Premises Cable Installation Guideline

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About This Guide

Overview

The Premises Cable Installation Guideline contains recommendations for handling and installing Superior Essex premises copper and fiber cable products in enterprise environments. These guidelines are designed to help ensure a successful installation. Failure to adhere to any of the applicable guidelines may void the product warranty.

Organization

Topics in this guideline are designed to guide customers through cable installation and testing. The guideline consists of the following topics:

- Telecommunication Standards
- Typical Infrastructure Components
- Structured Cabling Topology
- Media
- Cable Installation
- Cable Termination and Splicing
- Testing and Documentation

Conventions

For easier use, the following conventions are found throughout the guide:

CONVENTION	DESCRIPTION
Bold	Indicates references to industry publications
Italics	Indicates industry terms, concepts and references to other Technical Guidelines
NOTE	Indicates supplemental or additional information
TIP	Indicates information helpful to complete a procedure but not required
⚠	Cautionary information for safe testing or installation of cable media

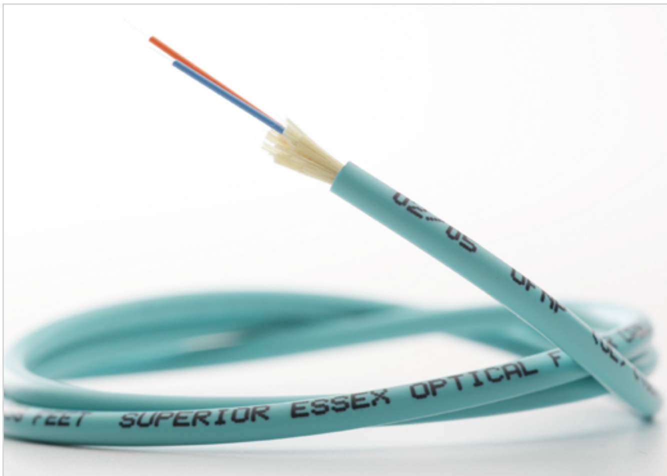
Confidential and Proprietary Statement

The information included in the Premises Cable Installation Guideline is intended to be used for Superior Essex cables only. For more detailed information, Superior Essex recommends the latest edition of the BICSI® Information Technology Systems Installation Methods Manual.

Customer Service and Technical Support

- Customer Service at 800-551-8948
- Technical Support at 877-263-2818

Chapter 1 - Introduction



Superior Essex Premises Communications Cables

The premises cable product line from Superior Essex includes nearly every type of copper and fiber cable used for voice and data communications inside buildings. From 3600 pair copper riser cable to high performance Category 6A and optical fiber cables, Superior Essex is able to supply virtually all of the cabling needs for an enterprise or campus installation.

Our premises cable products meet the rigorous performance standards expected by engineers and installers, and they include many unique benefits that translate into easier and faster installations.

Superior Essex manufactures the following Premises cable types:

- Voice Grade Copper Cables: Category 3, ARMM, Station Wire
- Copper Data Cables (Indoor): Category 5e, Category 6, Category 6A
- Central Office Tinned Copper Cables
- Tight Buffered Fiber Cables (Indoor and Indoor/Outdoor)
- Ribbon Fiber Cables
- Loose Tube Fiber Cables (Indoor and Indoor/Outdoor)
- Interlock Armored Fiber and Copper Cables
- Coaxial Cables
- Composite Cable Designs: Copper/Fiber/Coax cable combinations

For more information about specific products, please visit the Superior Essex Communications web site at **SuperiorEssex.com**

Chapter 2 - Telecommunication Standards

Telecommunication Standards govern the installation and handling practices of cabling materials. This section provides commonly used standards of the American National Standards Institute/ Telecommunications Industry Association (ANSI/TIA).

TIA-568

TIA-568 is one of the most commonly used standard sets in this industry. These standards address commercial building cabling for telecom products and services and are formally titled ANSI/TIA-568-C.0-2009, -C.1-2009, -C.2-2009, -C.3-2008 and -C.4-2011 along with several addenda published as needed.

This Premises Cable Installation Guideline is written to ensure compliance with these standards primarily; however, some countries, industries, or even individual customers may require adherence to different sets of standards. Additionally, while this document is in compliance with the TIA-568 standards as of its publishing, these standards are subject to periodic revision. In the event of any questions or conflicts regarding requirements, please contact Superior Essex Technical Support.

Perhaps the best known features of TIA-568 are the pin/pair assignments for eight-conductor 100-Ohm balanced twisted pair cabling. These assignments are named T568A and T568B, and are frequently referred to (erroneously) as TIA-568A and TIA-568B.

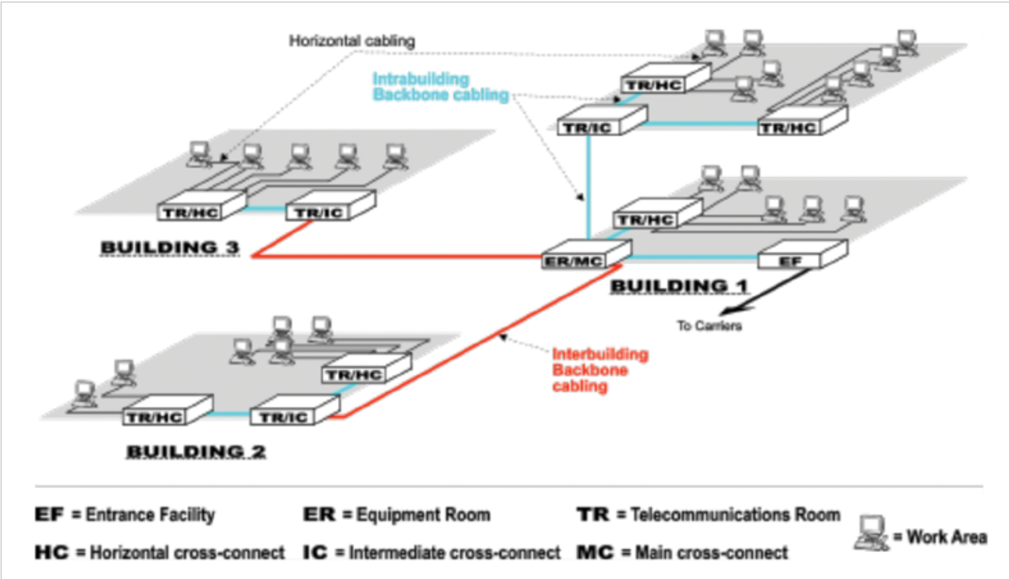
TIA-568 defines standards that enable the design and implementation of structured cabling systems for commercial buildings, as well as between buildings in campus environments.

The bulk of the standards define cable types, distances, connectors, cable system architectures, cable termination standards and performance characteristics, cable installation requirements, and methods of testing installed cable.

The main standard is broken down as follows:

STANDARD	DESCRIPTION	OVERVIEW
TIA-568-C.0	Defines generic requirements for all types of customer premises	TIA-568-C.0 specifies minimum generic requirements for telecommunications cabling within all types of customer premises. This standard specifies generic telecommunications cabling requirements, including cabling system structure, topologies and distances, installation, performance and testing.
TIA-568-C.1	Defines additional requirements specific to office-oriented commercial building cabling	TIA-568-C.1 builds on C.0 and specifies minimum requirements for telecommunications cabling within office-oriented commercial buildings and between buildings in a campus environment. This standard defines terms, cabling requirements, distances, telecommunications outlet/connector configurations, physical topology, and provides additional useful information.
TIA-568-C.2	Addresses components of balanced twisted-pair cable systems	TIA-568-C.2 specifies minimum requirements for the various components, transmission performance models, and measurement procedures required for verification of balanced twisted-pair cabling. This standard also defines field measurement instruments, including reference measurement procedures for all defined parameters. Four-pair and multi-pair balanced cabling systems are covered.
TIA-568-C.3	Addresses components of fiber optic cable systems	TIA-568-C.3 specifies minimum performance requirements for components of an optical fiber cabling system (e.g., cable, connectors). It is intended to be used by manufacturers. Recognized cables include: • 50/125 µm multimode optical fiber cables • 62.5/125 µm multimode optical fiber cables • Single mode optical fiber cables This standard illustrates the rationale and goal of the document and presents a list of definitions, abbreviations, acronyms, and units of measure.
TIA-568-C.4	Addresses components of broadband coaxial cable systems	TIA-568-C.4 specifies minimum performance requirements for components of a 75-Ohm broadband coaxial cabling system (e.g., cable, connectors), including transmission, mechanical, and compatibility requirements. It also includes cabling installation and connector termination procedures, as well as field testing procedures.

Chapter 3 - Typical Infrastructure Components



As defined by TIA/EIA, a structured cabling system consists of six infrastructure subsections: Entrance Facility, Equipment Room, Telecommunications Room, Backbone Cabling, Horizontal Cabling and Work Area.

Entrance Facility

Entrance Facility (EF) refers to the entrance to a building for both public and private network service cables (as well as antenna transmission lines where applicable), including the entrance point at the building wall or floor, and continuing to the entrance room or entrance space.

The EF may include the following:

- Service entrance pathways
- Cables
- Connecting hardware
- Primary (electrical) protection devices
- Transition hardware
- Demarcation point

Equipment Room

The purpose of the Equipment Room (ER) is to provide space and preserve an appropriate operating environment for any size telecommunications equipment. ERs supply an entire building (or even a campus) while Telecommunications Room (TR) only serve one floor of a building or a portion of a floor.

ERs are used to:

- Accommodate portions of common control equipment such as voice, intrusion detection, data, video, fire alarm, energy management, etc.
- Provide work space for service employees.
- Provide for termination and cross-connection of backbone and horizontal cables.

Telecommunications Room

The Telecommunications Room (TR) houses the connection point between the building backbone and horizontal distribution pathways.

TRs are used to:

- Maintain a controlled environment for the telecommunications equipment, splice closures, and connecting hardware.
- Provide a point of termination for horizontal and backbone cables on compatible connecting hardware.

Backbone Pathways and Cabling

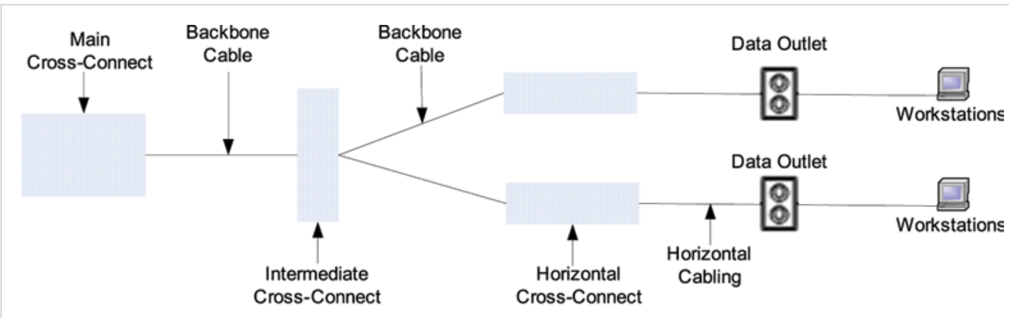
Backbone Pathways and Cabling, as the name suggests, carry the signals between the entrance facilities, equipment rooms and telecommunications rooms. Pathways are the vertical and horizontal route of the cable, including support structures. The backbone cabling system enables interconnections between EFs, TRs, ERs, and main terminal space. The distance between the terminations in the entrance facility and the MC should be documented and made available to the service provider.

The backbone also extends between buildings in a campus environment. It includes backbone cables, cross-connects, mechanical terminations, and patch cords or jumpers used for backbone-to-backbone cross-connections.

Horizontal Pathways and Cabling

Horizontal Pathways and Cabling provide the method of conveying signals between the telecommunications outlet/connector in the Work Area (WA) and the HC. This kind of cabling and its connecting hardware are known as a link. The cable is known as "horizontal" because that is the primary orientation of the cabling. However, horizontal pathways include the horizontal and vertical route of the cable, including support structures.

The distance between the terminations in the HC and the WA should be documented and made available to the service provider.



Work Area

The Work Area consists of the communication outlets (wall boxes and faceplates), wiring, and connectors needed to connect the work area equipment (computers, printers, etc.) via the horizontal wiring subsystem to the TR.

- The standard requires that a minimum of two outlets be provided at each wall plate - one for voice and one for data.
- Horizontal cable lengths must take into consideration the maximum length of work area cables to be utilized.
- Patch cords are designed to provide easy routing changes, and the equipment cords are considered to have performance equivalent to patch cords of the same kind and category.

Cross-Connect

Cross-connects facilitate the termination of cabling elements and their connections to other elements of the system. Cross-connects are housed in ERs and TRs. They are generally classified as follows:

- Main cross-connect (MC): Transition point between the entrance cables and backbone cabling.
- Intermediate cross-connect (IC): Transition point between the backbone cable of the MC and HC.
- Horizontal cross-connect (HC): Transition point between backbone cabling and horizontal cabling, typically serving a single floor or portion of a floor.

Chapter 4 - Structured Cabling Topology

Basic Topology

Topology is the physical or communication path layout of a network or internetwork.
Three basic topologies include:

- Star
- Bus
- Ring

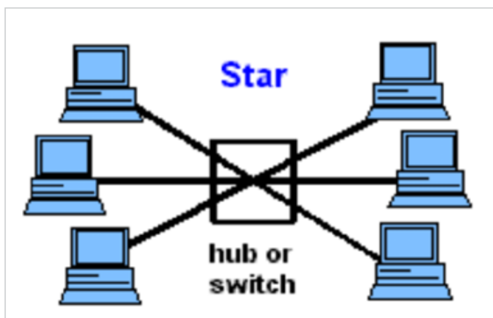
From these three, a number of hybrid topologies have evolved:

- Tree
- Star-wired ring
- Clustered star
- Hierarchical star

TIA/EIA-568 mandates that the physical topology is the star topology. It has the flexibility to be configured to accommodate each of the logical topologies (star, bus, ring, and hybrids).

Star Topology

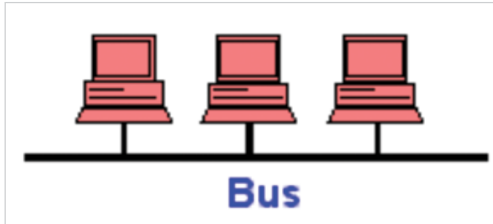
The star topology reduces the chance of network failure by connecting all of the systems to a central node. When applied to a bus-based network, this central hub rebroadcasts all transmissions received from any peripheral node to all peripheral nodes on the network, sometimes including the originating node. All peripheral nodes may thus communicate with all others by transmitting to and receiving from the central node only. The failure of a transmission line linking any peripheral node to the central node will result in the isolation of that peripheral node from all others, but the rest of the systems will be unaffected.



ADVANTAGES	DISADVANTAGES
• Good performance • Easy to set up and to expand • Any non-centralized failure will have very little effect on the network • Easy to detect faults • Data Packets do not have to travel through any unnecessary nodes	• Requires more cabling than other topologies • If the hub/switch fails the entire system is affected

Bus Topology

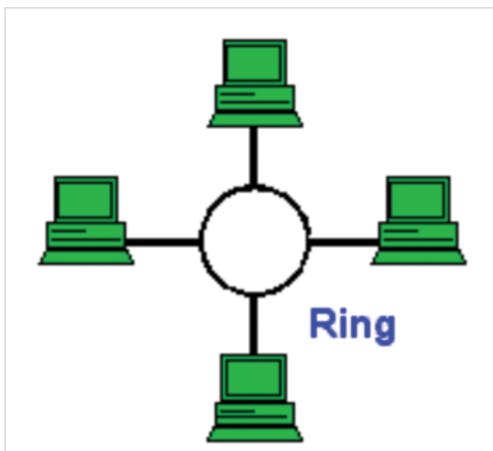
Bus topology is a network architecture in which a set of clients are connected via a shared communications line called a bus. There are several common instances of the bus architecture, including one in the motherboard of most computers.



ADVANTAGES	DISADVANTAGES
• Easy to implement and extend • Requires less cabling than a star topology • Well-suited for temporary or small networks not requiring high speeds (quick setup)	• Difficult to administer/troubleshoot • Limited cable length and number of stations • If there is a problem with the cable, the entire network goes down • Maintenance costs may be higher in the long run • Performance degrades as additional computers are added or on heavy traffic • Proper termination is required (loop must be in closed path) • Significant Capacitive Load (each bus transaction must be able to stretch to most distant link)

Ring Topology

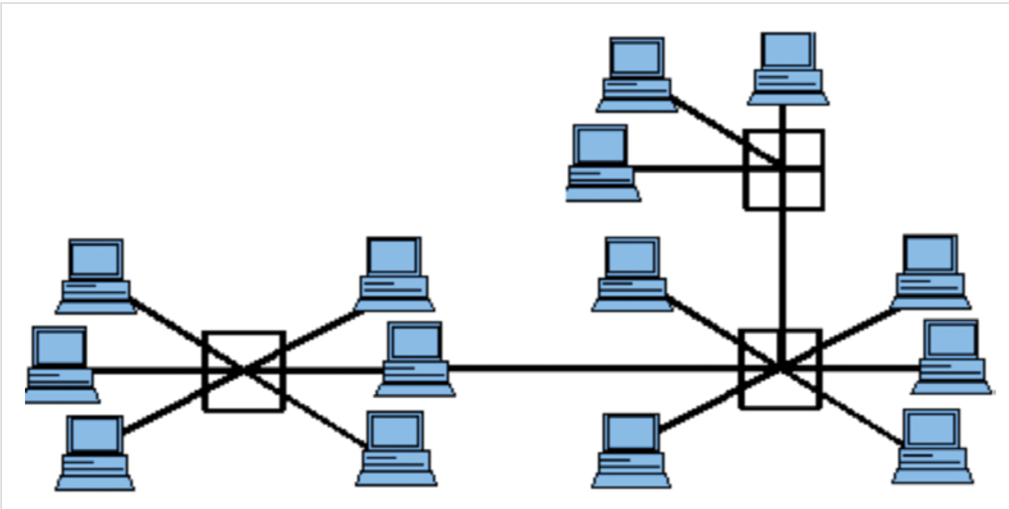
In ring topology, each node connects to exactly two other nodes, forming a circular pathway for signals called a ring. Data travels from node to node, with each node handling every message. In many cases, signals travel in both directions on separate paths to form a counter-rotating ring.



ADVANTAGES	DISADVANTAGES
• Reliability – with a counter-rotating ring, if one pathway or component fails, the ring continues to operate	• Difficult to add nodes • May be unable to accommodate other logical topologies

Hybrid Topology

The hybrid topology scheme combines multiple topologies into one large topology. The hybrid network is common in large wide-area networks. Because each topology has its own strengths and weaknesses, several different types can be combined for maximum effectiveness.



ADVANTAGES	DISADVANTAGES
• One company can combine the benefits of several different types of topologies. • Workgroup efficiency and traffic can be customized.	• Devices on one topology cannot be placed into another topology without some hardware changes.

NOTE: Superior Essex only recommends use of the Star Topology in Local Area Networks (LANs).

Chapter 5 - Media

Some networks utilize only one type of cable, while other networks use a variety of cable types. The type of cable chosen for a network is related to the network's topology, protocol, and size. Understanding the characteristics of different types of cable and how they relate to other aspects of a network is necessary for the installation of a successful network.

Superior Essex manufactures virtually every type of copper and fiber cable used for voice and data communications inside and between buildings. This section describes the primary media types referenced in the installation and testing guidelines. Media are listed within the following groups:

- **Balanced Twisted Pair Copper Cable**
  - » Unshielded twisted-pair
  - » Shielded twisted-pair
  - » Patchcords
- **Optical Fiber Cable**
  - » Multimode
  - » Single mode

Balanced Twisted Pair Copper Cable Media

Balanced twisted pair cable is a form of wiring in which two conductors are wound together ("twisted") for the purposes of canceling out electromagnetic interference (EMI) from external sources and crosstalk from neighboring conductors. "Balanced" twisted pair simply means that both conductors of a pair have matched electrical and physical properties. In premises applications, balanced twisted pair cable is typically selected based on performance categories specified in TIA/EIA-568.

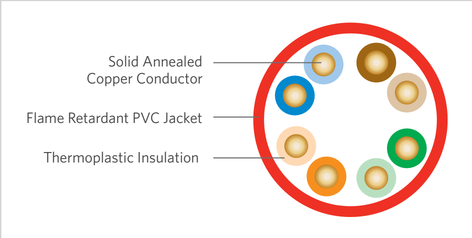
Unshielded Twisted-Pair (UTP)

UTP cables are not shielded. This lack of shielding results in a high degree of flexibility and durability, as well as lower cost. No shield to bond/ground also results in a simpler installation. The disadvantage of no shielding is reduced protection against electromagnetic interference (EMI). UTP cables are found in many Ethernet networks and telephone systems.

UTP cabling is the most common cable used in computer networking. It is a variant of twisted-pair cabling. UTP cables are often called Ethernet cables after Ethernet, the most common data networking standard that utilizes UTP cables.

UTP cable is characterized by the following:

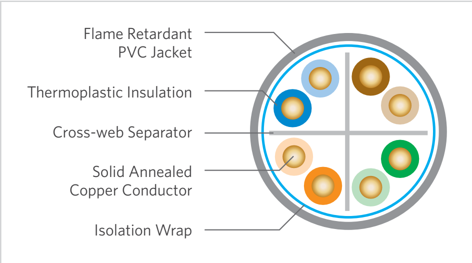
- Four-pair cables are typically used for horizontal cabling. Higher pair counts are often used for backbone cabling.
- Its conductors are not surrounded by a metallic shield to prevent electrostatic or electromagnetic coupling.



See Technical Guideline **Balanced Twisted Pair Transmission Categories** *for a list of UTP Transmission Categories.*

Isolation Wrap Twisted-Pair (XP)

XP cables are a design innovation from Superior Essex that utilize a non-conductive isolation wrap containing discontinuous sections of metallized material held in place by a polymeric layer. The result is a cable that offers the EMI resistance of a shielded cable while being fully compliant with UL 444 requirements for an unshielded twisted pair product. This means no shield bonding and grounding requirements. Simply trim the isolation wrap away at termination points.

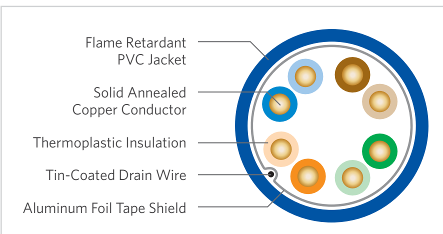


Shielded Twisted-Pair

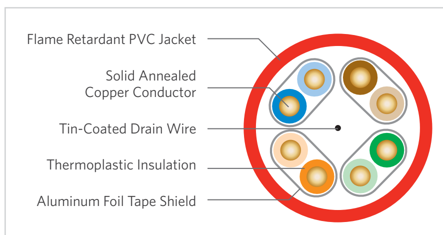
Shielded Twisted-Pair copper cable features a metallic shield to prevent electrostatic or electromagnetic coupling. This shielding effect significantly reduces the instances of interference-related network problems.

As with UTP, four-pair cables are typically used for horizontal cabling and higher pair counts are often used for backbone cabling. Four-pair shielded is offered in two versions:

- **Four-Pair Screened Twisted-Pair (F/UTP)**
  F/UTP (also referred to as ScTP) cabling has an outer metal shielding covering the entire group of copper pairs. This type of shielding protects the cable from external EMI (including Alien Crosstalk); however, the shield and drain wire add cost as well as size. The shield and drain wire also require bonding and grounding.



- **Four-Pair Shielded Twisted-Pair (U/FTP)**
  U/FTP (also referred to as STP) cabling includes metal shielding over each individual pair of copper wires. This type of shielding also protects the cable from external EMI (including Alien Crosstalk). In addition, U/FTP provides better Near End Crosstalk (NEXT) performance than F/UTP; however, the multiple shields add more cost and size. Like F/UTP, the shield and drain wire require bonding and grounding.



Patch Cords

Patch cords may be shielded or unshielded and often feature stranded conductors for added flexibility. For this reason, patch cords are allowed to exhibit 20 to 50 percent more attenuation than horizontal cable featuring solid conductors.

Patch cords are most commonly 4-pair twisted-pair cables using "RJ-45" connectors with TIA/EIA-568 wiring.

UTP Patch cords can be as short as 8 cm (3 in), to connect stacked components or route signals through a patch bay, or as long as 6 m (20 ft) or more for snake cables. (As length increases, cables are usually thicker, and/or made with more shielding, to prevent signal loss (attenuation) and the introduction of unwanted radio frequencies and hum (electromagnetic interference).

Horizontal cable lengths must take into consideration the maximum length of work area cables, patch cords and equipment cables to be utilized.

MAXIMUM LENGTH OF HORIZONTAL AND WORK AREA CABLES				
	24 AWG UTP/24 AWG F/UTP Patch Cords		26 AWG F/UTP Patch Cords	
H = Horizontal Cable m (ft)	W = Work Area Cable m (ft)	C = Combination of Work Area Cables, Patch Cords, and Equipment Cable m (ft)	W = Work Area Cable m (ft)	C = Combination of Work Area Cables, Patch Cords, and Equipment Cable m (ft)
90 (296)	5 (16)	10 (33)	4 (13)	8 (26)
85 (279)	9 (30)	14 (46)	7 (23)	11 (35)
80 (262)	13 (44)	18 (59)	11 (35)	15 (49)
75 (246)	17 (57)	22 (72)	14 (46)	18 (59)
70 (230)	22 (72)	27 (89)	17 (56)	21 (70)

Optical Fiber Cable Media

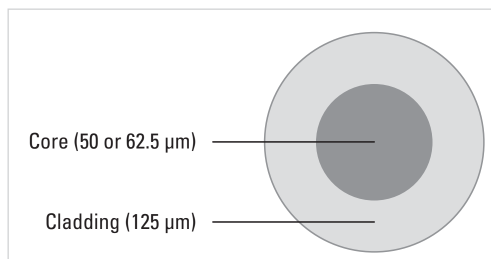
An optical fiber is a single, hair-fine filament drawn from molten silica glass. These fibers are often used as the transmission medium in high-speed, high-capacity communications systems that convert information into light, which is then transmitted via fiber optic cable.

Optical fiber is composed of three key elements: Core, Cladding and Coating. The core is the innermost part of the fiber through which light pulses are guided. Cladding surrounds the core to keep light in the center of the fiber. The core and cladding are inseparable layers of glass. The coating is a layer of polymer that surrounds the cladding to protect the glass.

Optical fiber cable may be Single mode, Multimode or a hybrid of two or more media types.

Multimode Fiber (MMF)

In general, multimode fiber allows a less expensive system (because the components other than the fiber itself are generally less expensive), but provides less bandwidth and distance capabilities than single mode fiber (SMF) systems. However, since the distance and bandwidth capabilities of MMF are generally sufficient for premises applications, MMF is the most common type used for backbone and horizontal runs within buildings and campus environments.

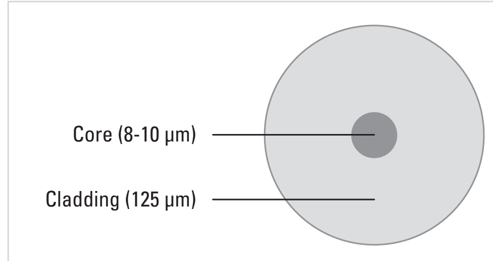


Multimode fiber cables include the following:

- **62.5/125 multimode - 62.5 micron core, 125 micron cladding**
  - Typical light source is light emitting diode (LED) operating at 850 nm or 1300 nm
  - TeraGain® 62.5/125 Standard
- **50/125 multimode - 50 micron core, 125 micron cladding**
  - Typical light source is light emitting diode (LED) operating at 850 nm or 1300 nm
  - TeraGain 50/125 Standard
- **50/125 laser optimized multimode - 50 micron core, 125 micron cladding**
  - Typical light source is vertical cavity surface emitting laser (VCSEL) operating at 850 nm
  - TeraGain 50/125 10G-150 – Guaranteed for 10 Gigabit Ethernet up to 150 m
  - TeraGain 50/125 10G-300 – Guaranteed for 10 Gigabit Ethernet up to 300 m
  - TeraGain 50/125 10G-550 – Guaranteed for 10 Gigabit Ethernet up to 550 m

Single Mode Fiber (SMF)

Due primarily to the small core size, SMF requires high end lasers and precise components, which typically result in overall higher system costs. However, the distance and bandwidth capabilities make SMF the primary choice for long haul networks.



SMF cables include the following:

- 8-10 micron core, 125 micron cladding
- Typical light source is a laser operating at 1310 nm or 1550 nm
- Conventional Single mode
- Reduced Water Peak (RWP) Single mode – improved attenuation performance in the E band (around 1383 nm)
- TeraFlex RWP – improved bend performance
- Non-Zero Dispersion Shifted (NZDS) Single mode – optimized for transmission in the C band (around 1550 nm)

Optical Fiber Cable Types

- **Tight-Buffered Cable**
  Tight-buffered optical fiber cable (single mode or multimode) protects the fiber by supporting each strand of glass in a coating, increasing the diameter to 900 µm. This cable is available with various jacket types to meet building codes requirements. Tight buffered construction is available for all fiber types.
- **Loose Tube Cable**
  Loose-tube optical fiber cable is used primarily outdoors. This cable allows fiber to expand and contract with changes in temperature. However, indoor/outdoor loose tube cables offer the double advantage of outdoor robustness and riser rating for easy transition from outdoors to indoors. Loose tube construction is available for all fiber types.

Chapter 6 - Cable Installation

Preparing for Installation

Communications cables are designed with installation in mind. That being said, there are certain limitations to cable performance that must be respected during installation. In general, the four most critical characteristics to remain mindful of are tensile strength, bend radius, crush resistance, and temperature rating. These characteristics vary among cables types, sizes, and even manufacturers. It is critical for the designer and installer to be familiar with these criteria before the installation process begins.

Pre-Installation Testing

Superior Essex communications cables are manufactured to high standards and tested rigorously in order to relieve end users of the burden of pre-installation testing. In normal situations, such testing is not necessary and the cable can be installed, as received, with confidence. However, pre-installation testing should be conducted if the customer specification requires it or if there is evidence of cable mishandling or damage.

If pre-installation testing is required, see "Chapter 8 - Testing" on page 35 for additional information.

Pulling Tension

Many cables are pulled into position. When pulling a cable, it is critical to 1) attach the pulling line in the correct manner; 2) avoid exceeding the maximum tensile strength of the cable; and 3) relieve the pulling tension once the cables are in place.

In premises applications, lubricants are generally not necessary or recommended. However, pulling tension may be significantly reduced by using lubricant and thus may be deemed necessary in longer pulls. If so, use one that is specifically designed for the task at hand. For twisted pair cables, use only thin film lubricants. Be aware that other types of lubricants may affect performance of twisted pair cables, although this effect is generally temporary.

- **4-pair UTP / U/FTP / F/UTP Cable**
  The maximum allowable pulling tension is 25 lbs per cable. Multiple cables can often be attached to a single pulling line, which is simply tied to the end of the cable and wrapped with tape to produce a tapered end.
- **Higher Pair-Count Twisted-pair Copper Cable**
  Tensile strength for twisted pair cables comes primarily from the conductors. The maximum allowable pulling tension for twisted pair copper cables with greater than 4 pairs is based on the wire gauge and number of pairs.

  See Technical Guideline, **Copper Wire and Cable Maximum Pulling Tension***, for further information.*
- **Coax Cable**
  The maximum allowable pulling tension for coaxial cable is dependent on the size and material of the center conductor. Copper-clad steel (CCS) is stronger than bare copper. The pull tension for coaxial cables with CCS or copper center conductors shall not exceed the maximum value. When pulling a combination of different types of cables, pull tension should not exceed the maximum value for the minimum strength cable.

COAX	CABLE TYPE	MAXIMUM PULLING TENSION
CCS	Series 11 (CMR)	371 lbs
Copper	Series 11 (CMR)	140 lbs
CCS	Series 11 (CMP)	210lbs
Copper	Series 11 (CMP)	110lbs
CCS	Series 6	75 lbs
Copper	Series 6	40 lbs
Copper	RG-59	40 lbs

- **Optical Fiber Cable**
  The maximum pulling tension for indoor or indoor/outdoor fiber cables varies based on the design. TIA standards require the following minimum rated installation loads:

OPTICAL FIBER CABLE TYPE		MAXIMUM PULLING TENSION
Interconnect cables (simplex, duplex or quad)		50 lbs
Plenum Cables	≤12 fibers	100 lbs
	>12 fibers	150 lbs
Riser and General Purpose Cables	≤12 fibers	150 lbs
	>12 fibers	300 lbs

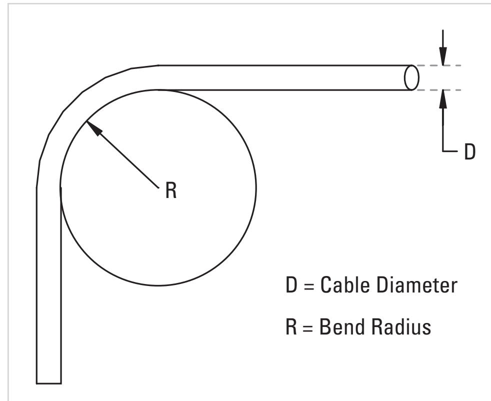
Superior Essex optical fiber cables often exceed these minimum requirements. If needed, refer to the product specifications in the catalog or at **SuperiorEssex.com**.

Of equal importance is the method of pulling line attachment. The pulling line must be attached to the strength yarns underneath the jacket and not the jacket itself.

See Technical Guideline, **Using a Pulling Grip on Fiber Optic Cable***, for further information.*

Bend Radius

Cable is rarely installed perfectly straight from point to point. Accordingly, communications cables are designed to bend, but as with pulling tension, there are limitations to bend radius that must be observed.



- **4-Pair UTP Cable**
  The minimum allowable bend radius is 4X the cable diameter. This applies to permanent bends such as in an outlet or cable support, as well as temporary bends such as installation aids.
- **4-Pair F/UTP / U/FTP Cable**
  The minimum allowable bend radius is 8X the cable diameter. This applies to permanent bends such as in an outlet or cable support, as well as temporary bends such as installation aids.
- **High Pair-Count Twisted-Pair Copper Cable**
  The minimum allowable bend radius for twisted pair copper cables with greater than 4 pairs is based on the cable construction.
  See Technical Guideline, **Copper Wire and Cable Minimum Bend Radius***, for further assistance.*
- **Coax RG-11, RG-6/RG-59 Cable**
  The minimum allowable bend radius for installation of Coax RG-6 cable is 10X the cable diameter under no-load conditions and 20X the cable diameter when the cable is under tensile load. Bend radius for installation under tensile load and without tensile load of RG-11 cable is 15X the cable diameter.
- **Optical Fiber Cable**
  The minimum allowable bend radius for optical fiber cables is based on the cable type and/or diameter.

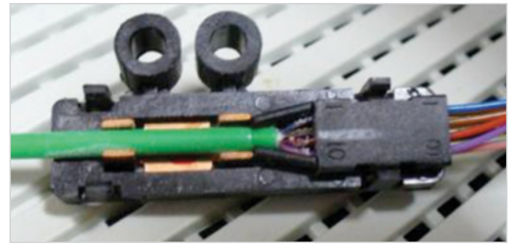
Optical Fiber Cable Type	Minimum Bend Radius: Install[1]	Minimum Bend Radius: Long Term[2]
Interconnect Cables	50 mm (2 in)	25 mm (1 in)
All other premises fiber optic cables	15X[3]	10X[3]
Outside plant fiber optic cables	20X[3]	10X[3]

[1]Install refers to during installation (under tensile/dynamic load).
[2]Long Term refers to post-installation when the cable is at rest.
[3]X = multiple of cable diameter. (Example 10X cable diameter of 0.5" = 5" bend radius.)

Crush Resistance

Crush resistance is a very important attribute that is easily quantifiable in a test laboratory but difficult to predict in an installation environment. As similarly stated previously, communication cables are designed to withstand crush, but there are limitations that must be observed (although difficult to quantify). Crushing a cable can cause many issues from temporary, intermittent anomalies to permanent failure. Below are several caveats regarding the crushing of cables:

- Beware of the cable-tie/clamp. Over-zealous cinching of cable ties or clamps is certain to wreak havoc on communication cables. Use hook and loop fasteners instead, which should always be applied loosely as well.
- Avoid stepping on or running over cables with vehicles and equipment.
- Beware of other locations that may constrict cables or conductors and put them at risk for damage.
- Do not staple communications cable with standard staples which may crush the cable. Use properly-sized cable staples.



Fiber loose tube crushed in breakout kit

Temperature Rating

Due to the dynamic forces at play during installation, premises cables often have stricter temperature ratings for installation than allowed for storage/shipping and/or operation. To ensure that all the cable materials are safely within the installation temperature ratings, cables may need to be temperature conditioned immediately prior to installation. The conditioning time required will vary with the temperature differential (greater differential means more conditioning time) and package size (bigger packages require more time). If in doubt, allow a minimum of 48 hours in the allowed temperature range. The allowable installation temperature range is printed on most packaging, posted at **SuperiorEssex.com**, printed in the catalog, and is available by calling Superior Essex Tech Support at 877-263-2818.

Cable Lengths and Types

The cabling installer must verify the size and type of package on which the cable will be delivered and plan to accommodate. Many horizontal cables are packaged such that they can be carried by hand and dispensed right out of the package, whereas backbone cables often require forklifts and reel stands.

In addition, at the start of every installation, the installer should verify that the correct cable is being installed and that it is of sufficient length.

Fire Resistance

Most premises cable applications require some form of fire resistance rating. These ratings are typically specified and made law by local and national authorities, and ultimately enforced by the local Authority Having Jurisdiction (AHJ). It is the responsibility of the installer to ensure that properly rated cables are installed in all locations. For more information on US and Canadian Fire Resistance Ratings, see the following Technical Guidelines:

- **NEC Fire Resistance Ratings**
- **Optical Fiber Cable Fire Resistance Ratings**
- **Using OSP Indoors: Why Can't I Use OSP Cable Indoors?**
- **What is Indoor/Outdoor Cable?**

Special Situations

- **Water**

  Most premises cables are designed for a dry environment. If there is reasonable chance that a cable will encounter water, use a cable that is designed for the purpose. Generally these are known as indoor/outdoor cables. For specific guidance, call Superior Essex Tech Support.

- **On-Grade/Below-Grade Conduit**
  Slab-on grade construction where pathways are installed underground or in concrete slabs in direct contact with soil (e.g., sand and gravel) is considered a wet location.
  *See Technical Guideline, **Copper Twisted Pair for Below-Grade Conduit**, if installing twisted pair copper in this type of location.*
- **Sunlight**
  Most premises cables are designed to be used in areas shielded from direct sunlight. If there is reasonable chance that a cable will encounter direct sunlight, use a cable that is designed for the purpose. Generally these are known as indoor/outdoor cables. For specific guidance, call Superior Essex Tech Support.
- **Paint**
  Do not allow premises cable to be painted. The National Electrical Code (NEC) requires that indoor communications cables be "listed" for the application and marked with the listing. Paint may alter the fire resistance and/or smoke generation properties of the cable, which are strictly defined by the NEC listing. The listing does not make allowance for paint to be added to the cables. Indoor rated communications cables are also intended for dry locations and thus feature minimal moisture blocking ability. Paints, water, and other liquid contaminants can soak into the cable materials, potentially altering the transmission properties of the cable, particularly those with metallic conductors. Any safety or performance failure due to such a contamination of the cable is not covered under any standard or extended warranty programs.
- **Separation from Power Sources**
  Communications cables are, by design or necessity, often installed in close proximity and/or in the same pathway as power service cables. The electrical energy of the power cables can have significant effect on the performance and safety of the communications plant. Cable design and placement are very important to ensure that electromagnetic interference (EMI), or dangerous levels of electrical energy are not induced into telecommunication cables. When installing communication cables near power service cables, proper separation must be maintained.
  *Safety and signal integrity can be maintained by following the separation guidelines described in Technical Guideline, **Pathway Separation Between Telecommunication Cables and Power Cables**.*

Special Equipment and Tools

The type of equipment required to perform the pull depends on the direction of the pull. If pulling from the bottom up, a winch may be required. If pulling from top down, a reel brake may be required.

In any case, specialized cable-handling devices are required, which may include:

- Winches
- Cable reel brake
- Temporary take-up devices
- Bullwheels
- Pulleys
- Mesh grips
- Bull lines

Pull Strings

Pull strings (aka lines or ropes) are needed to pull cable into conduits and other enclosed areas. Conduits often come with pull strings pre-installed. Methods for installing the pull string or rope through a conduit include:

- **Fishtape Method**
  A fish tape is a tool used by electricians to route new wiring through walls. Made of a narrow band of spring steel, by careful manipulation, the tape can be "fished" (guided) through the confined spaces within wall cavities. Once guided through, the new wiring can be pulled into the wall by attaching it to the end of the fish tape and pulling the tape back from whence it came.
- **Air-Propelled Methods**
  - A vacuum is on one end and a foam ball is attached to the pull string on the other end.
  - A compressed air bottle or mechanical blower can be used to propel the pull string attached to the propellant object.

Installing Support Structures

Proper support structures are critical for proper installation of a cabling system. All cable support structures, such as conduit, outlet box, pull box, j-hooks, and cable trays must accommodate the limitations of the cable.

Guidelines for Cable Support Structures

Following are recommendations to follow when installing common cable support structures. This list is not exhaustive.

Conduit

- Bends must accommodate the bending radius of the cable.
- No more than two 90° bends in a cable run – pull boxes may be used to break up a run.
- Pull boxes must be installed in conduit runs exceeding 100 feet (30m).
- Conduit segment must not exceed the allowable permanent link length.
- Do not exceed maximum fill ratios.
  See Technical Guideline, **Premises Cable Conduit Fill Quick Reference**, *for more information.*
- Slab-on grade construction where pathways are installed underground or in concrete slabs in direct contact with soil (e.g., sand and gravel) is considered a wet location.
  See Technical Guideline, **Copper Twisted Pair for Below-Grade Conduit**, *if installing twisted pair copper in this type of location.*

J-Hooks/Cable Slings

- Must be of sufficient width to support the bend radius of the cable.
- J-Hooks should have beveled or rounded edges.
- Should be spaced randomly at 60” or less intervals for UTP cables (the greater the data rate, the more important this becomes).

Cable Tray

- Sized to accomodate cabling at no more than 50% fill.
- 12" free space above tray to allow access.
- Tray shall be grounded and bonded per ANSI/TIA 607-B and NEC.

Outlet Box

- Sized to accomodate cable slack and maintain minimum bend radius.
- Recommend installing 4 -11/16" x 4 -11/16" x 2 -1/8" deep box.

Miscellaneous

- Any other structures, such as walls or joists that the cable passes through, must support the cable similarly (may require sleeves).
- Bundling:
  - Cables of different categories should not be bundled together.
  - Cable should not be tightly bundled anywhere.
  - Hook and loop straps are recommended; but traditional cable ties are not.
  - UTP cables should not be "dressed" or "combed", especially within 20 feet of the patch panel.
- Slack Storage:
  - Slack storage must not violate the minimum bend radius.
  - Twisted pair and coaxial cable slack should be stored in a Figure 8, "U" or "S" pattern. Coiling may degrade performance.

Pulling Cable

This section contains general guidelines to properly install a cable system.

⚠ Before beginning the job of pulling cable, ensure complete raceway system is installed and all materials and equipment are in place so that the cables can be handled properly.

PREPARATION	
Step	Action
1	Condition cables within appropriate temperature range if needed (see Temperature Rating subsection earlier in this chapter).
2	To ensure safety first, it is important to secure the Work Area.
3	For accuracy, post floor plan drawings in the Work Area.
4	Select and identify the cable labeling system that will be used.
5	Spot the pull points, transition points (TPs), and pull angles.
6	Spot and establish group pulls.
7	Situate and place the pull strings.
8	Position the cable reels or boxes.

INSTALLING A PULL STRING WITH FISH TAPE	
Step	Action
1	Establish the length of fishtape required.
2	Feed fishtape through the conduit/cavity.
3	Attach the pull string to the fishtape.
4	Pull the Fishtape out of the conduit/cavity.

INSTALLING A PULL STRING WITH COMPRESSED AIR	
Step	Action
1	Select a lightweight propellant object, designed for the purpose and compatible with the duct.
2	Tie the pull string to the object.
3	Position the propellant object in the conduit.
4	Position the grommet on the conduit, and attach the air hose.
5	By using pressurized air, blow the object attached to the string through the conduit until it reaches the other end.
6	At the opposite end of the conduit, tie off the pull string to separate it from the propellant object.

HORIZONTAL CABLE PULLING WITHIN CONDUIT

Step	Action
1	Verify the cable(s) type and length.
2	Attach the cable(s) to the pull string – using correct method is critical! (see Pulling Tension subsection earlier in this chapter)
3	Identify the cable(s) at the pull end.
4	In premises applications, lubricants are generally not necessary or recommended. However, if a lubricant is deemed necessary, use one that is specifically designed for the task at hand. For UTP cables, use only thin film lubricants (other types of lubricants may affect performance of UTP cables, although this effect is generally temporary).
5	Pull the cable(s) with the pull string. If pull boxes are present, pull to the first pull box and continue pulling until the cable for the remaining pull has been pulled through the first section. • NOTE: If pulling tight buffer fiber cable through a pull box, or in other scenarios when pulling via the pull rope or mesh grip is not practical, avoid putting all the pull tension on the cable jacket. 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. As the cable is being pulled through the pull box, store it in a figure 8 pattern. Identify the cable(s) at each pull box. Repeat the pull in the next section and again as necessary until the pull is complete. If desired or mandated, pull enough for a slack loop at each pull box.
6	Identify the cables at the start end.
7	Cut the first 10 feet (3 m) of cable(s) off the pull end (maintain cable identification).

HORIZONTAL CABLE PULLING WITH OPEN CEILING

Step	Action
1	When planning the route, be sure to: • Beware of older fluorescent light fixtures (copper cables). • Maintain separation from power wiring (any cables with metallic components). • Avoid paralleling power wiring (copper cables). • Avoid any other possible hazards such as pinch points, sharp angles, heat sources, etc (all cables). The minimum cable bend radius must be maintained throughout the cable route.
2	Verify the cable(s) type and length.
3	Attach the cable(s) to the pull string – using correct method is critical! (see Pulling Tension subsection earlier in this chapter)
4	Identify the cables at the pull end.
5	Pull the cable(s) with the pull string (avoid exceeding the maximum tensile strength of the cable, and relieve the pulling tension once the cables are in place).
6	Position cable in the support structures.
7	Identify the cables at the start end.
8	Cut the first 10 feet (3 m) of cable(s) off the pull end (maintain cable identification).

PULLING BACKBONE IN VERTICAL PATHWAY – FROM TOP DOWN

Step	Action
1	Verify the cable(s) type and length. If installing multiple cables, plan to install the largest/heaviest cable first.
2	Situate the cable reels to the upper floor of the vertical feed point.
3	Locate the cable pulling area and position reels on a jack stand or reel dolly with reel brake to control the speed of the pull.
4	If the path is not straight, install pulleys to guide the cable around bends (be sure to maintain bend radius!).
5	Attach the cable to the pull/guide line – using correct method is critical! (see Pulling Tension subsection earlier in this chapter)
6	Identify the cable(s) at the pull end.
7	Pull the cable with the pull/guide line.
8	In the vertical pathway, route and secure cables. At a minimum, install a support grip at/near the top. Other support grips may be required based on the weight and long-term tension capabilities of the cable.
9	Identify the cable(s) at the start end.

PULLING BACKBONE IN VERTICAL PATHWAY – FROM BOTTOM UP	
Step	Action
1	Verify the cable(s) type and length. If installing multiple cables, plan to install the largest/heaviest cable first.
2	Position cable reels into place and secure the pulling area.
3	If the path is not straight, install pulleys to guide the cable around bends (be sure to maintain bend radius!)
4	Attach the cable to the pull line – using correct method is critical! (see Pulling Tension subsection earlier in this chapter)
5	Identify the cable(s) at the pull end.
6	Pull the cable with the pull line. (MAKE CLEAR THAT CABLE SHOULD NOT BE PULLED TIGHT AND THAT SLACK IS PREFERRED)
7	In the vertical pathway, route and secure cables. At a minimum, install a support grip at/near the top. Other support grips may be required based on the weight and long-term tension capabilities of the cable.
8	Identify the cable(s) at the start end.
9	Cut the first 10 feet (3 m) of cable(s) off the pull end (maintain cable identification).

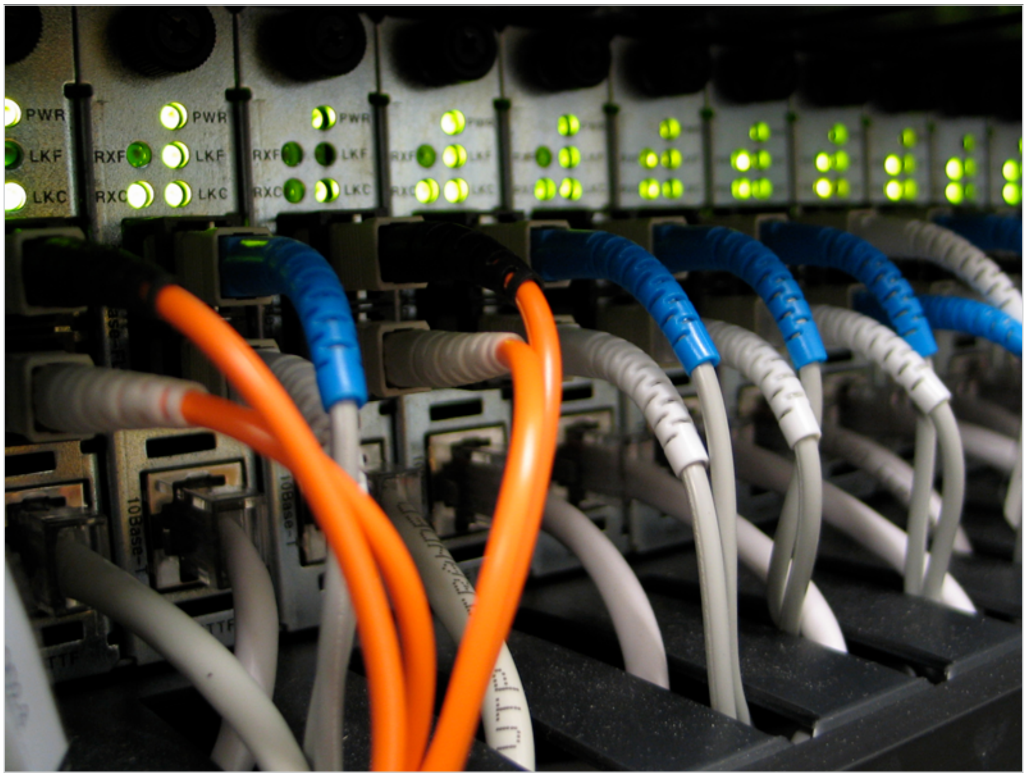
PULLING BACKBONE CABLE IN A HORIZONTAL PATHWAY	
Step	Action
1	Verify the cable(s) type and length. If installing multiple cables, plan to install the largest/heaviest cable first.
2	Position cable reels into place and secure the pulling area.
3	If the path is not straight, install pulleys to guide the cable around bends (maintain bend radius!)
4	Identify the cable(s) at the pull end.
5	Attach the cable to the pull line – using correct method is critical! (see Pulling Tension subsection earlier in this chapter)
6	In premises applications, lubricants are generally not necessary. However, if a lubricant is deemed necessary, use one that is specifically designed for the task at hand.
7	Pull the cable(s) with the pull line. If pull boxes/hand holes are present, pull to the first box and continue pulling until the cable for the remaining pull has been pulled through the first section. • NOTE: If pulling tight buffer fiber cable by hand through a pull box, or in other scenarios when pulling via the pull rope or mesh grip is not practical, avoid putting all the pull tension on the cable jacket. 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. As the cable is being pulled through the pull box, store it in a figure 8 pattern. Identify the cable(s) at each pull box. Repeat the pull in the next section and again as necessary until the pull is complete. If desired or mandated, pull enough for a slack loop at each pull box.
8	Identify the cable(s) at the start end.
9	Cut the first 10 feet (3 m) of cable(s) off the pull end (maintain cable identification).

Firestopping

Firestopping is the process of installing an approved firestopping system to stop the progress of fire along the cable pathway through fire-resistance rated walls, partitions, floors or ceilings. Approved firestopping methods and materials are used to significantly reduce the possibility of spreading fire, smoke, and toxic gases throughout a building.

This is a life safety issue enforced by national and/or local code. Refer to the applicable codes to determine the requirements and then follow the firestopping system manufacturer's instructions for proper installation.

Chapter 7 - Cable Termination and Splicing



Correct cable termination and splicing practices are vital for the complete and accurate transfer of both analog and digital information signals. Proper procedures will save time and improve the quality of the job.

Although there are common standards to ensure interoperability between cable and connectivity, many connectivity and associated equipment features are manufacturer specific. Therefore, the following guidelines should be used in conjunction with the instructions/guidelines relevant to the connectivity solution being employed.

Balanced Twisted Pair Copper

In general, Insulation Displacement Connectors (IDCs) should be used for all balanced twisted pair connections. These connectors allow connections to be made without removal of the conductor insulation.

The wiring scheme of twisted pair conductors is such that the colors are consistent from one end of the system to the other, (i.e., dark blue to dark blue, light blue to light blue).

Four-Pair Horizontal

Four-pair horizontal cables primarily utilize the 8P8C modular jack or plug.

8P8C Modular Jack

8P8C Plug

In most scenarios, cabling is terminated on jacks and the plugs come pre-installed on patch cords to complete the connection. However, field-installable plugs are available and, if used, should be installed based on the manufacturer's instructions. Shielded connectors should be used with U/FTP or F/UTP cable.

TIA/EIA-568-B recognizes two pin/pair assignments for four-pair cable: T568A and T568B, with T568A as the primary and T568B if required to accommodate certain cabling systems. In practice T568A is used primarily in residential and government applications (the US government only recognizes T568A), while T568B is used primarily in commercial applications. The important point is that only one method be used within the network.

Standard	EIA/TIA 568A							
Swatch								
Number	1	2	3	4	5	6	7	8
Code	WG	G	WO	Bl	WBl	O	WBr	Br
Color	White-Green	Green	White-Orange	Blue	White-Blue	Orange	White-Brown	Brown

Standard	EIA/TIA 568B							
Swatch								
Number	1	2	3	4	5	6	7	8
Code	WO	O	WG	Bl	WBl	G	WBr	Br
Color	White-Orange	Orange	White-Green	Blue	White-Blue	Green	White-Brown	Brown

Acceptable methods of identifying the "white" conductor of a pair include band marking, longitudinal striping and ColorTip®.

Band marking consists of banding each insulated conductor with the color of the mating conductor (in the blue/white pair, the blue conductor would have white bands and the white conductor would have blue bands).

Longitudinal Striping consists of striping the length of each conductor with the color of its mating conductor (in a blue/white pair, the blue conductor would have a longitudinal white stripe along its length, the white conductor would have a blue stripe).

ColorTip is a unique method of pair identification where the pair colors are identified by using a primary color, matched with a pastel shade (in the blue/white pair, the pairs are distinguished by bright blue matched with a pastel blue shade). One advantage of this method is the ability to maintain pair integrity in low light environments.

Backbone Twisted-Pair

Twisted-pair cables larger than four-pair are generally terminated on a termination block such as the 66 block or 110 block (pictured below). These blocks, like the 8P8C's above, utilize IDC technology for a quality connection.

110 Blocks

Copper IDC Termination

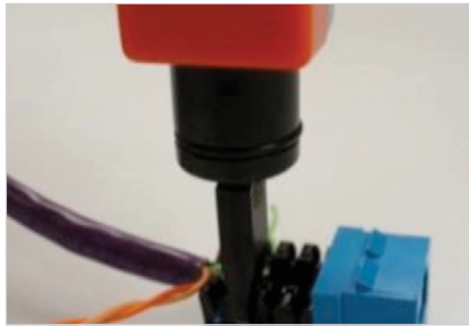
When terminating a twisted-pair cable, it is imperative to maintain the twist of the pairs as close as possible to the termination point. This becomes more crucial as the performance level increases (i.e., less important on CAT 3 and extremely crucial on CAT 6A). The best practice is to maintain the twist all the way to the termination point.

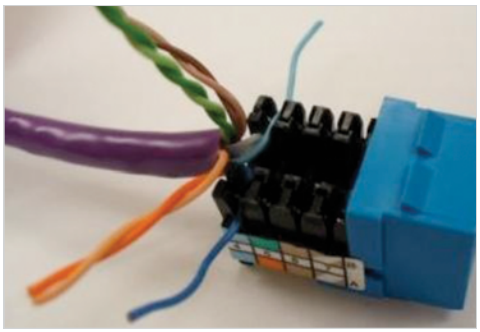
Following are the maximum allowable amounts of untwisting:

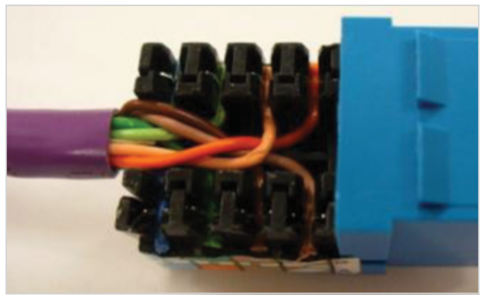
Twisted Pair Cable Type	Maximum Untwist Amount
Category 3	3"
Category 5e	½"
Category 6	½"
Category 6A	¼"

The cable jacket should also be left intact as close as possible to the termination point.

For some terminations, it is critical to punch pairs down in order, so that the other pairs can be kept out of the way. Attempting to position all pairs before commencing punchdown will lead to crushed conductors.



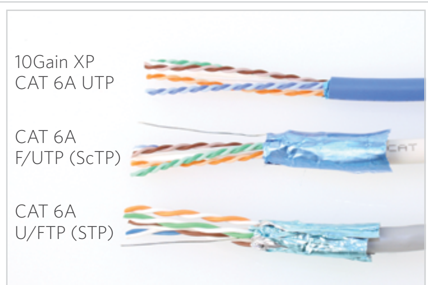


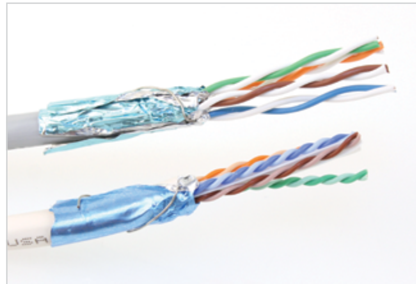


TERMINATING TWISTED-PAIR CABLE	
Step	Action
1	Verify that appropriate termination components have been selected, particularly in regards to performance category.
2	Arrange the wiring scheme and organize cable by destination (i.e., rack, panel, etc.). Avoid dressing or combing the cable, especially in high-performance applications, which can enable alien crosstalk.
3	Trim the cable length to reach the termination point without putting the cable under stress or violating the bend radius. Be sure to maintain cable identification!
4	Follow the hardware manufacturer's instructions for punching down the pairs and assembling the outlets, patch panels, maintaining the proper bend radius (refer to the Bend Radius subsection in Chapter 6 for more information) etc. Remember to maintain jacket coverage and pair twist as close as possible to the termination point and exercise care when removing the jacket so as to avoid nicking any underlying insulation.
5	Loosely bundle all exposed cable, preferably with hook-and-loop style straps. 
6	Clear out the Work Area.

SUPERIOR ESSEX

TERMINATING F/UTP AND U/FTP CABLE

Step	Action
1	Verify that appropriate termination components have been selected, particularly in regards to performance category.
2	Arrange the wiring scheme and organize cable by destination (i.e., rack, panel, etc.). Avoid dressing or combing the cable, especially in high-performance applications, which can enable alien crosstalk.
3	Trim the cable length to reach the termination point without putting the cable under stress or violating the bend radius. Be sure to maintain cable identification!
4	Trim the cable jacket back approximately 1.5” from the end of the cable using the appropriate cable stripping tool. Exercise care when removing the jacket to avoid nicking any underlying insulation.  
5	Pull the foil shield(s) back over the jacket. F/UTP features an overall shield, while U/FTP features a shield around each pair. Note: The non-conductive isolation wrap utilized in the 10Gain XP and the CAT 6A cable (part no. 6B-272-XX) is not required to be bonded. Simply trim the isolation wrap even with the cable jacket. 

TERMINATING F/UTP AND U/FTP CABLE		
Step	Action	
6	At this point, refer to connectivity manufacturers installation instructions for direction on drain wire termination as this requirement differs based on connector. Note: For connectors requiring the drain wire to be wrapped around the foil, wrap the drain wire around the foil and install a tie-wrap snuggly around the drain wire and foil to hold it securely in place. **Do not over-tighten the tie-wrap.** Tie-wrap should be tight enough to secure foil, but not enough to deform cable core.	 
7	Follow the hardware manufacturer's instructions for punching down the pairs and assembling the outlets, patch panels, etc. Maintain the proper cable bend radius (refer to the Bend Radius subsection in Chapter 6 for more information) and maintain jacket coverage and pair twist as close as possible to the termination point.	

Splicing Twisted-Pair Cable

Twisted-pair copper cable splicing is allowed only in backbone pathways. Cable in horizontal pathways should not be spliced. As a reminder, although there are common standards to ensure interoperability between cable and hardware, many hardware features are manufacturer specific. Therefore, the following guidelines should be used in conjunction with the instructions/guidelines relevant to the splicing solution being employed.

SPLICING TWISTED-PAIR CABLE	
Step	Action
1	Verify that the correct modular connectors have been chosen for splicing, making sure that the tools facilitate the modular connectors to be used. Listed below are the following factors to calculate splice and closure size: • Cable sheath type • Cable pair count • Wire gauge • Connector type • Number of banks of connectors • Splicing method
2	The space needs of the splice closure, the working space, and the cable pathway leading to the splice are important factors which need to be considered. The cable should not be bent so that it twists or violates the minimum bend radius. The following guidelines may be useful in considering space for the splice. • Overhead Splice = 27 in (69 cm) between closure and nearest overhead obstruction = 25 in. (64 cm) between closures • Horizontal Splice = 25 in (64 cm) above the floor • Vertical Splice = limited by space required to position cable, closure, and supporting structure
3	Use safety precautions to set up the splicing area using ladders or scaffolding, where required (continued on following page).
4	Install a support structure for the splice, if necessary. Shift the cables to the support structure to position them for splicing. Sustain the proper bending radius of the cable, and keep room for the appropriate splice closure.

SPLICING TWISTED-PAIR CABLE	
Step	Action
5	Install the closure per the closure manufacturer's instructions, including but not limited to the following: • When the shield bond connectors are installed, connect the permanent bond across the splice opening before beginning to splice the conductors. If the permanent bond cannot be placed at this time, a temporary bond strap should be placed between the two cables to prevent the potential for electric shock. • Secure the ends of each binder group with vinyl tape to prevent loss of conductor pair identification. • 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. • Securely align the cables, so that the splice opening does not spread or collapse during the splice operation. • Verify to see that each wire (i.e., ring and tip) is positioned properly.
6	Identify the cables using labels with cable number and pair count.
7	Clear out the Work Area.

Optical Fiber

Optical fiber cable for premises applications comes in many varieties of construction. When terminating or splicing these cables, the cable ends must be prepared to provide access to the fiber. If unfamiliar with the proper procedure for a particular design, consult the manufacturer's guidelines.

Fiber Cable Termination

Listed below are various methodologies for optical fiber termination. Each has advantages and disadvantages, including the skill level required. Most methods are available for all connector styles (SC, ST, FC, LC, etc.). As with other connectivity components, procedures are rather component specific. Installers should refer to the applicable procedures.

NOTE: It is imperative to remember that there is a difference in the tolerance between Single Mode Fibers (SMF) and Multimode Fibers (MMF) mechanical connectors. You may use SMF connectors on MMF, but you may not use MMF connectors on SMF.

FIBER CABLE TERMINATION	
Termination Methodology	Description
Pigtail Splicing	This method involves splicing a factory-made assembly onto the end of the cable. The assembly consists of a short piece of cable, pre-terminated on one end with the connector of choice. The advantage is that the connectors are pre-installed. The non-terminated end is spliced (typically fusion) to the cable. For more details, see the Fiber Cable Splicing subsection towards the end of this chapter.
No Polish Connectors	This method is similar to pigtail splicing, minus the short piece of cable and using a mechanical splice rather than fusion. The connector actually contains a mechanical splice designed to mate with the fiber of the installed cable. The advantage is that the connector end face does not require field polishing.
Heat-Cured Termination	This method utilizes a heat-cured epoxy to secure the connector to the cable end. The installed fiber terminates at the connector end face and must be field polished.
Ultraviolet (UV) Light-Cured Termination	This method utilizes a UV-cured epoxy to secure the connector to the cable end. The installed fiber terminates at the connector end face and must be field polished.
Crimp Termination	This method utilizes a mechanical crimp or compression to secure the connector to the cable end. The installed fiber terminates at the connector end face and must be field polished.
Anaerobic Termination	This method utilizes a fast-cure adhesive to secure the connector to the cable end. The installed fiber terminates at the connector end face and must be field polished.

Loose-Tube vs. Tight-Buffer

Two broad classifications of optical fiber cable are loose-tube and tight-buffer.

Loose-tube cable designs are constructed with the optical fiber(s) loosely placed within a protective tube. This design is seen more often in outside plant (OSP) applications. However, many OSP loose-tube cables terminate indoors. In addition, there is growing use of indoor and indoor/outdoor cables in loose-tube designs.

Tight-buffer fiber has an additional layer of plastic (typically 900 µm diameter) that protects the fiber when the additional cable layers have been removed. This allows tight-buffer fibers to have a connector installed directly on the fiber. Connectors designed for this have a strain-relief boot designed to fit the tight buffer. Tight-buffer splices, including pigtail splices, should still be protected with a splice sleeve and stored in a splice tray.

- NOTE: Certain types of connectors are made to terminate directly onto tight-buffers, but some are designed to incorporate the jacket and strength yarns on simplex and zipcord cables. Be sure to verify compatibility between cable and connectors before installation begins.

Loose-tube fiber does not have the additional protection and is more vulnerable to damage when exposed. Therefore, loose-tube fibers require a break-out kit (also known as a fan-out kit) to install a connector directly on the end of the fiber. The break-out kit includes a tube that slides over the fiber, protecting it and building the diameter up (typically 900 µm diameter) to fit standard connectors. Loose-tube splices, including pigtail splices, should also be protected with a splice sleeve and stored in a splice tray.

See Technical Guideline, **Recommended Breakout Kits***, for additional information.*

TERMINATING OPTICAL FIBER CABLE

Step	Action
1	Verify that the correct termination components have been selected, compatible with both the fiber and the connecting hardware.
2	Arrange the wiring scheme and organize cable by destination (i.e., rack, panel, etc.). If desired, optical fiber cable may be dressed or combed for a neat appearance.
3	Trim the cable length to reach the termination point without putting the cable under stress or violating the bend radius. Be sure to maintain cable identification!
4	Follow the connectivity hardware manufacturer's instructions for installing the termination hardware/connectors. • Beware of anything crushing or excessively bending fibers and/or tubes. • Properly bond and ground any cables with metallic components. • If using a pigtail, protect all splices with a splice sleeve and suitable splice enclosure (see the next subsection, Fiber Cable Splicing).
5	Loosely bundle all exposed cable, preferably with hook-and-loop style straps.
6	Clear out the Work Area.

Fiber Cable Splicing

In general, splices are best avoided and often can be due to the relatively short distances typical of premises networks. If splices are required, fusion splices are recommended due to lower attenuation. However, mechanical splices are allowed.

All fusion splices should be protected by a splice sleeve. All splices should be housed in a splice tray. All outdoor splices should be stored in an environmentally suitable splice closure. As a reminder, although there are common standards to ensure interoperability between cable and hardware, many hardware features are manufacturer specific. Therefore, the following table should be used in conjunction with the instructions/guidelines relevant to the splicing solution being employed.

FIBER CABLE SPLICING

Step	Action
1	Verify that the correct splicing method has been chosen, making sure that the tools and hardware facilitate the method to be used. Listed below are the following factors to calculate splice and closure size: • Cable construction • Cable fiber count • Splice type • Splice location
2	The space needs of the splice closure, the working space, and the cable pathway leading to the splice are important factors that need to be considered. The cable should not be bent so that it twists or violates the minimum bend radius.
3	Use safety precautions to set up the splicing area using ladders or scaffolding, where required.
4	Install a support structure for the splice, if necessary. Sustain the proper bending radius of the cable, and keep room for the appropriate splice closure.
5	Install the closure per the closure manufacturer's instructions, and perform the splice per the splice/splicer manufacturer's instructions, including but not limited to the following: • Cable preparation – often the cable manufacturer's guidelines and closure manufacturer's guidelines must both be referenced to achieve the proper procedures and measurements. • Secure all cables to prevent movement relative to the closure. • Properly bond and ground any cables with metallic components. • Provide ample fiber length inside the closure. Consider both current access and possible future changes. Balance fiber length on both sides of the splice to aid in neat fiber storage. • Protect all splices with a splice sleeve and store all splices and slack fiber in a splice tray. • Label the splice per the customer specification (ANSI/TIA/EIA-606 Administration Standard for the Telecommunications Infrastructure of Commercial Buildings recommended) and update as-built drawings as necessary.
6	Clear out the Work Area.

Chapter 8 - Testing

Testing verifies that installation has been completed in accordance with all of the terms and conditions of the contract and industry standards. The complete testing process consists of three distinct phases: visual verification; test measurements; and documentation.

1. **Visual Verification**
   Visual verification includes inspection of all pathways and spaces (where possible), telecommunications closets, and equipment rooms. At minimum, the following elements are inspected: infrastructure, grounding and bonding, cable placement, cable termination, equipment and patch cords, and the proper labeling of all components.
2. **Test Measurements**
   Although there are common standards to ensure interoperability between cabling and test equipment, many test equipment features are manufacturer-specific. Therefore, test measures should be used in conjunction with the instructions/guidelines relevant to the test equipment being employed.
3. **Documentation**
   Once testing is complete, it is highly recommended to document test results. Documentation is vital to establishing long-term performance and integrity of cable networks by revealing problems not detected during installation and providing a baseline for comparison to future measurements.

Test Equipment

Field test equipment is used as most appropriate and cost-effective for the type of cables being installed. Many test sets are capable of performing all required tests, while others are designed to perform a few tests or even a single specific test. A comprehensive listing of test equipment can be found in the BICSI Telecommunications Cabling Installation Manual.

Pre-Installation Testing

As mentioned in Chapter 6: Cable Installation, Superior Essex communications cables are manufactured to high standards and tested rigorously to relieve end users of the burden of pre-installation testing. In normal situations, pre-installation testing is not necessary; however, such testing should be conducted if the following conditions exist:

- The customer specification requires pre-installation testing.
- There is evidence of cable mishandling or damage, including but not limited to the following:
  - Physical damage to the cable or packaging
  - Cable reels delivered or stored on their sides
  - End caps missing on OSP cables, particularly non-filled copper cables

Balanced Twisted Pair Copper Cable Testing

Balanced twisted pair copper cable testing evaluates the proper installation and functioning of horizontal and backbone copper cabling. Test methods for Backbone copper cabling depend on the category of cabling employed. Test methods for Horizontal copper cabling vary depending on the category as well as whether the permanent link or the entire channel is being tested.

The Permanent Link configuration is the permanent portion of the overall cable run, and consists of up to 90 m (295 ft) of horizontal cabling and one connection at each end and may also include an optional transition/consolidation point connection.

The Channel Link encompasses the entire cable run, including all patch cords and cross connections. The channel link test configuration is more comprehensive, in that the quality of the additional components, the proper installation, and the network equipment all play a role in the transmission performance of the entire network.

Field Testing and Certification

Certification test sets verify that a cabling system meets the transmission performance required by the applicable standard. Test sets fall within one of four certification levels, which define the accuracy of the instrument:

Twisted Pair Cable Type	Minimum Certification Level
Category 3	I
Category 5e	IIe
Category 6	III
Category 6A	IIIe

The following table lists the typical tests performed on balanced twisted pair cabling systems.

FIELD TESTING PERFORMANCE PARAMETERS – COPPER SYSTEMS				
Parameter	CAT 3	CAT 5e	CAT 6	CAT 6A
Wire Map	✔	✔	✔	✔
Length	✔	✔	✔	✔
Insertion Loss (Attenuation)	✔	✔	✔	✔
Propagation Delay	✔[1]	✔	✔	✔
Delay Skew	✔[1]	✔	✔	✔
NEXT (Near-end crosstalk) Loss	✔	✔	✔	✔
PSNEXT (Power sum near-end crosstalk) Loss	✔[2]	✔	✔	✔
Return Loss		✔	✔	✔
ACRF (Attenuation-to-crosstalk ratio, far-end) Loss		✔	✔	✔
PSACRF (Power sum attenuation-to-crosstalk far-end) Loss		✔	✔	✔
AFEXT (Alien far-end crosstalk) Loss				✔[3]
ANEXT (Alien near-end crosstalk) Loss				✔[3]
PSAACRF (Power sum attenuation to alien crosstalk ratio far-end)				✔[3]
Average PSAACRF				✔[3]
PSANEXT (Power sum alien near-end crosstalk) Loss				✔[3]
Average PSANEXT				✔[3]

[1]*Not required for backbone Category 3 cabling.*
[2]*Not required for horizontal Category 3 cabling.*
[3]*Indicates test parameters that may be based on either manufacturer certification or field test results.*

Testing Guidelines and Procedures

This section contains general guidelines and descriptions for each of the tests in the previous table. Specific instructions and associated calculations can be found in the BICSI Information Transport Systems Installation Methods Manual and TIA/EIA-568, along with its various addenda.

- **Set the Proper NVP**
  Many test sets contain cable libraries that allow the user to select a generic cable type (such as Category 6 UTP) and/or specific cable (such as Superior Essex NextGain CMP) that automatically loads pre-set cable parameters, including NVP. However, parameters are subject to change and should be verified against the applicable product data sheet. This is especially true of NVP which has significant affect on length measurement. To ensure the most accurate length measurement, verify and set the proper NVP for the cable being tested.
- **Wire Map or Continuity Testing**
  Continuity Testing is the most basic test to establish proper cabling installation. It is also referred to as a Wire Map test when utilizing handheld testers. Continuity testing evaluates the following elements:
  - Open circuits
  - Short circuits
  - Improper termination
  - Drain wire continuity (if applicable)

Wire map field testers, or Pair Scanners, are most practical to measure direct current loop resistance of twisted pair and F/UTP. To test using the pair scanner, perform the following:

Step	Action
1	Disconnect equipment.
2	Attach pair scanner to one end of cabling.
3	Diagnose and repair faulty cabling.
4	Scan a second time.
5	Document the test results.

- **Length Testing**

  In Length testing, verify the following:

  - The maximum permanent link length is 90 m, plus 2 m at each end for leads, and an additional 10%, for a total of 103.4 m. The tester will not fail any length up to 104.4 m.
  - The maximum channel link length is 90 m, plus 10 m for all patch leads, fly leads and equipment leads, and an additional 10%, for a total of 110 m. The 10% is to allow for NVP (Nominal Velocity of Propagation) uncertainty.

  Limits are stricter for the permanent link since there are fewer components. It is important to set the tester to the correct type of link being tested.

Other Test Parameters	Description
Insertion Loss (Attenuation)	Insertion Loss is measured as the signal loss between transmitter and receiver. It is evaluated across a frequency range and compared against a category or classification limit through that range. The category or classification limit determines pass/fail for each pair.
Propagation Delay	Propagation delay is measured as the time it takes for a signal to propagate from one end of a conducting pair in cabling, cables, or connecting hardware to the opposite end of that pair. Propagation delay is expressed in nanoseconds (ns). The category or classification limit determines pass/fail for each pair.
Delay Skew	Delay skew is measured as the difference between the pair with most propagation delay and the pair with the least propagation delay. Delay skew is evaluated from 1 MHz to the highest point and frequency of each category. Delay skew is expressed in nanoseconds (ns). The category or classification limit determines pass/fail for each pair.
NEXT Loss	NEXT (near-end crosstalk) loss testing is a measure of the unwanted signal coupling from a transmitter at the near end into neighboring pairs measured at the near end. It is evaluated across a frequency range and compared against a category or classification limit through that range. NEXT loss measurement must be performed at both ends of the cabling. The category or classification limit determines pass/fail for each pair.
PSNEXT Loss	PSNEXT (power sum near-end crosstalk) loss is the combined near-end crosstalk on a tested pair from all other operating pairs. PSNEXT loss is calculated using the results of the NEXT loss of the individual combinations.
FEXT Loss	FEXT (far-end crosstalk) loss is a measure of the unwanted signal coupling from a transmitter at the far-end into neighboring pairs measured at the near-end. FEXT loss is expressed in dB relative to the transmit signal level. NOTE: FEXT is not measured and reported by field test equipment.
Return Loss	Return Loss measures the difference between the test signal's amplitude and the amplitude of signal reflections returned by the cable expressed in dB.
ACRF Loss	ACRF (attenuation-to-crosstalk ratio, far-end) loss is a mathematical formula that is used to calculate the ratio of attenuation to NEXT loss for each combination of cable pairs. Results include Pass/Fail, Worst-case ACRF loss, Worst-case frequency, or Margin.
PSACRF Loss	PSACRF (power sum attenuation-to-crosstalk far-end) loss takes into account the combined crosstalk (statistical) on a receive pair from all far-end disturbers operating simultaneously. PSACRF loss is calculated as a power sum on a selected pair from all other pairs.
AFEXT Loss	AFEXT (alien far-end crosstalk) loss is unwanted signal coupling from a disturbing pair of a 4-pair channel, permanent link, or component to a disturbed pair of another 4-pair channel, permanent link, or component, measured at the far-end.
ANEXT Loss	ANEXT (alien near-end crosstalk) loss is the unwanted signal coupling from a disturbing pair of a 4-pair channel, permanent link, or component to a disturbed pair of another 4-pair channel, permanent link, or component, measured at the near-end.
PSAACRF	PSAACRF (power sum attenuation to alien crosstalk ratio far-end) is the difference in dB between the power sum alien far-end crosstalk from multiple disturbing pairs of one or more 4-pair channels, permanent links, or components, and the insertion loss of a disturbed pair in another 4-pair channel, permanent link, or component.
Average PSAACRF	Average PSAACRF is the mean of the PSAACRF measurements.

Other Test Parameters	Description
PSANEXT Loss	PSANEXT (power sum alien near-end crosstalk) loss is the power sum of the unwanted signal coupling from multiple disturbing pairs of one or more 4-pair channels, permanent links, or components to a disturbed pair of another 4-pair channel, permanent link, or component, measured at the near-end.
Average PSANEXT Loss	Average PSANEXT loss is the mean of the PSANEXT loss measurements.

Optical Fiber Cable Testing

Proper testing of Optical Fiber Cable increases the system's longevity, minimizes system downtime, reduces maintenance needs, and supports system upgrades and reconfigurations.

Fiber optic cable is tested for continuity and attenuation. Three test methods are commonly performed for Optical Fiber:

- Visible Light Source
- Power-meter-and light-source (One Jumper Method)
- Optical Time Domain Reflectometer (OTDR)

Visible Light Source Testing

Visible Light Source tests continuity in optical fiber stands. Optical fiber communication systems operate in the infrared region of the electromagnetic spectrum which is invisible to the human eye. However, (red) visible light sources are available for testing and troubleshooting optical fiber systems. They are also referred to as visual fault finders, visual fault locators, among other names.

To test using a visible light source, perform the following:

Step	Action
1	Connect the optical fiber flashlight to one end of a fiber strand (with most units, the fiber must be terminated).
2	Look at the opposite end. ⚠ Be careful not to look directly at active optical fiber strands. Laser light sources can cause serious eye damage.
3	If the light is not visible at the opposite end, a break or other problem is likely present somewhere along the length of the fiber. In many instances, the fault location will glow red from the light of the visible light source.
4	Document the test result information.

Power-Meter-and-Light-Source Testing

Power-meter-and-light-source (also known as the One Jumper Method) is the most accurate way to measure end-to-end signal loss of the fiber, referred to as attenuation. Listed below are TIA/EIA-568 insertion loss limits for the various components. Specific installations or protocols may impose stricter limits.

LOSS BUDGET (TIA/EIA SPECIFICATION LIMITS)	
Element	Insertion Loss
Splice	< 0.3 dB at all wavelengths
Connector Pair	< 0.75 dB at all wavelengths

Test results should be compared to the link attenuation allowance calculated as follows:

Link Attenuation Allowance (dB) = Cable Attenuation Allowance (dB) + Connector Insertion Loss Allowance (dB) + Splice Insertion Loss Allowance (dB) where:

- Cable Attenuation Allowance (dB) = Maximum Attenuation* (dB/km) x Length (km)
- Connector Insertion Loss Allowance (dB) = Number of Connector Pairs x Connector Loss Allowance (dB)
- Splice Insertion Loss Allowance (dB) = Number of Splices x Splice Loss Allowance (dB)

Maximum Attenuation values are available in the Superior Essex* **Optical Fiber Selection Chart.

To test using power-meter-and-light-source, perform the following steps.

Step	Action
1	Disconnect active equipment.
2	Acquire suitable light source for the single mode (generally 1310 nm or 1550 nm), multimode (850 nm or 1300 nm), and power meter.
3	Verify proper wavelength to set source and meter. • NOTE: Calibration of the equipment is required before each test. Follow the equipment manufacturer's procedures.
4	Acquire accurate test jumpers and couplers, which should be part of the light source and power meter kit.
5	Connect the jumper (containing the same fiber size as the system fiber) to the optical source and the optical power meter. Turn unit on. Record the reference power reading (Pref), displayed in dBm.
6	By applying an adapter, insert a second jumper (Test jumper 2) between the jumper used in Step 5 and the optical power meter. Verify the attenuation added by the second jumper is not greater than 0.75 dB: Pref - Pcheck ≤ 0.75 dB.
7	Attach the jumpers to the optical source and optical power meter. Disconnect the two jumpers at the adapter. Connect the optical source/Test jumper 1 to one end of the system fiber to be tested. Connect the optical power meter/Test jumper 2 to the other end of the system fiber. Document the test power (Ptest). Subtract the test power (Ptest) from the reference power (Pref), recorded in Step 5, to conclude the end-to-end attenuation: Attenuation (dB) = Pref – Ptest.
8	Document the test results.

NOTE: These are general guidelines. Equipment manufacturer's procedures may be more specific.

Optical Time Domain Reflectometer (OTDR) Testing

Optical Time Domain Reflectometer (OTDR) measures the fiber cable length, attenuation, and "events" along the length of the fiber. Events can be splices, breaks, or stress points (often called "kinks" or "steps") that cause excessive attenuation. The OTDR does this by sending light pulses down the cable and measuring the timing and power of light reflected back to the OTDR by the events and the fiber itself. It uses this information to display a "trace", which is a graph of power versus distance. An OTDR only requires access to one end of a fiber for testing. Because an OTDR is an indirect measurement method, it is not as accurate as a light source and power meter for measuring attenuation. However, due to its ability to display a graph of the fiber, it is particularly useful in troubleshooting. Like a power meter and light source, an OTDR tests at specific wavelengths (generally 1310 nm and/or 1550 nm for single mode and 850 nm or 1300 nm for multimode).

If using an OTDR for certification testing in a premises cable environment, there are several important factors to consider:

- Though OTDR's can test from a single end, all fibers should be tested from both ends to ensure the fiber is compliant end to end. OTDR's have a blind spot at the measuring end (which can hide problems). Also, because the OTDR is measuring reflected light, it may be impossible to tell if an event at the far end is the actual end of the fiber or a fault.
- If measuring individual splice loss with an OTDR, always measure the splice from both directions and average the two measurements (known as a bidirectional average). For further information, see Fusion Splicing Today's Single mode Fibers (good reference on OTDR testing, applicable to single mode and multimode) available at **SuperiorEssex.com**.
- The shorter the measurement distance, the less accurate the attenuation measurement becomes. This varies based on the specific OTDR. Check the manufacturer's specifications.

Documentation

As stated in Chapter 1, documentation is vital to the ongoing success of installation and maintenance of copper and optical fiber cabling systems.

As with visual inspection and test measurements, documentation should be the final step of each test administered.

Format

Documentation should be presented in a format requested by the customer or in accordance with ANSI/TIA/EIA-606, Administration Standard for the Telecommunications Infrastructure of Commercial Buildings.

Warranties

Certain requirements must be followed for the client to receive Superior Essex warranty coverage should any structured cabling products require servicing. For a detailed checklist of these requirements, please refer to **SuperiorEssex.com**.