assembly of one or more insulated conductors or optical fibers, within an enveloping sheath.* **2.** An assembly of one or more cable units of the same type and category in an overall sheath. It may include overall screen. (ISO, CENELEC) **3.** The act of installing cable.

cable assembly — A cable that has connectors installed on one or both ends. See jumper and pigtail.

cable brake — See reel brake.

cable-end locator kit — Set of numbered 8-pin modular plugs that can be identified by the cable tester. Also called an office locator kit.

cable head — End of the cable attached to the pulling device.

cable labeling system — Scheme employed when identifying cable or its associated hardware.

cable reel — A spool or bobbin for storing and distributing cable.

cable reel brake — See reel brake.

cable run — Length of installed media, which may include other components along its path.*

cable sheath — A covering over the optical fiber or conductor assembly that may include one or more metallic members, strength members, or jackets.*

cable support system — Combination of conduits, cable trays, support hooks, tie wraps, and any other hardware pieces designed specifically for use in a cabling installation to keep excess stress off the cables. May provide some mechanical protection to the cables being supported.

cable termination — **1.** Act of applying hardware to the end of a cable for the purpose of facilitating connection to active or passive transmission equipment. **2.** Hardware applied to the end of a cable for the purpose of facilitating connection to active or passive transmission equipment.*

cable tray (CT) — A support mechanism used to route and support telecommunications and other cable. Typically equipped with sides that allow cables to be placed within the sides over the tray's entire length.

cable tree — Vertical rack with multiple arms for holding small reels of cable.

cabling — A system of telecommunications cables, cords, and connecting hardware that can support the connection of information technology equipment. (ISO, CENELEC).

calibration — Task of verifying test equipment against a reference.

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campus — **1.** The buildings and grounds having legal contiguous interconnection. (TIA) Some examples include a college, university, industrial park, or military. **2.** A premises containing one or more buildings. (ISO), CENELEC)

capacitance — **1.** The ability of an electronic component to store electrical energy. **2.** Opposition to a change in voltage.

capstan — Device for pulling cable.

carbon block — See carbon protector.

carbon protector — An overvoltage protector that uses closely spaced carbon electrodes (granules) for voltage limiting.

carding brush — See badge reader.

category — A rating that defines the performance of cabling components and systems. Describes mechanical properties and transmission characteristics of balanced twisted-pair cabling and provides a numbered designation. Categories are defined in many regional standards (e.g., ANSI/TIA/EIA, ISO, AS/NZS, JIS).

category 3 — Balanced twisted-pair copper cabling specifications characterized in a frequency range from 1 to 16 MHz.

category 4 — Balanced twisted-pair copper cabling specifications characterized in a frequency range from 1 to 20 MHz. This category is no longer recognized in publishing standards.

category 5 — Balanced twisted-pair copper cabling specifications characterized in a frequency range from 1 to 100 MHz.

category 5e — Balanced twisted-pair copper cable specifications characterized in a frequency range from 1 to 100 MHz. This category specifies transmission parameters that were not characterized by Category 5 (e.g., power sum near-end crosstalk, return loss, equal level far-end crosstalk, and power sum equal level far-end crosstalk) and features more stringent near-end crosstalk than Category 5.

category 6A — Balanced twisted-pair copper cabling specifications characterized in a frequency range from 1 to 500 MHz.

category 6 — Balanced twisted-pair copper cabling specifications characterized in a frequency range from 1 to 250 MHz.

category 7 — Balanced twisted-pair copper cabling specifications characterized in a frequency range from 1 to 600 MHz.

category 7A — Balanced twisted-pair copper cabling specifications characterized in a frequency range from 1 to 1000 MHz.

catwalk	Elevated walkway provided in some buildings to help workers reach utilities.
cell	A single raceway of a cellular or underfloor duct system.*
cementitious	Material that is mixed with water. Similar in appearance to lightweight concrete or mortar, it can be troweled to a smooth finish.
central office (CO)	A common carrier switching center office (also called central office or public exchange) that is conveniently located in areas to serve subscriber homes and businesses. They provide telephony services (lines) that are connected on what is known as a local loop. The central office contains switching equipment that can switch calls locally or to long-distance carrier telephone offices.
certificate of need (CON)	The requirement that a health care organization obtain permission from an oversight agency before making changes. Generally applies only to facilities or facility-based services.
certification test set	A test set designed specifically to measure the properties of a circuit to determine whether the circuit meets certification standards.
change order	A written and signed document issued after the construction agreement has been signed authorizing additions to, deletions from, or modifications of the work to be completed or an adjustment in the contract sum or time. (CSI)
channel	The end-to-end transmission path connecting any two pieces of application-specific equipment. Equipment cords and work area cords are included in the channel. (CENELEC))
channel stock	Metallic, U-shaped bar with spaced holes often hung in a trapeze configuration for support of pathway systems (e.g., conduits and trays).
characteristic impedance	The input impedance of a circuit or a uniform transmission line with constant voltage to current ratio any point along the line.
chase nipple	A metallic bushing used with a locknut, inserted into a hole (typically in a metal enclosure) to protect cabling from abrasion on sharp edges.
chief of service	Member of a hospital staff who is elected or appointed to serve as the medical and/or administration head of a clinical service.
chromatic dispersion	A result of the phenomenon that the velocity of propagation in a medium is frequency dependent, which causes the frequency components of a pulse to lose phase coherence as it propagates (e.g., a transmitted pulse will spread out as it propagates).
cladding	The outer concentric glass layer that surrounds the optical fiber core and has a lower index of refraction than the core.
class D	The International Organization for Standardization/International Electrotechnical Commission balanced twisted copper cabling specifications characterized in a frequency range up to 100 MHz.

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class E	The International Organization for Standardization/International Electrotechnical Commission balanced twisted copper cabling specifications characterized in a frequency range up to 250 MHz.
class E_A	The International Organization for Standardization/International Electrotechnical Commission balanced twisted copper cabling specifications characterized in a frequency range up to 250 MHz.
class F	The International Organization for standardization/International Electrotechnical Commission balanced twisted copper cabling specifications characterized in a frequency range up to 600 MHz.
class F_A	The International Organization for Standardization/International Electrotechnical Commission balanced twisted copper cabling specifications characterized in a frequency range up to 1000 MHz.
cleave	Process of breaking an optical fiber by a controlled fracture of the glass to obtain an optical fiber end that is flat, smooth, and perpendicular to the optical fiber axis.
cleaver	Device that square-cuts the ends of optical fibers.
clinic	A health treatment facility primarily intended and appropriately staffed and equipped to provide emergency treatment and ambulatory services. A clinic is also intended to perform certain nontherapeutic activities related to the health of the personnel served.
clove hitch	Knot consisting of two half-hitches made in opposite directions, forming a nonslip loop.
clustered star	Similar to a tree topology, except that there are clusters of devices at the end of each branch. Also called a bus star topology.
coating	See buffer coating.
coaxial cable	A cable consisting of a central metallic conductor surrounded by a layer of dielectric material. This material may be a solid material or air spaced. The entire assembly is covered with a metallic braid or solid metallic sleeve. An outer jacket of nonconducting material may protect the cable.
code	A rule intended to ensure safety during the installation and use of materials, components, fixtures, systems, premises, and related subjects. Codes are typically invoked and enforced through government regulation.
codec	A device that can transform an analog signal into a digital bit stream (coder) and digital bit stream into an analog signal (decoder).
coefficient of expansion	Formula to determine the physical expansion of a material due to temperature change (e.g., conduit, cable).

communications	See also telecommunications.
communications plenum (CMP) cable	Type CMP communications plenum cable shall be listed as being suitable for use in ducts, plenums, and other spaces used for environmental air and shall also be listed as having adequate fire-resistant and low smoke-producing characteristics. (*NEC*) Cables must pass required test for fire and smoke characteristics of wires and cables, NFPA 262 or UL 910.
compartmentation	The segregation of components, programs, and information. Provides isolation and protection from compromise, contamination, or unauthorized access.
composite cable	Made up of disparate or separate parts (e.g., copper and optical fiber cables in one jacket).*
comprehensive healthcare clinic (CHCC)	A facility planned, designed, and constructed to provide comprehensive ambulatory care services, to include ambulatory surgery, and limited holding bed capability.
concentricity	The relationship of core and cladding that make up the fiber**.**
conductance (G)	The measure of the ease with which electrical current flows through a conductor. Uniformly distributed along the conductor length, conductance varies as a function of a conductor's geometry and the dielectric properties of the materials surrounding the conductor. One of the primary transmission parameters for transmission lines equal to the reciprocal of distributed insulation resistance.
conductor	A material or object that permits an electric current or light wave to flow easily.
conduit	**1.** A raceway of circular cross-section. **2.** A structure containing one or more ducts.*
conduit elbow	Bend in a section of conduit, usually at a specified radius and degree of turn.
conduit run	Multiple sections of conduit that are joined together with fittings.
conduit shoe	Device placed at the open end of a conduit to assist in bending a cable that extends out of the conduit.
conduit stub-out	A short section of conduit that is installed from a receptacle box, usually in a wall, through a suspended ceiling space a short distance to an adjacent hallway.

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conduit stub-up	A short section of conduit that is installed from a receptacle box, usually in a wall, to a suspended ceiling space immediately above the receptacle box.
cone	Safety marker that is used to designate a secure off-limits area for nonworkers.
connecting hardware	A device, or a combination of devices, used to connect cables or cable elements.
connector	A mechanical device used to provide a means for aligning, attaching, and achieving continuity between conductors or optical fibers.
connector insertion loss	Attenuation associated with the physical attachment of two connectors.
consolidation point (CP)	A location for interconnection between horizontal cables extending from building pathways and horizontal cables extending into work areas.*
Construction Specifications Institute (CSI)	Creates and maintains a construction specifications book that is used by the American Institute of Architects.
consultant	A specialist who provides services to the design team that is headed up by an architect or engineer who is under contract with the owner.
continuity tests	A test that validates whether a material can conduct current or light without significant interruption or degradation.
continuum of care	A way of looking at the level and type of care provided to individuals from the most acute and intensive to the least acute and least intensive. Integrated health networks of the future will be expected to provide the entire range of services contained on the continuum.
contractor	Company that performs specific tasks.
contract document	Plans, specifications, and other documents that together set forth the requirements of the contract and become legally enforceable when the agreement is signed. Executed agreements between owner and contractor that become part of the contract when the agreement is signed.
core	The central, light-carrying part of optical fiber through which a light pulse is transmitted.
coronary care unit (CCU)	A medical care unit in which there is appropriate equipment and a concentration of physicians, nurses, and others who have special skills and experience to provide optimal medical care for critically ill coronary or cardiac patients.

coupled bonding conductor (CBC)	A bonding conductor placed (e.g., strapped) on the outside surface of telecommunications cable; used to reduce transient noise.
coupler	A device for connecting two other devices (e.g., connectorized cables) together.
coupling	A mechanical device that is used to connect two sections together. See crosstalk.
crawl space	Limited access building space that may be used for the placement of cabling.
crimp	The act of clamping connectors to a conductor or cable.
crimp head	Section of a splicing rig that fits over an assembled modular connector on the splicing head to provide the crimping of the module.
cross-connect	A facility enabling the termination of cable elements and their interconnection or cross-connection.*
crossed pairs	Error condition where physical connection of a wire or wires in a pair of wires is made to another wire or wires in yet another pair of wires generally found in the same cable.
crosstalk	Unwanted transfer of signal from one or more circuits to other circuits.
cross threading	When the thread patterns of a nut and bolt do not match, a stripping (cross threading) of the thread pattern can occur during installation.
curing	Prepare over a period of time by chemical or physical process for use.
current (I)	Flow of electrons in a conductor measured in amperes.*
customer	Individual or company that has employed contractors to install their telecommunications system(s).
customer premises equipment (CPE)	Telecommunications equipment located on the customer's premises.*
cutover	The process of switching from old network components to new network components. Used when describing the switch of a piece of equipment (e.g., a computer terminal telephone) from an existing channel to a newly installed channel. See also flash cut and hot cut.
cutsheet	**1.** Listing of cable pair assignments used to specify desired circuit connections in a splice or cross-connect. This listing can also serve as the as-built of a splice or cross-connect field. **2.** Cable documentation that shows the existing cable plant, the new cable plant, and the cross-connects that will be relocated during cutover.
cut-through	A switching method in which messages are forwarded as they are received with no error checking. See also modified cut-through and store-and-forward.

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D

daisy-chaining — Practice of wiring devices in a series, with a cable coming into the device, and another out of the device, as opposed to a bus with a continuous line and taps.

dark fiber — **1.** Fiber that is not in use and has no light transmitted. **2.** Excess fiber installed in anticipation of system expansion; may or may not be terminated.

datagram — A data unit created at the Network layer of the Open Systems Interconnection model. It contains the data and control information necessary to transfer a message from one network to another. Also called a packet.

data network — An interconnected system of computers, peripherals, and software over which commands, files, and messages are sent and received.

DB## connector — A connector widely used for connections between data equipment, available in a variety of configurations (e.g., DB15, DB25). Also called a D-subminiature connector.

dBm — **1.** Decibel referenced to one milliwatt (mW); 0 dBm is equal to 1 mW; 10 dBm is equal to 100 mW. **2.** Psophometrically weighted noise power in decibels, with respect to a power level equivalent to an 800 Hz test tone at 0 dBm.

dead zone — Space on a fiber trace following a Fresnel reflection in which no measurement can be made.

decibel (dB) — A logarithmic unit used for measuring the relative power or strength of a signal. See bel.

delay skew — The difference in propagation delay between any two pair within the same cable sheath.*

demarcation point DP) — **1.** A point where the operational control or ownership changes.* **2.** The point of interface between service providers and customer facilities.

demodulator — An electronic device that removes the modulation from signals.

design specification — A written document that defines a goal or set of goals including specific performance and design parameters.

designation strip — Colored label placed on terminal blocks and used for identification (e.g., circuits).

detection badge — See exposure monitor.

detector (optical) — Optoelectronic transducer that converts optical power to electrical current.

device (protection) — A protector, protector mount, protector unit, or protector module.

die — Steel block or plate with small conical holes through which wire is drawn.

dielectric — **1.** The nonconducting properties of an insulating material that resists the passage of electric current. The insulation surrounding a copper conductor is known as a dielectric. **2.** A material that is nonmetallic and nonconductive. **3.** A nonconductor of direct electric current.

dielectric constant — A unit of relative electric permittivity of an insulator.

digital — See digital signal.

digital signal — A signal that changes from one state to another in discrete steps. Contrast with analog signal.

digital subscriber line (DSL) — A type of digital technology designed to use existing (legacy) cabling to support high data transfer rate applications. See xDSL.

direct-buried cable — A telecommunications cable designed to be installed under the surface of the earth, in direct contact with the soil. Contrast with underground cable.*

direct connection — Act of connecting a cable to customer equipment without the use of a patch panel or terminal block.*

direct current (dc) — **1.** Current flow that has a constant magnitude and direction. **2.** The letters dc are also used generically to refer to any constant waveform or signal (e.g., a battery voltage of 3 Vdc). Contrast with alternating current (ac).

direct current (dc) loop resistance — Cable conductor resistance with the far end of the cabling shorted. This is the resistance for two conductors of a metallic cable.

dispersion — **1.** The loss of signal resulting from the scattering of light pulses as they are transmitted through a medium. **2.** The characteristics of the sound coverage field of a speaker.

distribution frame — A structure with terminations for connecting the cabling of a facility in such a manner that interconnection or cross-connections may be readily made.

- Main—When the structure is located at the entrance facility or main cross-connect and serving the building or campus.
- Intermediate—When the structure is located between the main cross-connect and the telecommunications room.*

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distribution ring (D-ring)	Wire management ring shaped like the letter D for routing and supporting distribution cables and jumpers/patch cables on a backboard.
distribution system	A bridging engine in access points that is used to connect access points together. The connection can be wired or wireless.
divestiture	Transferring of title or loss of ownership as a result of government orders, usually as a result of misdeed or in the interest of avoiding a monopolistic business environment.
dopant	An impurity added usually in minute amounts to a pure substance to alter its properties. Typically used during the manufacture of optical fiber cables.
down conductor	Conductor that connects air terminals to ground on the outside of a structure.
download	Transfer of a file from one network device to another.
downtime	Interval during which a functional system is inoperable.
drag line	Pull cord or line installed in a cable pathway. The line may be used for pulling in a stronger strength rope to pull cable(s) of greater mass and weight into the finished conduits. See pull cord.
drain wire	A noninsulated conductor placed in electrical contact with a shield.*
dressing	Placing cables into a neat and symmetrical pattern for proper alignment and positioning for termination.
dressing block	Plastic receptacle used to form and hold connectors to allow wire termination.
drop cable	**1.** A branch cable. **2.** The cable allowing connection and access to and from the trunk cable of a network.
drywall	An interior wall construction consisting of gypsum or plasterboard.
D-subminiature connector	See DB## connector.
duct	**1.** A single enclosed raceway for conductors or cables. See conduit and raceway. **2.** A single enclosed raceway for wires or cables usually used in soil or concrete. **3.** An enclosure in which air is moved. Generally part of the heating, ventilating, and air-conditioning system of a building.*
duplex	A simultaneous two-way independent transmission in both directions.

E

earth current — Alternating or direct current that flows in the earth whether momentary, intermittent, or continuous.

earth ground — An electrical connection to earth obtained by a grounding electrode system. See also approved ground and ground.

earth resistance tests — The testing of earth electrodes and the measurement of soil resistivity.

earthing — Grounding to earth potential.

elastomeric — Made of one of several substances that resemble rubber (i.e., flexible).

electrical coupling — Transfer of energy between two or more electrically conducting bodies. This energy can be through a direct connection or an indirect connection (e.g. electromagnetic interference/radio frequency interference).

electrical distribution panel (EDP) — An assembly, mounted in or on a wall and accessible primarily from the front, consisting of enclosures, buses, and switches to control light, heat, or power circuits. Similar to electrical distribution cabinet except the panel is mounted to a vertical surface and a cabinet(s) are floor mounted.

electrical drawing — Two-dimensional graphical representation of the electrical components of a construction project (e.g., power distribution, lighting).

electrical metallic tubing (EMT) — Thin-wall metal tubing that does not have threaded ends, which is widely used in electrical distribution systems and as a pathway for telecommunications cabling.

electromagnetic compatibility (EMC) — A measure of equipment tolerance to external electromagnetic fields.

electromagnetic induction — Current flow in telecommunications conductors produced by coupling of a magnetic field (e.g., by current in power lines, the cable shield, or other cable pairs).

electromagnetic field tester — The tester measures the presence of electromagnetic fields. Used to identify possible electromagnetic interference sources and their strength.

electromagnetic interference (EMI) — Radiated or conducted electromagnetic energy that has an undesirable effect on electronic equipment or signal transmissions.*

Electronic Industries Alliance (EIA) — An alliance organized along specific electronic product and market lines, and, as a standards association, develops and publishes industry standards.

electrostatic discharge — Electrical release of static electricity generated by interaction of dissimilar materials.

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elevation drawing	A two-dimensional graphical representation of a vertical plane (e.g., a drawing showing a wall-mounted cross-connect as seen standing on the floor looking at the wall).
emergency preparedness plan	Formal written plan of action for coordinating the response of a hospital staff in the event of a natural or technological disaster.
endcap	**1.** The endplate of a splice enclosure specifically arranged for the cable(s) entering and exiting the enclosure. **2.** Closure at the end of a cable tray or series of modular furniture units.
endothermic	Absorbing heat energy.
endplate	See endcap.
engineered judgment	Decision by a firestopping professional for a slight variance in usage of an approved firestop system.
entrance facility (EF [telecommunications])	**1.** An entrance to a building for both public and private network service cables (including wireless), including the entrance point at the building wall and continuing to the entrance room or space.* **2.** A facility that provides all necessary mechanical and electrical services, that complies with all relevant regulations, for the entry of telecommunications cables into a building. (ISO)
entrance point (EP [telecommunications])	The point of emergence for telecommunications cabling through the point of emergence for telecommunications cabling through an exterior wall, a floor, or from a conduit.*
equal level far-end crosstalk (ELFEXT)	Crosstalk measured at the opposite end from which the disturbing signal is transmitted, normalized by the attenuation contribution of the cable or cabling.
equalizing conductor	Term typically used for electrical power installations. Refers to the equalization of different ground (earth) points of a building to keep them at the same potential (zero volt).
equipment grounding conductor	The conductor used to connect the noncurrent-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor, the grounding electrode conductor, or both, at the service equipment.
equipment rack	Typically a vertical aluminum or steel support rack that holds equipment and cable terminations.
equipment room (ER [telecommunications])	An environmentally controlled centralized space for telecommunications equipment that usually houses a main or intermediate cross-connect.*

Ethernet A LAN protocol using a logical bus structure and carrier sense multiple access with collision detection.

event table Results of some optical time domain reflectometers for optical fibers that list each event and its location, loss, and reflectance (if any).

exothermic Chemical change causing the release of heat (e.g., exothermic weld uses an exothermic chemical reaction releasing a large quantity of heat to weld two metals together).

exposed When a circuit is in such a position that in case of failure of supports or insulation, contact with another conductor may result.

exposure monitor A device worn by a cabling installer indicating the level of exposure to a hazardous substance.

F

F connector A 75-ohm radio frequency connector typically used in cable television and on entertainment devices for coaxial cable. Used for RG 59/6 and RG 7/11 type cables to attach drop cables to directional couplers (taps), splitters, and other devices. F connector does not have center pins. F connector uses the solid copper center conductor of the coaxial cable itself as the center pin to establish the connection.

faceplate A protective and/or decorative plate for an outlet.

false ceiling See suspended ceiling.*

false event Reading on an optical time domain reflectometer that is caused by the improper use of the test set or the test setup presents a false reading or indication in the test results.

fanned Separated cable conductors, strands, or pairs.

fan out **1.** Physical preparation of wire pairs exiting the jacketed cable to facilitate placement and termination in a splice or connecting block. **2.** Device used to enable termination of optical fiber strands. See furcating harness. **3.** Multifiber cable constructed in the tight-buffered design for easy connectorization.

far-end crosstalk (FEXT) loss A measure of the unwanted signal coupling from a transmitter at the near end into another pair measured at the far end, and relative to the transmitted signal level. Also called input/output far-end crosstalk loss.*

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fastener	Screw, bolt, or nail-like device that is used to secure an item to a wall, floor, or ceiling.
fault voltage (current)	See foreign voltage (current).
Federal Communications Commission	Regulatory body for United States (U.S.) interstate telecommunications services and international service originating in the United States.
ferrule (optical fiber)	The alignment sleeve portion of an optical connector used to protect and align the stripped fiber.
fiber	See optical fiber.
fiber connector (FC)	Type of optical fiber connector identifiable by its round, screw-operated locking nut. It is usually metal. Its ruggedness leads it to be widely used in test equipment. When not referring to the specific type of connector designated FC, the device used to hold and align one or more fibers in interface with another fiber or fibers.
fiber distributed data interface (FDDI)	Fault-tolerant token-passing network protocol based on single or dual optical fiber rings.
fiber distribution unit	Administrative housing used to terminate fiber cables and connectors for the purpose of interconnections and cross-connection.
fiber fault finder	Small handheld visible light source consisting of a light-emitting diode, lamp, or visible laser. Used to identify fibers, faulty connectors, fiber breaks, or critical bends. The bad connector, or break in the fiber will glow from the light source and be visible on many fiber sheath types (zip, 2.5 mm [0.10 in] or smaller).
fiber optic cable	See optical fiber cable.
fiber optic flashlight	See optical fiber flashlight.
fiber optics	A communications system that uses optical fiber as its medium.
fiber span	The length of optical fiber cable between poles or maintenance holes.
fiber strand identifier	Clamp-on testing unit for optical fiber that places a microbend into the cable to detect light escaping from the fiber.
filled cable	Cable that contains water-blocking nonsolid material inside the sheath to prevent the penetration of moisture.

fire break — A fire-rated material, device, or assembly of parts installed along a cable, other than at a cable penetration of a fire-rated barrier, to prevent the spread of fire along a cable.*

fireproof — A property of a material (e.g., masonry, block, brick, concrete, and gypsum board) that does not support combustion even under accelerated conditions. No material is entirely fireproof.

fire rating system — See fire resistance rating.

fire resistance — A property of a material or assembly of materials that can withstand combustion and delay the passage of flame for some known period of time.

fire resistance rating — The time in hours, or fraction thereof, that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire under specified conditions of test and performance criteria.
NOTE: This resistance is compared to industry-recognized standards (fire rating).

fire retardant — Any substance added to delay the start of ignition or fire or slow the spread of the flame of any material.

fire shield — A fire-rated material, device, or assembly of parts between pathways (e.g., between two parallel cable trays or between layers in vertically stacked trays) to prevent propagation of flames from one pathway to an adjacent pathway.*

firestop — A fire-rated material, device, or assembly of parts installed in a penetration of a fire-rated barrier.*

firestopping — The process of installing (specialty) listed, fire-rated materials into penetrations in fire-rated barriers to re-establish the fire-resistance rating of the barrier.*

firestop system — A specific installation consisting of the material(s) (firestop penetration seals) that fill the opening in the wall or floor assembly, and around and between any items that penetrate the wall or floor (e.g., cables, cable trays, conduit, ducts, pipes), and any termination devices (e.g., electrical outlet boxes) along with their means of support.

firewall — **1.** A continuous barrier used to prevent fire spreading from one fire zone or area to another. **2.** One or more security mechanisms (hardware and/or software) designed to prevent, detect, suppress, and/or contain unauthorized access to a network.

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fire zone	A contained area completely enclosed by fire-resistant rated walls, floors, and ceilings.
fish tape	Tool or device that can be extended from the beginning of a pathway to the other end to assist in installing a pull line or to pull in a cable.
flash cut	A process of migrating from an existing system to another where all circuits are cutover at once. See also cutover and hot cut.
flashing	Pieces of sheet metal or the like used to cover and protect certain joints and angles.
flexible conduit	Raceway of circular cross-section that is bendable without the use of tools.
floor plan	**1.** A scaled diagram or plan of a building floor or other structure shown as if seen from above. **2.** Plan showing the layout of a building floor.
foiled twisted-pair (FTP) cable	A cable medium with twisted insulated copper conductors surrounded by a foil shield and equipped with a drain wire bound in a single sheath. The pair twist protects the cable from electromagnetic interference up to 30 MHz while the foil screens up to and above 100 MHz. See screened twisted-pair cable.
foldback splicing	Process of folding back conductors in a splice for future maintenance or rearrangements.
footprint	Area where a piece of equipment or furniture rests on the floor with its moving parts in a closed position.
foreign voltage (current)	Any unwanted voltage (current) imposed on a system that is not supplied from the central office or from telephone equipment, or from within the system itself. Also called fault voltage (current).
form and dress cable	Line up cables side-by-side, shape into sweeping arcs, and join cable into bundles with tie wrap, or other means, to hold bundles together.
forming	Placing cables into a neat and symmetrical pattern for proper alignment and positioning.
frequency (freq)	The number of cycles or sine waves occurring in a given time; if the unit of time is one second, the frequency is stated in hertz (Hz); one Hz is equal to one cycle per second.
Fresnel reflection	Whenever light traveling in a material encounters a different density material, some of the light is reflected back to the light source, while the rest continues.

furcating harness Assembly used to increase the effective outer diameter of strands within an optical fiber cable to enable connector termination, typically provided in either 6- or 12-strand configurations. Also called a fan out.

furcation Process of covering a 250 micron coated fiber with a 900 micron buffer tube to facilitate field connectorization.

furcation tubing Flexible tubes used to increase the effective outer diameter of coated optical fiber strands (typically from 250 micron to 900 micron) to enable connector termination and provide physical protection of the coated strands.

fuse An overcurrent protective device with a circuit-opening fusible element that is severed (open) when heated by the passage of an overcurrent.

fuse cable link A length of cable that is two gauges smaller than the conductors of the cable being protected and at least 0.6 m (2 ft) long. Fuse cable is inserted in the plant and intended to open on excessive foreign power currents.

fuse link See fuse cable link.

fusion splice A permanent joint accomplished by applying localized heat sufficient to fuse or melt the ends of two optical fibers together, forming a continuous single fiber.

G

Gantt chart A simple chart that diagrams a project schedule.

Gigabit Ethernet A LAN protocol with a 100 times higher transmission rate (1000 Mb/s) than Ethernet. See Ethernet.

gigabit per second (Gb/s) Transmission rate denoting one billion bits per second.

gigahertz (GHz) A unit of frequency denoting one billion cycles per second (hertz).

graded index fiber An optical fiber design in which the refractive index of the core is lower toward the outside of the fiber core and increases gradually in layers toward the center of the core. The refractive index reflects the rays inward and allows them to travel faster in the lower index of refraction region. The purpose is to reduce modal dispersion and thereby increase fiber bandwidth.

ground A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of earth. See approved ground and earth ground.

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ground electrode	See grounding electrode.
ground fault circuit interrupter (GFCI)	A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof, within an established period of time, when a current to ground exceeds the values established for a Class A device. (*NEC*®)
ground loop	Interference in electrical communication links due to the ground at each end being at different potentials.
ground potential rise	A voltage difference between a grounding electrode system and the earth return currents produced by a lightning strike or a power fault current.
grounded	Connected to earth or to some conducting body that serves in place of the earth.
grounded conductor	A system or circuit conductor that is intentionally grounded.
grounding	See grounded.
grounding bushing	A fitting for attaching a ground wire to a conduit.
grounding electrode	A conductor, usually a rod, pipe, or plate (or group of conductors) in direct contact with the earth for the purpose of providing a low-impedance connection to the earth.*
grounding electrode conductor (GEC)	The conductor used to connect the grounding electrode to either the equipment grounding conductor, or to the grounded conductor of the circuit at the service equipment, or at the source of a separately derived system.*
grounding equalizer (GE)	A conductor that interconnects elements of the telecommunications grounding infrastructure (formerly TBBIBC).
grounding system	A system of hardware and wiring that provides an electrical path from a specified location to an earth ground point.
grunt sack	Bag that is raised and lowered on a rope to provide a means of safely passing tools and small materials between individuals working in a construction environment.

H

half-tap — Splicing of a cable or individual pairs where the through cable/conductor is not cut until the cutover takes place. This is a "hot cut" penetration step.

hand trace — Act of physically hand tracing a cable, patch cord, jumper, or cross-connect from one known point to another known point to determine its path.

hanger — Device that is used to hold something in position.

heat shrink tubing — Rubber (or similar material) tubing that shrinks upon the application of heat. Used to insulate splices, connectors, or to create weather or environmental protection to a connection.

hermaphroditic connector — Connector that is neither male nor female.

hertz (Hz) — **1.** A unit of measure used to express the range of frequencies associated with a given signal or communications channel. This range is also called bandwidth. **2.** A unit of frequency equal to one cycle per second. A commonly used rate is megahertz.

hierarchical star topology — An extension of the star topology utilizing a central hub connecting two or more middle layer hubs.

high pair-count cable — Cables consisting of multipair conductors formed into binder groups of 25 pairs.

horizontal cable — **1.** A permanent element of the horizontal cabling that connects the telecommunications outlet/connector at the work area and the first piece of connecting hardware in the horizontal cross-connect (floor distributor). **2.** Four-pair 24 AWG [0.51 mm (0.020 in)] unshielded twisted-pair cable.

horizontal cross-connect (HC [floor distributor (FD)]) — A group of connectors (e.g., patch panel or punch-down block) that allows equipment and backbone cabling to be cross-connected with patch cords or jumpers. Floor distributor is the international equivalent term for horizontal cross-connect.

hot cut — A cutover where the active cables are unplugged from the old system and plugged into the new system. See also cutover and flash cut.

hot red light — Low-intensity laser.

hub — A network device that provides a centralized point for Ethernet LAN communications, media connections, and management activities of a physical star topology cabling system.

hybrid cable — An assembly of two or more cables, of the same or different types or categories, covered by one overall sheath.* Contrast with bundled cable.

hybrid optical fiber cable — An optical fiber cable containing two or more fiber types (e.g., multimode and singlemode).*

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I

impedance — A unit of measure expressed in ohms. The total opposition (resistance, capacitance, and inductance) a circuit, cable, or component offers to the flow of alternating current.

impedance match — A condition whereby the impedance of a particular circuit, cable or component is the same as the impedance of the circuit, cable or device to which it is connected.

impulse noise — Discrete noise spikes that occur, having random amplitude and spectral content.

index-matching gel — Material used in optical fiber connections or splices that has a refractive index close to that of the fiber core; used to reduce reflections from the residual air gap.

index of refraction (IOR) — The ratio of the velocity of light in a vacuum to the velocity of a signal in another medium. Also called refractive index.

inductance (L) — **1.** The property of an electrical force field built around a conductor when current flows through it. **2.** The resistance to change in current.

induction — Phenomenon of a voltage, magnetic field, or electrostatic charge being produced in an object from the source of such fields.

inductive amplifier — Test device used to detect a signal placed on a cable for the purpose of tracing and identification. Also called a wand or probe.

inductive coupling — The transfer of electromagnetic energy from one circuit to another.

infection control program — Policies and procedures followed by a medical or dental treatment facility to minimize the risk of infection to patients and staff.

information transport systems (ITS) industry — Pathways, spaces, cabling systems, wireless systems, and infrastructure that support the transportation of data and data signaling between communication, data processing, data display, or information gathering devices.

infrared (IR) — Electromagnetic spectrum having wavelengths between 0.75 and 1000 micrometers (7.5×10^{-7} m – 1×10^{-3} m) or between 30 and 40,000 microinches ($3 \times 10^{-5} – 4 \times 10^{-2}$ in).

infrared conversion card — Allows a cabling installer to visually detect an infrared signal when that signal is directed at the card's phosphorus material.

infrastructure (telecommunications) — **1.** A collection of those telecommunications components, excluding equipment, that together provide the basic support for the distribution of all information within a building or campus.* **2.** Substructure of system used to support the cable plant being installed.

innerduct — A nonmetallic raceway, usually circular, placed within a larger pathway.*

inpatient care — The examination, diagnosis, treatment, and disposition of inpatients appropriate to the specialty and/or subspecialty under which the patient is being cared for as an inpatient to a hospital.

input impedance — The ratio of the voltage at the sending end of the line to the current in the line at the sending ends.

insertion loss — The signal loss resulting from the insertion of a component, or link, or channel, between a transmitter and receiver (often referred to as attenuation).* See attenuation.

insulating gap — Capacitor installed on the field side of an incoming cable.

insulating joint — **1.** A splice in a cable sheath where the continuity of the sheath and the shield is deliberately interrupted to prevent the flow of currents that may cause electrolytic corrosion. **2.** A direct current isolation gap that is bridged by a capacitor.

insulation — The dielectric material that physically separates wires and prevents conduction between them.

insulation displacement contact (IDC) — A type of wire termination in which the insulation that is surrounding a conductor is displaced at the connection point without physically stripping the insulation from the conductor and consequently makes a gas-tight connection to the conductor.
NOTE: Sometimes refered to as insulation displacement connection or insulation displacement connector.

integrated services digital network (ISDN) — A fully digital communications facility designed to provide transparent end-to-end transmission of voice, data, audio/video, and still images across the public switched telephone network.

intensive care unit (ICU) — A hospital unit in which patients requiring close monitoring and intensive care are housed for as long as needed. An ICU contains highly technical and sophisticated monitoring devices and equipment, and the staff in the unit is educated to give critical care.

interbuilding backbone cable — **1.** Cable that runs between buildings in a campus environment **2.** Outside plant cabling. **3.** Cable that handles traffic between buildings.

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interconnection	A connection scheme that employs connecting hardware for the direct connection of a cable to another cable without a patch cord or jumper, or single-port equipment connections to horizontal or backbone cabling.
interface	**1.** A shared boundary. A physical point of demarcation between two devices or systems where electrical signals, connectors, and timing are defined. **2.** The procedures, protocols, and codes that allow two devices to interact for the purpose of exchanging information.
intermediate care	That care rendered to patients whose physiological and psychological status is such that they require observation and nursing care for the presence of real or potential life-threatening disease or injury. These patients may require monitoring devices, ventilator support, IV therapy, frequent suctioning, dressing changes or reinforcements, and ambulation.
intermediate cross-connect (IC [building distributor (BD)])	The connection point between a backbone cable that extends from the main cross-connect (campus distributor [first-level backbone]) and the backbone cable from the horizontal cross-connect (floor distributor [second-level backbone]). Building distributor is the international equivalent term for intermediate cross-connect.
International Electrical Commission (IEC)	The commission responsible for international electronic standards.
International Organization for Standardization (ISO)	The organization responsible for defining international cabling standards.
Internet	A worldwide internetwork using TCP/IP (transmission control protocol/ Internet protocol).
interstitial space	Small or narrow space located above or below the occupant's space on each floor that is used for routing building services (e.g., lighting, heating, ventilating, and air conditioning, power, telecommunications, plumbing).
intrabuilding backbone cable	Cable that runs between telecommunications rooms inside a building. Can be vertical or horizontal in physical orientation.
intumescent	Ability to enlarge or swell (e.g., under the influence of heat).
inverter	A device that converts direct current into alternating current. *Dictionary.com.*
isolation gap	Procedure that isolates the building ground from the outside plant ground by removing the armor shield from the entrance cable for a short distance and inserting a capacitor to connect from one side of the armor shield to the other side. This may be accomplished at a splice point or in the entrance cable sheath itself.

J

jack — A common term for telecommunications outlet/connector. See also modular jack.

jacket — Outer layer of a cable. See cable sheath.

jackstand — Device for holding a large cable reel off the floor so the cable can be removed from the reel.

J-hook — A supporting device for horizontal cables that is shaped like a J. It is attached to some building structures. Horizontal cables are laid in the opening formed by the J to provide support for the cables.

job change order — See change order.

job plan — Comprehensive outline of all aspects of the project. It includes all work, material, labor, operations and scheduling, how and when the work is to be performed, how each aspect of the work will affect the remaining areas, and how the work will fit into the general contractor's construction schedule.

job site — The physical location where work is to be performed.

jumper — **1.** An assembly of twisted pairs without connectors, used to join telecommunications circuits/links at the cross-connect.* **2.** An optical fiber cable with connectors installed on both ends. See cable assembly and pigtail.

Joint Commission on Accreditation of Healthcare Organizations (JCAHO) — Private, not-for-profit organization composed of representatives of the American College of Surgeons, American College of Physicians, American Hospital Association, American Medical Association, and American Dental Association whose purpose is to establish standards for the operation of health facilities and services, conduct surveys, and determine accreditation.

junction box — A location in the pathway system that allows transition of pathways and access to cables.*

K

keyed — A jack, outlet, or connector is considered keyed when it requires a specific orientation in order to prevent mismating.

key service unit (KSU) — Electromechanical telephone main control unit where telephones have multiple buttons permitting the user to manually select outgoing or incoming central office phone lines. It is not necessary to dial 9 for an outgoing line.

key system — See key service unit (KSU).

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L

labor list — Complete list of all major units of labor to be employed on the project.

ladder rack — A device similar to a cable tray but more closely resembles a single section of a ladder. It is constructed of metal with two sides affixed to horizontal cross members.

ladder tray — See cable tray.

laser — See light amplification by stimulated emission of radiation.

laser diode (light amplification by stimulated emission of radiation) — Device that produces coherent, highly directional light with a narrow range of wavelengths used in a transmitter to convert information from electric to optical form.

lashing — Attachment of cable to another cable or support strand by wrapping thin steel or dielectric strands about them.

launch cable — Length of optical fiber cable used to condition the launch of the optical time domain reflectometer test signal so the correct results will be obtained.

lay — Length measured along the axis of a wire or cable required for a single strand (in stranded wire) or conductor (in cable) to make one complete turn about the axis of the conductor or cable. In a twisted-pair cable, the lay length is the distance it takes for the two wires to completely twist around each other.

lay direction — Direction of the progressing spiral twist in a cable while looking along the axis of the cable away from the observer. The lay direction can be either left or right.

leg — **1.** Portion of the conduit elbow that is straight. **2.** Segment of an end-to-end route or path (e.g., path from user to user via several networks and nodes within networks).

legend — A definition of symbology on a blueprint.

level — Absolute or relative voltage, current, or power measured at a certain point in the circuit or system.

life safety code — Standard developed and updated regularly by the National Fire Protection Association that specifies construction and operational conditions to minimize fire hazards and provide a system of safety in case of fire.

lifting belt — Safety device designed to be worn around the abdomen to help support the stomach muscles while encouraging proper posture.

light amplification by stimulated emission of radiation (laser) — A device that produces coherent, highly directional light with a narrow range of wavelengths used in a transmitter to convert information from electric to optical form.

light-emitting diode (LED) — A semiconductor diode that spontaneously emits incoherent light from the p-n junction when forward current is applied. It converts information from electrical to optical form. An LED typically has a large spectral width. LEDs give moderate performance at lower prices than laser diodes. LEDs are commonly used with multimode fiber in data enterprise and industrial applications.

light source — Used in conjunction with a power meter, the test equipment unit that normally contains a light-emitting diode or laser used to create a light wavelength for testing optical fiber cable loss or continuity.

lightning rod — See air terminal.

linewidth — Spread of wavelengths around the central wavelength of a signal source (e.g., laser).

link — See basic link test configuration and permanent link test configuration.

link state algorithm — Method of computation used to determine efficient routing in networks, based on Dijkstra's algorithm.

listed — **1.** Equipment included in a list published by an organization acceptable to the authority having jurisdiction (AHJ), that maintains periodic inspection of production of listed equipment, and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner. **2.** A product listed after it successfully completes a series of mechanical, electrical, and thermal characteristic tests that simulate all reasonable, foreseeable hazards.*

local area network (LAN) — A geographically limited data communications system for a specific user group consisting of a group of interconnected computers sharing applications, data, and peripheral devices (e.g., printers and CD-ROM drives) intended for the local transport of data, video, and voice.

logical topology — The actual method (ring, bus, star) by which different nodes in a network communicate with one another as compared to the physical connections. Contrast with physical topology.

long-term care — Routine help with everyday activities (e.g., eating, bathing, and dressing necessitated by chronic illness, disability, or frailty). Provided to individuals in their homes, in community settings, or nursing homes. A part of the continuum of care.

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loop resistance Measurement of the resistance of both conductors in a pair of conductors connected in series.

loose tube A type of optical fiber cable construction where one or more fibers are laid loosely in a tube. Also called loose-tube fiber.

loose-tube fiber Optical cable constructed of fiber strands individually covered with a 250 micron acrylate coating, usually encased in bundles of six or twelve strands.

loss Attenuation of a signal, usually measured in dB.

loss budget Total allowable loss between source and detector allocated among fiber, connectors, splices, and safety margin.

loss level Change or sudden spike up from the backscatter that indicates Fresnel reflections.

loss resolution Setting on an optical time domain reflectometer to determine data points.

low-intensity laser This device operates in the visible light range and is used to identify individual fibers that glow red at the point of a fiber break. Also called a hot red light.

low-voltage mounting bracket Device that may be inserted in or on a nonfire-rated finished wall allowing the mounting of a faceplate that may hold telecommunications outlet/ connectors.

M

macrobend Optical fiber cable bending due to installation. Such bends will increase attenuation in optical fiber cable. Contrast with microbend.

magnetic resonance imaging (MRI) A system that produces images of the body by using a strong magnetic field and computers to show the differences between gray and white matter in the brain and also shows other soft-tissue structures that cannot be demonstrated with x-ray technologies.

main building ground electrode Designated point to which all utilities in a building are connected.

main cross-connect (MC [campus distributor (CD)]) The cross-connect normally located in the (main) equipment room for cross-connection and interconnection of entrance cables, first-level backbone cables, and equipment cables. Campus distributor is the international equivalent term for main cross-connect.

main distribution frame (MDF) See main cross-connect.

main distribution panel (MDP) Primary electrical service entrance facility.

maintenance hole (MH [telecommunications]) **1.** A vault located in the ground or earth as part of an underground duct system and used to facilitate placing, connectorization, and maintenance of cables as well as the placing of associated equipment, in which it is expected that a person will enter to perform work. Formerly called manhole.* **2.** A hole through which access to an underground or enclosed structure may be used.

Manchester encoding A digital encoding scheme where a voltage change occurs in the middle of each binary digit sent. A high-to-low change represents the binary digit zero and a low-to-high change represents the binary digit one.

mandrel **1.** A rod or a shaft. **2.** Mechanical device sized to fit the inside diameter of a conduit. Pulled or pushed through a duct, it ensures concentricity of the structure and frees the structure from debris.

manhole See maintenance hole.

MasterFormat™ A document published by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC) that provides the organizational framework (standard master list of numbers and titles) of written instructions for the construction of commercial buildings. (CSI)

material safety data sheet (MSDS) Information system describing hazardous chemicals and materials.

materials list Complete list of all materials to be ordered and received for the project. This includes all capital items and miscellaneous materials.

measured tape Calibrated tape used to measure and pull lengths of conduit.

measurement resolution Setting on the optical time domain reflectometer to determine spacing of data points.

mechanical splicing The joining of two optical fibers through mechanical means to enable a continuous signal. These spliced connections may be temporary or permanent.

media (telecommunications) Wire, cable, or conductors used for telecommunications. See transmission media.*

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medical center — A large hospital that has been so designated and is appropriately staffed and equipped to provide a broad range of health care services. Serves as a referral center and conducts, as a minimum, a surgical graduate medical education program.

medical clinic — A freestanding health care treatment facility appropriately staffed and equipped to provide outpatient medical care that may include a wide range of clinical specialties.

megabit per second (Mb/s) — Transmission rate denoting one million bits per second.

megahertz (MHz) — A unit of frequency equal to one million cycles per second (hertz).

megahertz•kilometer (MHz•km) — The expression of optical fiber cable bandwidth where half power is realized at a specific point in frequency at 1 kilometer (i.e., 160 MHz•km at 850 nm and 500 MHz•km at 1300 nm).

megger — **1.** A device that can be used to measure electrical resistance in a grounding system. **2.** A testing unit used to generate a high voltage between cable conductors to detect current leakage between conductors or conductor to ground.

membrane penetration — An opening through only one surface or side of a barrier.*

mesh grip — Device attached to the end of a cable to facilitate pulling the cable. Also called cable sock. See wire mesh grip.

metropolitan area network (MAN) — A data communications network that covers an area larger than a campus and smaller than a wide area network. Typically interconnects two or more LANs and usually covers an entire metropolitan area (a large city and its suburbs).

microbend — Cable bend associated with the manufacture or construction of optical fiber cable. May be associated with compression of optical fibers. Contrast with macrobend.

micron (µm) — **1.** A unit of length equal to one millionth of a meter. **2.** An abbreviation for micrometer.

modal dispersion — **1.** Dispersion resulting from the different optical path lengths in a multimode fiber. Also called modal distortion. **2.** Characteristic of transmission in an optical fiber that results from different lengths of the light paths taken by the many modes of light as they travel down the fiber from source to receiver.

mode — **1.** Loosely, a possible light path followed by light rays, as in multimode or singlemode. **2.** Strictly, a distribution of electromagnetic energy that satisfies Maxwell's equations and boundary conditions in guided wave propagation (e.g., through a waveguide or optical fiber). **3.** A path of light in an optical fiber.*

mode field diameter (MFD)	Diameter of one mode of light propagating in a singlemode fiber. The mode field diameter replaces core diameter as a practical parameter in singlemode fiber.
modem	See modulator and demodulator.
modified cut-through	A switching method in which messages are forwarded as they are received, with minimal error checking. See also cut-through and store-and-forward.
modular connector	See modular jack and modular plug.
modular furniture	Groups of low-wall partitions, desks, and furniture assembled in original locations in open spaces within an office or work area.
modular jack	A female telecommunications connector that may be keyed or unkeyed and may have six or eight contact positions, but not all the positions need be equipped with jack contacts.*
modular patch panel (MPP)	A facility connecting hardware device enabling the terminating of cable elements on insulation displacement connector modules and their connections by means of a patch cord.
modular plug	A male telecommunications connector for cable or cords that may be keyed or unkeyed and may have six or eight contact positions, but not all the positions need be equipped with contacts.*
modulation	Any of several techniques (e.g., AM and FM) used to modulate a carrier signal with an information-bearing signal.
modulator	An electronic device that modulates baseband video, audio, and data signals to specific carrier frequencies for insertion into the broadband radio frequency distribution system.
mud ring	See low voltage mounting bracket.
multimeter	Test equipment that can perform a variety of electrical property measurements, usually including resistance, voltage, and current.
multimode	Transmits or emits more than one propagating mode.
multimode optical fiber	An optical waveguide that allows many bound modes to propagate.
multiplexer (mux)	A device that combines two or more signals over a single communications channel (e.g., time-division multiplexing and wavelength-division multiplexing).

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multiplexing (muxing) The merging of two or more, low-capacity communications channels into a common, high-capacity channel.

multiuser telecommunications outlet assembly (MUTOA) A grouping in one location of several telecommunications outlets/ connectors.*

mushroom Plastic guide in the shape of a mushroom, typically used for routing jumpers, cross-connects, and patch cords.

mutual capacitance Effective capacitance between the two conductors of a pair.

N

nanometer (nm) A unit of length equal to one billionth of a meter. The most common unit of measurement for optical fiber operating wavelengths.

nanosecond (ns) One billionth of a second.

narrative summary Medical report dictated prior to a patient's discharge from an inpatient facility and ultimately included in the patient's outpatient treatment record.

National Electrical Code® (NEC®) A safety code written and administered by the National Fire Protection Association (NFPA).

National Fire Protection Association (NFPA) Association that writes and administers the *National Electrical Code® (NEC®)*.

N-connector Used as a connector for Series-8, thicknet, and Series-11U coaxial cables. N-type connectors have a center pin that must be installed over the cable's center conductor.

near-end crosstalk (NEXT) loss **1.** The unwanted signal coupling between pairs. It is measured at the end of a cable nearest the point of transmission. Contrast with far-end crosstalk.
2. The signal transfer between circuits at the same (near) end of the cable.

near-field radiation pattern Distribution of the irradiance over an emitting surface (over the cross-section of an optical waveguide).

near infrared Part of the infrared spectrum near the visible spectrum, typically 700 nm to 1500 nm or 2000 nm; it is not rigidly defined.

needs assessment	Evaluation of the requirements or demands for health services by a population or community.
neonatal intensive care unit (NICU)	An intensive care unit for high-risk newborn babies (neonates), directed by a board-certified pediatrician with subspecialty certification in neonatal medicine.
network	A group of two or more nodes that can communicate with each other, either directly through common wiring or indirectly through repeaters to separated wiring. See data network.
network interface card (NIC)	Circuitry in a device that provides the means to physically connect to the network.
network interface device (NID)	The point of connection between networks.*
nibble	Data unit made up of 4 bits. Also called a quartet (sometimes spelled nibble).
node	Addressable point on the network, with processing abilities (e.g., personal computer, terminal, printer).
noise	An unwanted electrical signal on a wire that provides a random or persistent disturbance that interferes with the clarity or quality of the expected signal and alters the shape of the signal.
nominal velocity of propagation (NVP)	The speed of a signal through a cable relative to speed of light.
nomograph	Chart showing three or more scales across which a straightedge may be held in order to read off a graphical solution to a three-variable equation.
nonreflective break	When a fiber is cut or broken, the end may shatter so that the angle at where the light hitting the end may not reflect at all.
nonreturn-to-zero (NRZ)	An encoding scheme in which "1s" are represented by one significant condition and "0s" are represented by another, with no neutral or rest condition. A condition may represent an optical or electrical pulse.
numerical aperture (NA)	**1.** A number that expresses the light-gathering ability of a fiber, defining the maximum angle to the fiber axis at which light will be accepted and propagated through the fiber. NA = sin q, where q is the acceptance angle. **2.** Describes the angular spread of light from a central axis, as in exiting a fiber, emitting from a source, or entering a detector.

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O

Occupational Safety and Health Act (OSHA) — The federal statute creating the Occupational Safety and Health Administration.

Occupational Safety And Health Administration (OSHA) — A United States (U.S.) agency that develops and enforces safety and health standards that apply to the work conditions, practices, means, methods, operations, installations, and processes performed in U.S. workplaces, including telecommunications locations and at telecommunications field installations.

offset — A degree to which the cable or conduit changes direction.

ohm — A unit of measure of electrical resistance; one ohm is defined as the resistance that allows one ampere, the unit of electrical current to flow when one volt is applied.

ohmmeter — A device used to measure voltage and resistance.

Ohm's law — The mathematical relationship among electrical current, resistance, and voltage. The voltage in volts is equal to the current in amperes multiplied by the resistance in ohms.

open — Error condition in a cabling link or channel in which a fault occurs in the continuity of a circuit or conductor.

operating room — An area of a hospital equipped and staffed to provide facilities and personnel services for the performance of surgical procedures.

optical fiber — A transmission media using a thin filament of glass or plastic to transmit pulse light signals. Its bandwidth is higher than copper and not subject to electromagnetic interference. The optical fiber consists of a central core (glass or plastic) and an outer cladding. See plastic optical fiber.

optical fiber cable — An assembly consisting of one or more optical fibers.*

optical fiber connector — A device attached to the end of an optical fiber for the purpose of mating the fiber to a source, receiver, or to another fiber through an optical adapter.

optical fiber flashlight — Device that generates safe visible light (e.g., light-emitting diode) for verifying continuity of optical fiber with the naked eye.

optical power meter — Test equipment that measures the strength of a light wave (in dBm) over a fiber cable.

optical time domain reflectometer (OTDR) — An instrument that measures transmission characteristics of optical fiber by measuring the backscatter and reflection of injected light as a function of time. Used to measure attenuation of optical fiber, splices, connectors, and locate faults.

outside plant (OSP) Telecommunications infrastructure designed for installation exterior to buildings and is typically routed into the entrance facility.*

outlet/connector (telecommunications) A connecting device in the work area on which horizontal cable or outlet cable terminates.*

overfill The energy around a receive antenna that is lost due to its being outside the surface where it can be captured.

overfilled launch The condition when the cladding of an optical fiber is completely filled with light.

P

packet See datagram.

padding down Intentional attenuation of a signal.

pair count **1.** Indicates how many pairs of wires are in a cable. **2.** Pair identification serving a location.

pair scanner See wire map.

pair twist The uniform twist of an insulated copper pair that helps to reduce the negative effects of capacitance imbalance and electromagnetic induction.

patch cord A length of cable with a plug on one or both ends.

patch panel A connecting hardware system that facilitates cable termination and cabling administration using patch cords. See also modular patch panel.*

patching Means of connecting circuits via cords and connectors that can be easily disconnected and reconnected at another point.

pathway **1.** A sequence of connections that provides the connectivity between devices on a network or between networks on an internetwork. **2.** The vertical and horizontal route of the telecommunications cable. **3.** A facility for the placement of telecommunications cable.*

payout box Cardboard container with a hole for cable distribution directly from the box.

peak power (P_p) Maximum electrical energy available in an alternating current. It is a factor of voltage multiplied by the current (amperage). See average power and power.

pedestal A protective aboveground enclosure used most commonly to house a splice point or administrative terminal location.

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penetration Opening made in a barrier (architectural structure or assembly). There are two types of penetration:

- Membrane penetration pierces or interrupts the outside surface of only one side of a barrier.
- Through penetration pierces or interrupts both outside surfaces of a barrier.

peripheral device Equipment connected to and controlled by a station or a server (e.g., CD-ROM drives and modems).

permanent link test configuration The transmission path between two mated interfaces of generic cabling, excluding equipment cords, work area cords, and cross-connections but including the connecting hardware at each end. (ISO) Contrast with basic link test configuration.

personal protective equipment (PPE) Any number of safety apparatuses worn or used (e.g., hard hat, protective eyewear, gloves, clothing) that shields against possible injury while performing tasks.

personnel lift Mechanical device for lifting construction personnel when a ladder cannot be used safely because of the required working height or weight of equipment.

PERT chart A network chart or logic diagram. Generally used by the project manager to see how one change in the project affects the remaining tasks.

phased cutover A progression of transferring an old system to a new system.

photon A fundamental unit of light.

physical topology The material layout of a network that is defined by its cabling architecture.

picofarad One-trillionth of a farad.

pigtail One or more conductors or fibers with only one end terminated. See cable assembly and jumper.*

pinout Wiring scheme for the individual conductors in a telecommunications connector, jack, or plug.

plain old telephone service (POTS) Basic service that supplies standard single-line telephone, telephone lines, and access to the public switched network.

plastic optical fiber (POF) Optical fiber made of plastic rather than glass. See also optical fiber.

plenum A compartment or chamber to which one or more air ducts are connected and that forms part of the air distribution system.*

plenum cable	See communications plenum cable.
plenum rated	Meeting flammability and smoke requirements for the purpose of fire, life, and safety as described by the *National Electrical Code*®.
plugger	Stopper for the end of a syringe.
point of demarcation (DP)	See demarcation point.
poke-thru	A fire-rated device used to penetrate through the fire-resistive floor structure to permit the installation of electrical and/or telecommunications cables.*
polarity	The quality or condition inherent in a body that exhibits opposite properties or powers in opposite parts or directions or powers in contrasted parts or direction.
polyethylene (PE)	Thermoplastic material having excellent electrical properties. A low dielectric constant, a stable dielectric constant over all frequencies with very high insulation resistance. In terms of flexibility, polyethylene can be rated stiff to very hard, depending on molecular weight and density—low density being the most flexible and high density, high molecular weight formulation being very hard. Moisture resistance is rated excellent.
polymer	Substance made of many repeating chemical units or molecules. The term polymer is often used in place of plastic, rubber, or elastomer.
polyvinyl chloride (PVC)	A tough, flame-retardant, thermoplastic, water-resistant insulator.
port	A modular connection point on a device (e.g., a switch, a patch panel).
positive temperature coefficient (PTC)	A resistor whose resistance increases with temperature.
poststressed concrete	Concrete poured into a mold with metal cables exposed at each end.
powder-actuated fastener	A device used to attach material to concrete or steel that is installed using a powder-actuated drive tool.
power (P)	**1.** The rate of transfer or absorption of energy per unit time in a system. **2.** The energy required to operate an electrical device (e.g., a motor, amplifier, or telephone transmitter). See average power and peak power.
power pole	See utility column.
power sum equal level far-end crosstalk (PSELFEXT)	A computation of the unwanted signal coupling from multiple transmitters at the near-end into a pair measured at the far-end, and normalized to the received signal level.*

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power sum near-end crosstalk (PSNEXT) loss	A computation of the unwanted signal coupling from multiple transmitters at the near-end into a pair measured at the near-end.
prefusing	Machine cleaning of the fiber ends prior to performing a fusion splice.
preinstallation meeting	Internal meeting convened by the project manager and including the telecommunications installation team and appropriate contractors to discuss all aspects of upcoming construction project.
premises cabling	A generic term that includes interbuilding, intrabuilding, and horizontal cabling that is owned by a single tenant or landlord. Refers to the entire cabling system used for voice, data, video, and power on a user's premise.
prestressed concrete	Concrete poured into a mold containing tension rods or cable.
primary protector	**1.** A device that limits voltage between telecommunications conductors and ground (usually between 215 volt [V] direct current [dc] to 350 Vdc). **2.** A protective device placed on telecommunications conductors in accordance with NFPA 70.
prime contractor	Master contractor on a job site that may be serviced by several contractors.
private branch exchange (PBX)	A private telecommunications switching system.*
project log	A written log of everything that happens on a project hour-by-hour, day-by-day, or item-by-item.
project plan	Construction plan reflecting all aspects of the work to be performed using a priority schedule.
project schedule	**1.** Chronological order of events that will be accomplished on a project and in the order that they must occur (should be descriptive in text, not a definition). **2.** Scheduling document including all activities to take place in a construction project.
propagation	The motion of waves through or along a medium.
propagation delay	The time required for a signal to travel from one end of the transmission path to the other end.*
proposal	Detailed offer of services and/or resources, usually in exchange for other services or monies.
protector	A device used to protect facilities and equipment from abnormally high voltages or currents.

proton An elementary particle that is a fundamental constituent of all atomic nuclei.

pull cord A cord or wire placed within a raceway and used to pull wire and cable through the raceway.* See drag line and pull string.

pull point Location where it is possible to physically access the cables to pull them.

pull rope Attached between pull string and cable to obtain an increased amount of strength for pulling or moving high-pair-count cable.

pull string A cord or wire placed within a cable pathway and used to pull wire and cable through the raceway. See pull cord.

pulling eye Factory-installed device on a length of cable to which a swivel eye and pull rope are attached.

pulling sheave Pulley having a grooved rim for retaining a rope or cable.

pulling technique Collectively refers to the methods and materials employed to install cables.

pulse code modulation (PCM) A technique for representing an analog signal as a string of bits. The analog signal is converted to a bit sting by periodically sampling the amplitude of the analog signal and representing each sample as a binary number.

pulse repetition rate (PRR) Number of pulses per unit time.

punch down Process of terminating copper cable conductors on insulation displacement connection terminals by use of a handheld tool.

punching down See punch down.

punch list A short list of tasks that are required to be completed in order to close out a work order.

Q

quad cable A 4-conductor nontwisted-pair cable with a red, green, black, and yellow conductor.

quote See proposal.

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R

raceway — Any enclosed channel designed for holding wires or cables.*

rack unit (RU) — A unit of measure of vertical space in an equipment rack. One rack unit is equal to 45 mm (1.75 in).

radio frequency (RF) — The group of electromagnetic energy within the electromagnetic spectrum whose wavelengths are between the audio and the light range (usually between 535 kHz and 300 GHz).

radio frequency interference (RFI) — Electromagnetic interference within the frequency band for radio transmission. See electromagnetic compatibility and electromagnetic interference.*

rat — Lightweight object that can be sent into a conduit to aid in installing a pull string.

Rayleigh scattering — Scattering of light by objects and particles that are small in comparison to the wavelength of the light. In glass, local variations in the molecular structure may be modeled as embedded small scattering objects. See scattering rebar.

real-time — The recording, processing, storage, transmission, and viewing of a message created by an activity as it occurs. Contrast with store-and-forward.

receiver, optical — An optoelectronic circuit that converts an optical signal to an electrical serial logic signal. It contains a photodetector, amplifier, discriminator, and pulse-shaping electronics.

record drawing (as built) — A plan, on paper, that graphically documents and illustrates the installed telecommunications infrastructure in a building, or portion thereof.*

rectifier — **1.** An apparatus in which current flows more readily in one direction than the other, for changing an alternating current into a direct current. *Dictionary.com* **2.** Converts alternating current (ac) to direct current (dc).

red iron — Structural steel assembly painted with five coats of zinc oxide paint, or prerusted for a specified time in the open environment.

reel brake — A device used to control the rate of removal of a cable from a cable reel.

reel dolly — See jackstand.

reflection — See Fresnel reflection.

reflection coefficient — Ratio of the amplitude of the reflected wave and the amplitude of the incident wave. (*Glossary of Telecommunications Terms)*

reflective break	Reflection at an optical fiber cable break caused by the abrupt change in the index of refraction. See Fresnel reflection.
refraction	Angular change in direction of a beam of light at an interface between two dissimilar media or a medium whose refractive index is a continuous function of position (e.g., a graded-index medium).
refractive index	See index of refraction.
Registered Communications Distribution Designer (RCDD)®	A designation for individuals who demonstrate expertise in the design, integration, and implementation of telecommunications (voice, data, video, audio, and other low-voltage control) transport systems and their related infrastructure components.
registered jack (RJ)	The FCC Part 68 registration program for jacks.
reinforcing bar	Steel bar or rod used in concrete construction to provide additional strength. Also called rebar.
relay rack	A vertical metallic frame or equipment bay that is equipped with threaded holes at a predefined spacing. It can be floor mounted (free standing) or wall mounted.
request for information (RFI)	A written request for clarification or information about the contract documents, products, or services offered. It may be issued from a supplier of products or the customer may issue services for it.
request for proposal (RFP)	Detailed document of requested services and equipment of a buyer submitted to others for responses.
request for quotation (RFQ)	Document that solicits quotes for telecommunications projects or equipment and provides vendors with all the information necessary to prepare a quote.
resistance	A measure of opposition a material offers to the flow of direct current.
resistance unbalance	Difference in resistance, expressed in ohms, between the conductors of a pair. May also be expressed in terms of percentage by the ratio of unbalance in ohms to the lowest conductor resistance.
resistivity	Resistance per unit of measure. Measure can be of length (e.g., 100 ohms per meter) or volume (e.g., 500 ohms per cubic meter).
retrofit	**1.** To furnish a device or system with new parts or equipment not available at the time of manufacture. **2.** The installation of a structured cabling system into a pre-existing residential structure.
retrofitting	To modify systems that are already in service using parts made available after the time of original installation.

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return loss A ratio, expressed in dB, of the power of the outgoing signal to the power of the reflected signal.*

return to zero (RZ) Digital code having two information states in which code the signal returns to a rest state during a portion of the bit period.

ribbon cable An assembly of several fibers laid side by side in a geometric plane and fastened together.

rigging System of ropes or pulleys used to move material and equipment.

ring Means for identification of one conductor of a pair. Historically, associated with the wire connected to the ring portion of an operator's telephone plug.

ring network See ring topology.

ringing tool Device used to remove cable sheaths.

ring topology Network topology in which nodes are connected in a point-to-point serial fashion in an unbroken circular configuration. Each node receives and retransmits the signal to the next node.

riser cable See backbone.

roll bar See mandrel.

rolling cut Cutover where the cross-connects are relocated one pair after another.

rule of percentage In a retrofit, the authority having jurisdiction will determine the percentage of existing cable permitted to remain.

S

safety committee Committee composed of medical, dental, nursing, engineering, administrative, and other staff members whose purpose is to oversee safety practice.

safety margin Power loss (dB) value used to assure optical fiber cable performance criteria will be satisfied over the life of the network. Includes expected losses in source power, splice losses, and wear and tear of connectors. See loss budget.

same-day surgery (SDS) program A hospital program for the performance of elective surgical procedures on patients who are admitted to and discharged from the hospital on the day of surgery.

scaffold A temporary structure for holding workers and materials during the erection, repair, or decoration of a building. Also called tower assembly. *(dictionary.com)*

scanner	Device that verifies cabling segments for wiring scheme compliance (e.g., opens, shorts, crossed, reversed and split pairs). The device may also measure cable length and cable performance.
scattering	The deflection of light from the path it would follow if the refractive index were uniform or gradually graded. Caused primarily by micro-defects, impurities, and molecular structure in the fiber. See Rayleigh scattering.
scissor lift	Personnel lift composed of a working platform mounted on a large scissor jack.
scope of work (SoW)	A document that provides detailed statements and descriptions of the work content for the project requirements.
screened twisted-pair (ScTP) cable	A balanced cable with an overall screen.*
scribing tool	**1.** Device used to remove cable sheaths. **2.** Device used to remove excess bare fiber during termination. Also called a cleaving tool.
secondary voltage (supplemental/auxiliary) protector	A secondary voltage protector installed in series with the indoor communications wire and cable between the primary protector and the equipment. The secondary protector provides overcurrent protection that will safely fuse at currents less than the current-carrying capacity of the device that it is intended to protect.
sensitivity	In optical fiber receivers, the minimum power required to achieve a specified bit error rate. See bit error rate.
server	A network device that combines hardware and software to provide and manage shared services and resources on the network.
service loop	A surplus of cable at the point of termination to facilitate potential future arrangements.
service provider (SP)	The operator of any service that furnishes telecommunications content (transmissions) delivered over access provider facilities.* See access provider.
sheath	See cable sheath.*
shield	A metallic layer placed around a conductor or group of conductors.*
shielded twisted-pair (STP) cable	Cable made up of multiple twisted copper pairs with an additional metallic shield covering each individual pair. The entire structure is then covered with an overall shield or braid and an insulating sheath (cable jacket).
short	Low-resistance connection between two conducting materials.

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short circuit	An accidentally established low-resistance connection between two points in an electrical circuit.
shorting bar	Maintains continuity of a logical ring after the removal of a hermaphroditic connector, normally called a data connector.
shorting plug	Device to create a direct-connect between two or more conductors at one end of a cable for test purposes.
signal generator	Test equipment that generates a distinctive tone(s) that is placed on a cable pair for identification purposes. Sometimes referred to as a tone generator.
signaling dynamic range	Combination of the total pulse power of a laser source and the sensitivity of the associated sensor. Measurements are listed as a value reported in dB where larger values mean longer distance measurement capability.
signal-to-noise ratio (SNR)	Ratio of the electrical signal power and the noise power in a receiver, expressed in dB. The prime-determining factor in bit error rate. See attenuation-to-crosstalk ratio (ACR) and bit error rate (BER).
simplex	A process during which signals are transmitted in only one direction; one station is the transmitter and the other is the receiver.
sine wave	The variation of a wave, described by a trigonometric function, from zero to maximum (positive) back through zero to minimum, and back to zero (negative).
singlemode optical fiber	**1.** Optical fiber with a relatively small diameter, featuring a core of 8-9 micron (micrometers) and a cladding diameter of 125 micron; light is restricted to a single path, or mode, in a singlemode fiber. **2.** An optical fiber that carries only one path of light.*
site drawing	A two-dimensional graphic representation of the land and any exterior pathways that are being installed upon which a construction project will take place.
site survey	A process used to identify the characteristics of an environment impacting the installation of network components. Required for the design of any network.
sleeve	An opening, usually circular, through the wall, ceiling, or floor to allow the passage of cables.*
slot	An opening through a wall, floor, or ceiling, usually rectangular, to allow the passage of cables.*

small form factor (SFF) connector	A connector that consists of two fibers secured in a plug approximately the size of an 8-position modular jack.
snake rod	Telescoping pole used to route horizontal cable above dropped ceilings.
space (telecommunications)	An area used for housing the installation and termination of telecommunications equipment and cable (e.g., common equipment rooms, equipment rooms, common telecommunications rooms,telecommunications rooms, work areas, and maintenance holes/hand holes).*
spatial resolution	Setting on an optical time domain reflectometer to determine how close individual data points are spaced in time and distance.
special care unit (SCU)	A medical care unit in which there is appropriate equipment and a concentration of physicians, nurses, and others who have special skills and experience to provide optimal care to critically ill patients. This excludes a close observation room (COR).
spike	A very brief surge of energy.
splice	**1.** A joining of conductors meant to be permanent.* **2.** A device that joins conducting or transmitting media.
splice bank	Placement of 25-pair modules in a symmetrically spaced configuration within a splice enclosure.
splice case	A metal or plastic housing with a semicylindrical cavity used in identical pairs to clamp around a cable splice to provide a closure.
splice closure	A device used to protect a splice.*
splice tray	A container used to organize and protect fiber splices, as well as a means for storing fiber slack.
splicing head	Section of a splicing rig that supports the crimp head. It can be either single or dual.
splicing rig	Specific manufacturer's tool kit for terminating modular connectors.
split grip	Wire mesh grip that is open on one side.
split pair	Transposition of two conductors of separate pairs.
spool	**1.** A combination of hardware and software commonly used by print servers to redirect requests destined for a printer. **2.** Cylindrical containers of cable. See cable reel.

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standard Guideline documentation that reflects agreements on products, practices, or operations by nationally or internationally recognized industrial, professional, trade associations, or governmental bodies. (*Telecom Glossary 2000*)

standard network interface (SNI) Device that serves as a demarcation point between the local exchange carrier and the customer. Usually a modular jack with some type of mounting for the modular jack.

standing wave ratio The ratio of the amplitude of a standing wave at an antinode to the amplitude at a node.

star topology A topology in which telecommunications cables are distributed from a central point.*

star-wired ring Physical star configured as a ring. Also known as a collapsed ring through a hub that performs all appropriate routing operations.

station An input or output point in a communications system (e.g., a telephone, computer, or fire alarm station).

station location Telephone or computer location.

step-index fiber An optical fiber, either multimode or singlemode, in which the core refractive index is uniform throughout so that a sharp step in refractive index occurs at the core-to-cladding interface.

stick Slang term used to describe a section of conduit.

store-and-forward **1.** The recording, processing, storage, transmission, and viewing of an activity after it has occurred. Contrast with real-time. **2.** A switching method in which messages are stored as they are received, fully checked for errors, and then forwarded. See also cut-through and modified cut-through.

STP-A An IBM designed, shielded twisted-pair cable consisting of two individually shielded 22 AWG [0.64 mm (0.025 in)] conductor pairs, with an overall shield capable of supporting transmission to 300 MHz.

straight splice Splice in which cable enters one endcap and, after splicing the cable, exits the other endcap of the closure.

straight tip (ST) Type of optical fiber connector identified by its bayonet housing. Housing may be metallic or plastic.

strand **1.** A single string of wire used to make up a larger wire or cable by twisting a number of strands together. Galvanized steel stranded cable is used as support strand and guy wire. **2.** A single unit of optical fiber within a cable.

stranded cable	A cable with individual conductors composed of groups of wires twisted together.
strand identifier	Clamp-on unit that inserts a microbend into optical fiber cable and detects light escaping from the fiber.
strength member	That part of an optical fiber cable composed of aramid yarn, steel strands, fiberglass filaments, or fiberglass-reinforced epoxy composite rod that increases the tensile strength of the cable.
structural return loss (SRL)	Ratio in dB of the test signal power and the reflected signal power due to impedance variations in the cable.
stub-out	Conduit installed from a wall outlet to a raceway.
stub-up	Conduit installed from a wall or floor outlet into the accessible ceiling space above.
subcommittee (SC)	Subcommittee as defined by standards committees.
submittal	Information that a contractor must submit to the design team for review and approval.
subscriber connector (SC)	The optical fiber SC (SCFOC/2.5) has a square front profile with push-pull latching mechanism maintaining the polarity of duplex cables.
surface-mounted raceway	Plastic or metallic raceway that is installed on the surface of a wall, floor, or ceiling that provides a protective pathway for cables and/or power from public access.
surge arrestor	Protective device for limiting surge voltages by discharging or bypassing surge current, and it also prevents continued flow of follow current while remaining capable of repeating these functions. (*NEC*®)
suspended ceiling	A ceiling that creates an area or space between the ceiling material and the structure above.*
sweep	Bend that has a gentle arc rather than a sharp bend.
swing-floor phasing	The act of removing personnel and property from one location to another in order to facilitate renovation of the space vacated.
switch	**1.** A multiport bridge on which each port represents a separate network communications channel. See bridge. **2.** A voice communications device that utilizes switching technology to establish and terminate calls (e.g., private branch exchange).

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T

telecommunications — Any transmission, emission, and reception of signs, signals, writings, images, and sounds; that is, information of any nature by cable, radio, optical, or other electromagnetic systems.*

telecommunications bonding backbone (TBB) — A conductor that interconnects the telecommunications main grounding busbar (TMGB) to the telecommunications grounding busbar (TGB).*

telecommunications bonding backbone interconnecting bonding conductor (TBBIBC) — Two or more telecommunications grounding busbars in a multistory building. See grounding equalizer.

telecommunications closet (TC) — See telecommunications room.*

telecommunications equipment bonding conductor (TEBC) — Bonding conductor that should be installed from each piece of equipment in the telecommunications room or equipment room to the telecommunications grounding busbar or telecommunications main grounding busbar.

telecommunications grounding busbar (TGB) — A common point of connection for telecommunications system and equipment bonding to ground, and located in the telecommunications room or equipment room.*

Telecommunications Industry Association (TIA) — An association that publishes telecommunications standards and other documents.*

telecommunications main grounding busbar (TMGB) — A busbar placed in a convenient and accessible location and bonded, by means of the bonding conductor for telecommunications, to the building service equipment (power) ground.*

telecommunications outlet (TO) — An assembly of components consisting of one or more connectors mounted on a faceplate, housing, or cross-connect cabling. See outlet/connector (telecommunications).*

telecommunications room (TR) — An enclosed architectural space for housing telecommunications equipment, cable terminations, and cross-connect cabling.*

Telecommunications Systems Bulletin (TSB) — Document published by the Telecommunications Industry Association used to provide guidance for design methodologies or installation practices that pertain to telecommunications cabling systems. The next published edition of a related standard typically adopts these bulletins.

telemedicine	A term that encompasses various technologies as part of a coherent health service resource management program, which captures, displays, stores, and retrieves medical images and data for the creation of a computerized patient record and managed care.
telephone test set	Voice circuit testing device used to identify circuits and perform diagnostics (e.g., butt set).
telephony	**1.** Speech transmission by radio sets or telephony sets. **2.** Describing telephone equipment and telephone technology.
telescoping pole	Pole used for lifting and moving cable in open ceilings.
temporary cabling	Cables and equipment that are installed to provide service on a temporary basis (e.g., providing parallel system during a retrofit installation where the temporary cables are removed after cutover).
terminal block (TB)	Protected or unprotected unit that serves to terminate cable conductors and is a transition point between cable conductors.
terminate	See cable termination.
termination	This term is outdated. See space (telecommunications).*
termination point	A cable connection point.
terminator	An impedance-matching device placed at the end of the telecommunications transmission line.
tertiary care	Provision by a large medical center, usually serving a region or state and having sophisticated technological and support facilities, of highly specialized medical and surgical care for complex medical problems.
thicknet	Considered to be obsolete. See 10BASE5 in Abbreviations and Acronyms.
thinnet	See 10BASE2 in Abbreviations and Acronyms.
through penetration	A continuous opening that passes through both surfaces of a fire-rated barrier.*
throughput	The amount of data transferred between two points in a given amount of time.
TIA/EIA	Trade associations involved in developing telecommunications industry standards.

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tie wrap	Plastic hook and loop strip used for binding and dressing cable.
tight buffer	A cable construction where each fiber is tightly buffered by a protective thermoplastic coating to a diameter of 900 microns.
tight-buffered optical fiber cable	Type of cable construction whereby each glass fiber is tightly buffered by a protective thermoplastic coating to a diameter of 900 microns. Each low-speed channel is allocated a specific time position in the bit stream.
timber hitch	A type of knot.
time-division multiplexing (TDM)	Transmission technique whereby several low-speed channels are combined into a single high-speed channel for transmission. Each low-speed channel is allocated a specific time position in the bit stream.
time domain reflectometer (TDR)	A device that sends a signal down a cable, then measures the magnitude and amount of time required for the reflection of that signal to return. TDRs are used to measure the length of cables as well as locate cable faults.
tip	Means for identification of one conductor of a pair. Historically, associated with the wire connected to the tip portion of an operator's telephone plug.
token ring	Network protocol in which attached devices share a common cabling system for communications purposes without the possibility of a collision between transmissions. A device is only able to send a message when it is in possession of a special electronic sequence of bits called a token.
tone generator	Device used to apply an electrical signal to a circuit to assist in identification or fault location.
topology	The physical or logical arrangement of a telecommunications system. See logical topology and physical topology.*
total internal reflection	Confinement of light within a fiber because the angle of incidence is within the numerical aperture.
trade size	Name given to materials to identify a nominal size.
trailer string	Line attached to the end of a cable(s) being pulled. May be used for future additional pulls.
transceiver	**1.** A radio transmitter and receiver combined into a single unit. **2.** A device that acts as an interface between the network and the connected device.
transfer impedance	A measure of shielding performance determined by the ratio of the voltage on the conductors enclosed by a shield to the surface currents on the outside of the shield.*

transition point (TP) A location in the horizontal cabling where flat undercarpet cable connects to round cable.*

transmission The movement of information as electrical or optical signals from one point to another via a medium.

transmission media The physical carriers of electromagnetic signal energy (e.g., copper, fiber, and air) radiation. See also media and media telecommunications.

transmitter (TX) **1.** An optoelectronic circuit that converts an electrical logic signal to an optical signal. **2.** In fiber optics, using a source such as light-emitting diode or laser.

trapeze Support device using threaded rod and channel stock.

trench A furrow dug into the earth for the placement of direct-buried cable, or for the installation of conduit ducts.

tugger Device that acts as an assist mechanism for advancing a cable or groups of cables during installation.

twisted-pair Two individually insulated copper wires physically twisted together to form a balanced pair.

twisted-pair cable A multiconductor cable comprising two or more copper conductors twisted in a manner designed to cancel electrical interference.

twisted-pair physical medium-dependent (TP-PMD) A network protocol that allows for 100 Mb/s transmission.

two-point method Method used to measure optical fiber cable loss utilizing two closely spaced cursors on an optical time domain reflectometer.

U

underground cable A telecommunications cable designed to be installed under the surface of the earth in a trough or duct that isolates the cable from direct contact with the soil. Contrast with direct-buried cable.*

Underwriters Laboratories, Inc.® (UL®) United States-based independent testing laboratory that sets safety tests and standards.

Underwriters Laboratories of Canada (ULC) A Canadian-based independent testing laboratory that sets safety tests and standards.

unidirectional signaling Signaling that occurs in one direction. Contrast with bidirectional signaling.

uninterruptible power supply (UPS) A device that is inserted between a primary power source (e.g., a commercial utility) and the primary power input of equipment to be protected (e.g., a computer system) to eliminate the effects of transient anomalies or temporary outages.

unshielded twisted-pair (UTP) cable Cable made up of one or more pairs of twisted copper conductors without metallic shielding. The entire assembly is covered with an insulating sheath (cable jacket).

utility column An enclosed passageway, usually placed between buildings, for the distribution of utility services.*

V

vampire tap Device used to provide an electrical connection to a transceiver into thick Ethernet cable without breaking/cutting the cable.

vault A telecommunications space, typically subterranean, located within or between buildings and used for the distribution, splicing, and termination of cabling. These spaces may be established as a maintenance hole in campus environments or they may include active equipment in addition to passive cabling such as in a controlled environment vault.

velocity of propagation Speed of transmission along a cable relative to the speed of light in a vacuum.

V-groove Position in fusion splicer where fiber strand is placed.

voice over Internet protocol (VoIP) A system in which voice signals are converted to packets and transmitted over a network using transmission control protocol/Internet protocol (TCP/IP).

volt (V) A unit of electromotive force or potential difference that will cause a current of one ampere to flow through a resistance of one ohm.

voltage Electrical potential or potential difference expressed in volts.

volt-ohmmeter (VOM) An instrument used to measure electrical characteristics. See multimeter.

W

wall mount bracket Support device having a diagonal brace between the vertical section and the horizontal section, and mounted to a wall.

wand	Test device that is used to detect a signal placed on a cable for the purpose of identification.
wavelength	The length of a wave measured from any point on one wave to the corresponding point on the next wave (e.g., from crest to crest). The wavelength of light is usually measured in nanometers.
Web	Used as a noun, it is shorthand for the World Wide Web (WWW) services found on the Internet.
wide area network (WAN)	An internetwork that uses telecommunications links to connect geographically distant networks.
winch	A device that acts as an assist mechanism for advancing a cable or groups of cables during installation.
wire	An individually insulated solid or stranded metalllic conductor.*
wire management	Components placed in racks or on walls to support the routing of cables.
wire map tester	An instrument used to determine circuit opens, shorts, crossed pairs, improper wiring, and the determination of proper pin configuration; additionally, some units indicate cable length.
wireway	A supported pathway for cables.
wirewrap	Termination of conductors by wrapping the conductor around a post.
work area cable (cord)	A cable connecting the telecommunications outlet/connector to the terminal equipment.*
work area (work station)	A building space where the occupants interact with telecommunications terminal equipment.*
work area outlet	A connecting device for termination of horizontal media. See telecommunications outlet/connector.
working group (WG)	Working group as defined by standards' committees.
workstation	A telecommunications device used in communicating with another telecommunications device.

Z

Z-gap	Spacing in fusion splicing.

* Terms marked with an asterisk are reprinted with permission of Telecommunications Industry Association (TIA).

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Abbreviations, Acronyms, and Units of Measure

10BASE2	IEEE 802.3 standard for baseband Ethernet at 10 Mb/s over 50 ohm thin coaxial cable.
10BASE5	IEEE 802.3 standard for baseband Ethernet at 10 Mb/s over 50 ohm coaxial trunk and attachment unit interface.
10BASE-T	IEEE 802.3 standard for baseband Ethernet at 10 Mb/s over twisted-pair cabling.
100BASE-FX	IEEE 802.3 standard for baseband Ethernet at 100 Mb/s over multimode optical fiber.
100BASE-TX	IEEE 802.3 standard for baseband Ethernet at 100 Mb/s over twisted-pair cabling.
1000BASE-LX	IEEE 802.3 standard for long wave length baseband Ethernet at 1000 Mb/s (1 Gb/s) over multimode optical fiber using a 1310 nm laser source.
1000BASE-SX	IEEE standard for baseband Ethernet at 1000 Mb/s (1 Gb/s) over multimode optical fiber using a 850 nm laser source.
1000BASE-T	IEEE standard for baseband Ethernet at 1000 Mb/s (1 Gb/s) over four twisted-pairs, using Category 5 or higher cabling.
1000BASE-TX	TIA standard for baseband Ethernet at 1000 Mb/s (1 Gb/s) over four twisted-pairs, using Category 6 or higher cabling.
2.5 generation (2.5G)	2.5G extends 2G systems, adding features such as packet-switched connections and enhanced data rates. 2.5G networks include enhanced data for GSM evolution (EDGE) and general packet radio service (GPRS). These networks support wireless access protocol (WAP), mail management system (MMS), short message service (SMS) mobile games, and search and directory.

A

A	ampere
AAL	asynchronous transfer mode (ATM) adaptation layer
ABNT	Associacão Brasileira de Normas Técnicas (Brazilian Technical Standards Association)
ABS	acrylonitrile-butadiene-styrene
ac	alternating current
AC	access provider
ACA	Australian Communications Authority
ACD	automatic call distributor
ACEG	alternating current equipment ground
ACIG	Australian Communications Industry Forum
ACR	attenuation-to-crosstalk ratio
A-D or A/D	analog-to digital conversion
ADA	Americans with Disabilities Act
ADO	auxiliary disconnect outlet
ADPCM	adaptive differential pulse code modulation
ADSL	asynchronous digital subscriber line
A/E	architect or engineer
AF	audio frequency
AFF	above finished floor
AH	ampere hour
AHA	American Hospital Association
AHJ	authority having jurisdiction
AHU	air handling unit
AI	analog input
AIA	American Institute of Architects
AIOD	automatic identification of outward dialing
ALPETH	aluminum polyethylene
AM	amplitude modulation
AM	automated mapping
AME	architectural, mechanical, electrical

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AMEP	architectural, mechanical, electrical, and plumbing
AMES	architectural, mechanical, electrical, structural
AMI	alternate mark inversion
AMP	ampere
AMPS	advanced mobile phone service
ANSI	American National Standards Institute
AO	analog output
AP	access point
AP	access provider
APC	angle physical connector
APC	angle polished connector
ARCnet	attached resources computing network
ARPANET	Advanced Research Projects Agency Network
ARPAP	resin-coated aluminum, polyethylene aluminum, polyethylene
AS	Australian Standard
ASC	Accredited Standards Committee
ASCII	American standard code for information interchange
ASHE	American Society for Healthcare Engineering
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.
AS/NZS	Australia/New Zealand Standard
ASP	aluminum, steel, polyethylene
ASTM®	American Society for Testing and Materials
ATDM	asynchronous time division multiplexing
ATIS	Alliance for Telecommunications Industry Solutions
ATM	asynchronous transfer mode
ATM	automatic teller machine
ATR	all-threaded-rod
AT&T	American Telephone and Telegraph Company
AUI	attachment unit interface
AWG	American wire gauge
AXT	alien crosstalk

B

B or Bur	buried
BACnet®	building automation and control network®
BAS	building automation system
BBMD	building automation and control network (BACnet®) broadcast management device
BC	bonding conductor
BCT	bonding conductor for telecommunications
BD	building distributor
BEF	building entrance facility
BER	bit error rate
BIBB	building automation and control network (BACnet®) interoperability building block
BIC	Building Industry Consultant
B-ICI	broadband intracarrier interface
BICS	Building Industry Consulting Service
B-ISDN	broadband integrated services digital network; also BISDN
bit	binary digit
BMS	building management system
BNC	Bayonet Neill-Concelman
BOM	bill of material
BRI	basic rate interface
BRISDN	basic rate integrated services digital network
b/s	bit per second
BS	British Standard
BSI	British Standards Institution
BTL	BACnet® Testing Laboratories
Btu	British thermal unit
BVLL	building automation and control network (BACnet®) virtual link layer
BWA	broadband wireless access

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C

C	capacitance
C	capacity
C	Celsius
C	flush- or surface-mounted jack
CA	cable
CAD	computer-aided design
CAFM	computer-aided facility management
CAH	critical access hospital
CAI	common air interface
CAL	common application language
CALEA	Communications Assistance for Law Enforcement Act
CAM	computer-aided manufacturing
CAN	Canada
CAP	carrierless amplitude and phase
CARF	Commission on Accreditation of Rehabilitation Facilities
CATV	community antenna television (cable television)
CB	citizens band
CB	conduit bank
CBC	coupled bonding conductor
CCIA	Computer Communications Industry Association
CCIR	Consultative Committee on International Radio
CCITT	Consultative Committee of International Telegraph and Telephone (now known as the International Telecommunication Union-Telecom [ITU-T] or International Telecommunication Union-Telecommunication Standardization Sector [ITU-TSS])
CCSA	common control signal arrangement
CCT	circuit (European)
CCTV	closed-circuit television
CD	campus distributor
CD	compact disc

CD	construction document
CDF	combined distribution frame
CDMA	code division multiple access
CDO	community dial office
CDPD	cellular digital packet data
CE	common element
CE	conformité Européene
CE	curved elliptical
CEBus®	Consumer Electronics Bus
CEC	*Canadian Electrical Code*
CE Code	*Canadian Electrical Code*
CEI	Comitato Elettrotecnico Italiano (Italian Electrotechnical Committee)
CEMF	counter electromotive force
CEN	Comité Européen de Normalisation
CENELEC	Comité Européen de Normalisation Electrotechnique (European Committee for Electrotechnical Standardization)
CEPT	European Conference of Postal and Telecommunications Administrations
CEV	controlled environment vault
CF	cellular floor
CFR	*Code of Federal Regulations*
CHAMPUS	Civilian Health and Medical Program of the Uniformed Services
CIC	Consumer Electronics Bus (CEBus®) Industry Council
CIO	chief information officer
CISCA	Ceilings and Interior Systems Construction Association
CISPR	International Special Committee on Radio Interference
ckt	circuit
CL	closet
CLEC	competitive local exchange carrier
CLIP	classical Internet protocol
CLOS	closet

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CLR circuit layout record

CM common mode

CM construction manager

CM control module

CMG communications general

CMP communications plenum

CMR communications riser

CMRR common-mode rejection ratio

CMU concrete masonry unit

CMUC undercarpet communications

CMX communications, limited

CO central office

coax coaxial cable

codec coder/decoder

COE central office equipment

CON certificate of need

CO-OSP customer-owned outside plant

COR close observation room

COT central office terminal

CP consolidation point

CPC central premises communications

CPE customer premises equipment

CPE customer provided equipment

CP-FSK continuous phase frequency shift keying

CPMS cable pressure-monitoring system

CPR cardiopulmonary resuscitation

CPU central processing unit

CPVC chlorinated polyvinyl chloride

CR change request

CR curved rectangle

CREDFAC conduits, risers, equipment space, ducts, and facilities

CRM cardiac rhythm management

CRT cathode ray tube

CS Canadian standard

CSA® Canadian Standards Association

CSA customer serving area

CSC Construction Specifications Canada

CSI claims status inquiry

CSI Construction Specifications Institute

CSMA/CA carrier sense multiple access with collision avoidance

CSMA/CD carrier sense multiple access with collision detection

CSU channel service unit

CT cable tray

CTS clear to send

CTS conventional terminating set

CW continuous wave (on-off)

D

D-A or D/A digital-to-analog conversion

DAC dual attachment concentrator

DAF dedicated access facility

DAMPS digital advanced mobile phone service

DAS dual-attachment station

dB decibel

DB direct-buried

DB duct bank

DB (A) decibels adjusted for frequency

DBIA Design Build Institute of America

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dB/km decibel/kilometer

dBm decibel milliwatt

dBmV decibel millivolt

dBrnc decibels above reference noise (with C-message weighting)

DBS direct broadcast satellite

dc direct current

DCE data circuit-terminating equipment

DCO digital central office

DCS digital cellular system

DD design development

DD distribution designer

DD distribution device

DDC direct digital control

DDE direct data entry

DDS digital data service

DEC Digital Equipment Corporation

DECT digital European cordless telephone

demarc demarcation point

demux demultiplexer

DGM data grade medium

DGP data gathering panel

DI digital input

DIST district

DIX Digital/Intel/Xerox

DL ductliner (innerduct)

DLC digital loop carrier

DM differential mode

DMD differential mode delay

DMT discrete multitone

DNS domain name system

DO digital output
DoJ Department of Justice
DoT Department of Transportation
DP demarcation point
DP dual polarized
DPAM demand priority access method
DQDB distributed queue dual bus
D-ring distribution ring
DS digital sound
DSL digital subscriber line
DSS digital satellite signal
DSSS direct sequence spread spectrum
DSU digital service unit
DSX digital signal cross-connect
DTE data terminal equipment
DTR dedicated token ring
DVD digital versatile disc
DVR digital video recorder
DW distribution wire
DXI data exchange interface

E

EBC equipment bonding conductor
EC European Community
ECP executive cellular processor
ECTFE ethylene chlorotrifluoroethylene
EDGE enhanced data for GSM evolution
EDI electronic data interchange
EDP electrical distribution panel

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EEA	European economic area (composed of European Union, Iceland, Norway, Liechtenstein)
EF	entrance facility
Eff	efficiency
EFT	electrical fast transient
EHF	extremely high frequency
EIA	Electronic Industries Alliance
EIB	European installation bus
EIBA	European Installation Bus Association
EIN	employer identification number
EJCDC	Engineers Joint Contract Documents Committee
EKS	electronic key system
ELFEXT	equal level far-end crosstalk
e-mail	electronic mail
EM	electromagnetic
EMC	electromagnetic compatibility
EMF	electromotive force
EMI	electromagnetic interference
EMI/RFI	electromagnetic interference/radio frequency interference
EMP	electrical magnetic protection
EMP	electromagnetic pulse
EMR	electronic medical records
EMS	emergency medical service
EMS	energy management system
EMT	electrical metallic tubing
EN	European norm
ENT	electrical nonmetallic tubing
ENV	European norm voluntary
E&O	errors and omissions
EoDSL	Ethernet over digital subscriber line

EOLR	end-of-line resistor
EP	entrance point
EPR	earth potential rise
ER	equipment room
ESD	electrostatic discharge
ESN	electronic serial number
ESS	electronic switching system
ETS	European installation bus tool software
ETSI	European Telecommunications Standards Institute
ETV	educational television
e/w	equipped with
EX or EXT	extension
EXCH	exchange

F

F	Fahrenheit
F	farad
FA	fire alarm
FAA	Federal Aviation Administration
FACP	fire alarm control panel
fax	facsimile
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission
FCC	flat conductor cable
FD	floor distributor
FDA	Food and Drug Administration
FDDI	fiber distributed data interface
FDM	frequency-division multiplexing

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FDMA	frequency division multiple access
FDR	feeder
FEC	forward error correction
FEP	fluorinated ethylene propylene
FEXT	far-end crosstalk
FFSK	fast frequency shift keying
FHSS	frequency-hopping spread spectrum
FIC	facility interface code
FIPS PUB	Federal Information Processing Standard Publication
FLA	flooded lead acid
FLC	flat conductor cable
FLL	fixed loss loop
FLS	fire-life-safety
FM	Factory Mutual
FM	frequency modulation
FMC	flexible metal conduit
FMT	flexible metallic tubing
FO	field order
FOTP	fiber optic test procedure
FOV	field of view
FPN	fine print note
FRAD	Frame Relay access device
freq	frequency
FRPP	flame-retardant polypropylene pipe
ft	foot
FTP	file transfer protocol
FTP	foil twisted-pair
F/UTP	overall foil screened with unshielded twisted-pair
FWHM	full width half maximum
FX	foreign exchange

G

G	conductance
ga	gauge
Gb	gigabyte
Gb/s	gigabit per second
GC	general contractor
GE	grounding equalizer
GEC	grounding electrode conductor
GFCI	ground-fault circuit interrupter
GHz	gigahertz
GIS	geographic information system
GMP	guaranteed maximum price
GPR	ground potential rise
GPRS	general packet radio service
GPS	global positioning system
GRC	galvanized rigid conduit
GRI	graded refraction index
GRP	glass reinforced plastic
GSM	Global System for Mobile Communications; formerly; Groupe Spécialité Mobile
GTE	General Telephone and Electric

H

h	hour
H	henry
H	horizontal
HC	horizontal cross-connect
HCCMC	Health Care Code Maintenance Committee
HCFC	hydrochlorofluorocarbon
HCO	Health Care Organization
HDSL	high bit-rate digital subscriber line
HEPA	high efficiency particulate air

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HF high frequency

HFC hydrofluorcarbon

HFE hydrofluoroether

HGVT horizontal ground vibration test

HHS US Department of Health and Human Services

HICPAC Healthcare Infection Control Practices Advisory Committee

HIM Health Information Management

HIMSS Health Information Management Systems Society

HL7 Health Level 7

HME home medical equipment

HRFWG Home Radio Frequency (RF) Working Group

HSTR high-speed token ring

HTTP hypertext transfer protocol

HVAC heating, ventilating, and air conditioning

Hz hertz

I

I ampere

I current

IAB Internet Activities Board

IAEI International Association of Electrical Inspectors

IB intelligent building

IBCS intelligent building cabling system

IBI Intelligent Building Institute

IC intermediate cross-connect

ICAO International Civil Aviation Organization

ICC International Code Council

ICEA Insulated Cable Engineers Association, Inc.

ICRA infection control risk assessment

ICU intensive care unit

ID identification; identifier

ID	indicating device
ID	inside diameter
ID	inside dimension
ID	intelligent device
IDC	insulation displacement connector
IDC	insulation displacement contact
IEC	Independent Electrical Contractors
IEC	International Electrotechnical Commission
IEE	Institution of Electrical Engineers
IEEE	Institute of Electrical and Electronics Engineers, Inc.®
IETF	Internet Engineering Task Force
IF	intermediate frequency
IG	isolated ground
IMC	intermediate metal conduit
in	inch
IOM	Institute of Medicine
IOR	index of refraction
IP	Internet protocol
IP	insulation piercing
IPA	isopropyl alcohol
IPC	insulation piercing contact
IPLMS	intelligent Physical Layer management system
IPT	Internet Protocol Telephony (see VOIP)
R	infrared
IR	inherent reasonableness
IR	insulation resistance
IRC	Institute for Research in Construction
IrDA	Infrared Data Association
IROB	in-range out-of-building
IS	international standard

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ISA industry standard architecture

ISDN integrated services digital network

IS-LAN integrated services local area network

ISM industrial, scientific, and medical

ISO International Organization for Standardization

ISOC Internet Society

ISP Internet service provider

ISTP individual shielded twisted-pair

ITS information transport system

ITU International Telecommunication Union

ITU-R International Telecommunication Union—Radio

ITU-T International Telecommunication Union—Telecommunication

IVR interactive voice response

IW inside wiring

IXC interexchange carrier

J

JCAHO Joint Commission on Accreditation of Health Care Organizations

JIS Japanese industrial standard

JTC joint technical committee

K

kb kilobit

kB kilobyte

kb/s kilobit per second

kcmil thousand circular mils

kg kilogram

kHz kilohertz

km kilometer

KSU key service unit

KTS key telephone system

kVA kilovolt-ampere

kW kilowatt

kWh kilowatt hour

L

L inductance

LAD link access device

LADC local area data channel

LAN local area network

laser light amplification by stimulated emission of radiation

LATA local access transport area

lb pound

lbf pound-force

LBO line buildout

LC latching connector

LC load coil

LCD liquid crystal display

LCE limited common element

LCTL longitudinal conversion transfer loss

LD laser diode

LDS local digital switch

LEC local exchange carrier

LED light-emitting diode

LEOS low earth-orbiting satellite

LF low frequency

LID local injection detection

LLC logical link control

LMSC Local and Metropolitan Area Network Standards Committee

locap low-capacitance (cable)

LonTalk® Local Operating Network talk (Echelon Corporation)

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LSA least squares averaging

LSA Lotfrei + Schraubfei + Abisolierfrei (no soldering, no screwing, no stripping of wires)

LSHF-F low smoke halogen-free flame retardant

LSZH low smoke zero halogen (low smoke and fume)

LT line terminal

LVD low voltage disconnect

M

µf microfarad

µm micron

m meter

mA milliampere

MAC medium access control

MAC move, add, or change

MAN metropolitan area network

MAP manufacturing automation protocol

MAU medium attachment unit

MAU multistation access unit

Mb megabit

MB megabyte

Mb/s megabit per second

MC main cross-connect

MCBN mesh common bonding network

MCC motor control center

MCM thousand circular mils

MDF main distribution frame

MDP main distribution panel

MF medium frequency

MF moderate frequency

MFD mode field diameter

M/G motor/generator set

MGN multiground neutral

MH maintenance hole

MHU multihospitality unit

MHz megahertz

MHz•km megahertz•kilometer

mi mile

MI mode indication

MIB management information base

MIC media interface connector

MIC mode indication common

mm millimeter

MM monitor module

MM multimode

MMF multimode fiber

MMS mail management system

modem modulator/demodulator

MP multipurpose

MPG multipurpose general

MPOP minimum point of presence

MPP modular patch panel

MPP multipurpose plenum

MPR multipurpose riser

MRI magnetic resonance imaging

MSC mobile switching center

MSDS material safety data sheet

MSG manufacturer steel grade

MS/TP master-slave/token-passing

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MTBF mean time between failures

MTHz megaterahertz

MT-RJ mechanical transfer registered jack

MT-RJ multiple transfer registered jack

MTS message telecommunications services

MTU multi-tenant unit

MU multiple use

MUTO multi-user telecommunications outlet

MUTOA multiuser telecommunications outlet assembly

mux multiplex; multiplexer

mW milliwatt

MxU multiplexer unit

N

N Newton

N/A not applicable

NA numerical aperture

NAHC National Association for Home Care

NBCC® *National Building Code of Canada* ®

NCQA National Committee for Quality Assurance

NCVHS National Committee on Vital and Health Statistics

NDC national drug code

NEC® *National Electrical Code*®

NECA National Electrical Contractors Association

NEMA® National Electrical Manufacturers Association®

NESC® *National Electrical Safety Code*®

NEXT near-end crosstalk

nF nanofarad

NFPA National Fire Protection Association

NGO	nongovernmental organization
NI	network interface
NIC	network interface card
NiCd	nickel cadmium
NICU	neonatal intensive care unit
NID	network interface device
nm	nanometer
NMHCC	National Managed Health Care Congress
NRC-IRC	National Research Council of Canada, Institute for Research in Construction
NRTL	nationally recognized testing laboratory
NRZ	non-return-to-zero
ns	nanosecond
NSF	national standard format
NVP	nominal velocity of propagation
NZS	New Zealand Standard

O

O&M	operation and maintenance
OD	outside diameter
OEM	original equipment manufacturer
OFL	overfilled launch
OFNR	optical fiber nonconductive riser
OHCA	organized health care management
OIU	optical interface unit
OLTS	optical loss test set
OPL	Omega Point Laboratory
OSHA	Occupational Safety and Health Act
OSHA	Occupational Safety and Health Administration
OSP	outside plant
OSPDRM	*Outside Plant Design Reference Manual*
OTDR	optical time domain reflectometer

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P

P	power
P_A	average power
PACU	post anesthesia care unit
PAS	professional activities study
PAS	profile alignment system
PBX	private branch exchange
PC	personal computer
PCC	premises communication cable (Canadian Standards Association [CSA] cable designation)
PCM	pulse code modulation
PCP	primary care physician
PCS	personal care services
PE	polyethylene
PERT	program evaluation review technique
PF	picofarad
PF/ft	picofarad per foot
PHY	physical layer device
PIC	plastic insulated conductor
PM	project manager
PMD	polarization mode dispersion
PNL	panel
PO	purchase order
POC	plan of care
PoE	power over Ethernet
POF	plastic optical fiber
POS	point of service
POTS	plain old telephone service (colloquial)
P_P	peak power
PPE	personal protective equipment
PRR	pulse repetition rate
PSACR	power sum attenuation-to-crosstalk ratio

PSELFEXT power sum equal level far-end crosstalk
psi pound per square inch
PSNEXT power sum near-end crosstalk
PSRO Peer Standards Review Organization
PSTN public switched telephone network
PTC positive temperature coefficient
PTT post, telephone, and telegraph
PVC polyvinyl chloride

Q

QA quality assurance
QIC qualified independent contractors
QoS quality of service

R

R resistance
RBC rack bonding conductor
RBOC Regional Bell Operating Company
RCDD® Registered Communications Distribution Designer
REA Rural Electrification Administration (now Rural Utilities Services [RUS])
RF radio frequency
RFI radio frequency interference
RFI request for information
RFP request for proposal
RFQ request for quote or quotation
RG radio grade
RGB rack grounding busbar
RHHI regional home health intermediaries
RJ registered jack

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RMC rigid metal conduit

RML restricted modal launch

RMRP regional medical review policy

rms root mean square

RMU rack mounting unit

RNC rigid nonmetallic conduit

ROM read-only memory

RTL recognized testing laboratory

RU rack unit

RUS Rural Utilities Service

Rx receiver; receive

RZ return to zero

S

s second

SAA Standards Association of Australia

SC subcommittee

SC subscriber connector

SCBA self-contained breathing apparatus

SCS structured cabling system

ScTP screened twisted-pair

SFF small form factor

S/FTP overall braid screen with foil screened twisted-pair

SF/UTP overall braid and foil screened with unshielded twisted-pair

SMF singlemode fiber

SMS short message service

SNI standard network interface

SNR signal-to-noise ratio

SoW scope of work

SP service provider
SRG signal reference grid
SRL structural return loss
SSA Social Security Administration
ST straight tip
STP shielded twisted-pair
STP-A enhanced shielded twisted-pair
SWA steel wire armor
SWRi Southwest Research

T

TAG Technical Advisory Group
TB terminal block
TBB telecommunications bonding backbone
TBBIBC telecommunications bonding backbone interconnecting bonding conductor
TCM total care management
TDM time division multiplexing
TDMM *Telecommunications Distribution Methods Manual*
TDR time domain reflectometer
TE telecommunications enclosure
TEBC telecommunications equipment bonding conductor
TEF triethylene fluoride
TEMPEST transient electromagnetic pulse emanation standard
TGB telecommunications grounding busbar
THz terahertz
TIA Telecommunications Industry Association
TMGB telecommunications main grounding busbar
TP transition point
TPO treatment, payment, or health care operations
TP-PMD twisted-pair physical medium dependent

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TQI total quality improvement

TR telecommunications room

TQM total quality management

TSB Telecommunications Systems Bulletin (formerly Technical Systems Bulletin)

TV television

Tx transmit

U

UB-92 Uniform Billing Code of 1992

UBC uniform building code

UCC Uniform Commercial Code

UDC universal data connector

UDS uniform data system

U/FTP overall unshielded twisted-pair with foil screened twisted-pair

UHCCS unsolicited claim status health care

UL® Underwriters Laboratories Inc.®

ULC Underwriters Laboratories of Canada

UPS uninterruptible power supply

US United States

USOC universal service order code

UTC undercarpet telecommunications cable

UTP unshielded twisted-pair

U/UTP overall unshielded twisted-pair with unshielded twisted-pair

UV ultraviolet

V

V volt

VA Department of Veterans Affairs

VA volt-ampere

VAMC Veterans Administration Medical Center

VAV	variable air volume
VCSEL	vertical cavity surface emitting laser
VF	voice frequency
VFL	visual fault locator
VGA	video graphics array
VOC	volatile organic chemical/volatile organic compound
VoIP	voice over Internet protocol (see also IPT [Internet Protocol Telephony])
VOM	volt-ohm-milliammeter

W

W	wall
W	watt
WA	work area
WAN	wide area network
WAP	wireless access point
WAP	wireless access protocol
WAP	wireless application protocol
WG	Working Group
W-H	Inchcape Warnock Hersey
Wi-Fi	wireless fidelity

X

X	complex or multilane connector
XDSL	x digital subscriber line

Z

Z_0	impedance

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ICEA *See* Insulated Cable Engineers Association
ICRA *See* infection control risk assessment
IDA *See* intermediate distribution area
IDC *See* insulation displacement connection
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