



ANSI/TIA-568-C.0-2009
APPROVED: FEBRUARY 2, 2009

TIA STANDARD

Generic Telecommunications Cabling for Customer Premises

TIA-568-C.0

February 2009

TELECOMMUNICATIONS
INDUSTRY ASSOCIATION

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(From Standards Proposal No. 3-0177, formulated under the cognizance of the TIA TR-42 User Premises Telecommunications Cabling Requirements, TR-42.1 Subcommittee on Commercial Building Telecommunications Cabling).

Published by

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Standards and Technology Department
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FOREWORD

(This foreword is not considered part of this Standard.)

This Standard was developed by TIA Subcommittee TR-42.1.

Approval of this Standard

This Standard was approved by TIA Subcommittee TR-42.1, TIA Engineering Committee TR-42, and the American National Standards Institute (ANSI).

ANSI/TIA reviews standards every 5 years. At that time, standards are reaffirmed, withdrawn, or revised according to the submitted updates. Updates to be included in the next revision should be sent to the committee chair or to ANSI/TIA.

Contributing organizations

More than 60 organizations within the telecommunications industry contributed their expertise to the development of this Standard (including manufacturers, consultants, end users, and other organizations).

Documents superseded

This Standard, in part, replaces ANSI/TIA/EIA-568-B.1 dated April 12, 2001 and its addenda.

This Standard incorporates and refines the technical content of:

- ANSI/TIA/EIA-568-B.1-1, *Addendum 1 – Minimum 4-Pair UTP and 4-Pair ScTP Patch Cable Bend Radius*
- ANSI/TIA/EIA-568-B.1-2, *Addendum 2 – Grounding and Bonding Specifications for Screened Balanced Twisted-Pair Horizontal Cabling*
- ANSI/TIA/EIA-568-B.1-3, *Addendum 3 – Supportable Distances and Channel Attenuation for Optical Fiber Applications by Fiber Type*
- ANSI/TIA/EIA-568-B.1-7, *Addendum 7 – Guidelines for Maintaining Polarity Using Array Connectors*
- TIA/EIA TSB125, *Guidelines for Maintaining Optical Fiber Polarity Through Reverse-pair Positioning*
- TIA TSB140, *Additional Guidelines for Field-Testing Length, Loss and Polarity of Optical Fiber Cabling Systems*
- TIA TSB153, *Static Discharge Between LAN and Data Terminal Equipment*

Relationship to other TIA standards and documents

The following are related standards regarding various aspects of structured cabling that were developed and are maintained by Engineering Committee TIA TR-42. An illustrative diagram of the TIA-568-C Series relationship to other relevant TIA standards is given in figure 1.

- *Commercial Building Telecommunications Cabling Standard* (ANSI/TIA-568-C.1);
- *Commercial Building Telecommunications Cabling Standard; Part 2: Balanced Twisted-Pair Cabling Components* (ANSI/TIA/EIA-568-B.2);
- *Optical Fiber Cabling Components Standard* (ANSI/TIA-568-C.3);
- *Commercial Building Standard for Telecommunications Pathways and Spaces* (TIA-569-B);
- *Residential Telecommunications Infrastructure Standard* (ANSI/TIA-570-B);
- *Administration Standard for Commercial Telecommunications Infrastructure* (ANSI/TIA/EIA-606-A);
- *Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications* (ANSI-J-STD-607-A).
- *Customer-Owned Outside Plant Telecommunications Infrastructure Standard* (ANSI/TIA-758-A).
- *Building Automation Systems Cabling Standard for Commercial Buildings* (ANSI/TIA/EIA-862)
- *Telecommunications Infrastructure Standard for Data Centers* (ANSI/TIA-942)
- *Telecommunications Infrastructure Standard for Industrial Premises* (ANSI/TIA-1005)

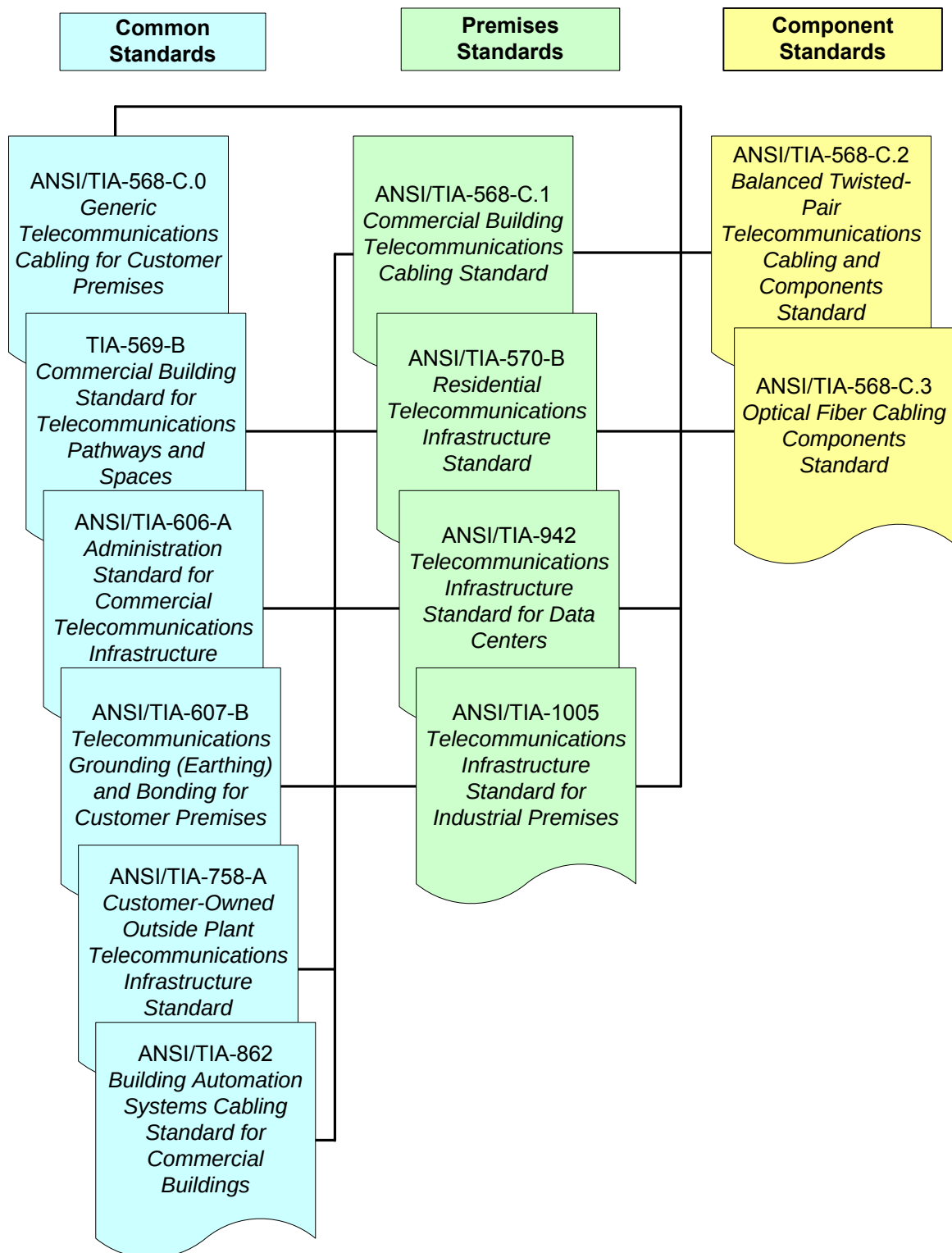


Figure 1 – Illustrative relationship between the TIA-568-C Series and other relevant TIA standards

The following documents may be useful to the reader:

- a) *National Electrical Safety Code*® (NESC®) (IEEE C2-2007)
- b) *National Electrical Code*® (NEC®) (NFPA 70-2008)

Useful supplements to this Standard are the following BICSI documents: the *Telecommunications Distribution Methods Manual*, the *Customer-owned Outside Plant Design Manual*, and the *Information Transport Systems Installation Manual*. These manuals provide practices and methods by which many of the requirements of this Standard are implemented.

Other references are listed in annex G.

Annexes

Annexes A and B are normative and considered a requirement of this Standard. Annexes C through G are informative and not considered a requirement of this Standard.

Introduction

Purpose

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.

This Standard is the foundation for premises telecommunications cabling infrastructure. Additional requirements are detailed in standards specific to the type of premises. For example, ANSI/TIA-568-C.1 contains additional requirements applicable to commercial building cabling.

Stewardship

Telecommunications infrastructure affects raw material consumption. The infra-structure design and installation methods also influence product life and sustainability of electronic equipment life cycling. These aspects of telecommunications infrastructure impact our environment. Since building life cycles are typically planned for decades, technological electronic equipment upgrades are necessary. The telecommunications infrastructure design and installation process magnifies the need for sustainable infrastructures with respect to building life, electronic equipment life cycling and considerations of effects on environmental waste. Telecommunications designers are encouraged to research local building practices for a sustainable environment and conservation of fossil fuels as part of the design process.

Specification of criteria

Two categories of criteria are specified; mandatory and advisory. The mandatory requirements are designated by the word "shall"; advisory requirements are designated by the words "should", "may", or "desirable" which are used interchangeably in this Standard.

Mandatory criteria generally apply to protection, performance, administration and compatibility; they specify minimally acceptable requirements. Advisory criteria are presented when their attainment may enhance the general performance of the cabling system in all its contemplated applications.

A note in the text, table, or figure is used for emphasis or offering informative suggestions, or providing additional information.

Metric equivalents of US customary units

The dimensions in this Standard are metric or US customary with soft conversion to the other.

Life of this Standard

This Standard is a living document. The criteria contained in this Standard are subject to revisions and updating as warranted by advances in building construction techniques and telecommunications technology.

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1 SCOPE

This Standard specifies requirements for generic telecommunications cabling. It specifies requirements for cabling system structure, topologies and distances, installation, performance and testing.

NOTE – The diversity of services currently available, coupled with the continual addition of new services, means that there may be cases where limitations to desired performance occur. When applying specific applications to these cabling systems, the user is cautioned to consult application standards, regulations, equipment vendors, and system and service suppliers for applicability, limitations, and ancillary requirements.

2 NORMATIVE REFERENCES

The following standards contain provisions that, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards published by them. ANSI and TIA maintain registers of currently valid national standards published by them.

- a) ANSI-J-STD-607-A-2002, *Commercial Building Grounding (Earthing) and Bonding Requirements For Telecommunications*
- b) ANSI/TIA-455-78B-2002, *Optical Fibres – Part 1-40: Measurement Methods and Test Procedures – Attenuation*
- c) ANSI/TIA-568-C.3-2008, *Optical Fiber Cabling Components Standard*
- d) ANSI/TIA-598-C-2005, *Optical Fiber Cable Color Coding*
- e) ANSI/TIA/EIA-568-B.1-2001, *Commercial Building Telecommunications Cabling Standard; Part 1: General Requirements*

NOTE – Cabling requirements (permanent link and channel) for category 3 and category 5e 100-ohm balanced twisted-pair cabling are currently contained in ANSI/TIA/EIA-568-B.1. When ANSI/TIA-568-C.2 is published the cabling requirements for category 3 and category 5e 100-ohm balanced twisted-pair cabling will be specified in that document.

- f) ANSI/TIA/EIA-568-B.2-2001, *Commercial Building Telecommunications Cabling Standard; Part 2: Balanced Twisted-Pair Cabling Components*

NOTE – When ANSI/TIA/EIA-568-B.2 is superseded by ANSI/TIA-568-C.2, the latter will become the referenced standard.

- g) ANSI/TIA/EIA-606-A-2007, *Administration Standard for Commercial Telecommunications Infrastructure*
- h) TIA-526-7-2002, *Measurement of Optical Power Loss of Installed Single-mode Fiber Cable Plant - OFSTP-7*
- i) TIA-526-14-A-2003, *Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant – OFSTP-14*
- j) TIA-569-B-2004, *Commercial Building Standard for Telecommunications Pathways and Spaces*

3 DEFINITION OF TERMS, ACRONYMS AND ABBREVIATIONS, AND UNITS OF MEASURE

3.1 General

For the purposes of this Standard, the following definitions, acronyms, abbreviations and units of measure apply.

3.2 Definitions

A-to-A patch cord, optical fiber: A duplex patch cord that connects position A on one end of the patch cord to position A on the other end of the patch cord.

A-to-B patch cord, optical fiber: A duplex patch cord that connects position A on one end of the patch cord to position B on the other end of the patch cord.

access provider: The operator of any facility that is used to convey telecommunications signals to and from a customer premises.

adapter: A device that enables any or all of the following:

- (1) different sizes or types of plugs to mate with one another or to fit into a telecommunications outlet,
- (2) the rearrangement of leads,
- (3) large cables with numerous wires to fan out into smaller groups of wires, and
- (4) interconnection between cables.

adapter, optical fiber: A mechanical device designed to align and join two optical fiber connectors (plugs) to form an optical connection.

adapter; optical fiber array: A mechanical device designed to align and join two array optical fiber connectors (plugs) to form an optical array connection.

adapter; optical fiber duplex: A mechanical device designed to align and join two duplex optical fiber connectors (plugs) to form an optical duplex connection.

administration: The method for labeling, identification, documentation and usage needed to implement moves, additions and changes of the telecommunications infrastructure.

array connector (multi-fiber connector): A single ferrule connector that contains multiple optical fibers arranged in a row or in rows and columns.

array patch cord: A length of optical fiber cable with an array connector on each end.

attenuation: The decrease in magnitude of transmission signal strength between points, expressed in dB as the ratio of output to input signal level.

backbone: A facility (e.g., pathway, cable or bonding conductor) for cabling Subsystem 2 and Cabling Subsystem 3.

bonding: The permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed.

cable: An assembly of one or more insulated conductors or optical fibers, within an enveloping sheath.

cable run: A 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.

cabling: A combination of all cables, jumpers, cords, and connecting hardware.

Cabling Subsystem 1: Cabling from the equipment outlet to Distributor A, Distributor B, or Distributor C.

Cabling Subsystem 2: Cabling between Distributor A and either Distributor B or Distributor C (if Distributor B is not implemented).

Cabling Subsystem 3: Cabling between Distributor B and Distributor C.

campus: The buildings and grounds having legal contiguous interconnection.

centralized cabling: A cabling configuration from an equipment outlet to a centralized cross-connect in the same building using a continuous cable, an interconnect, or a splice.

channel: The end-to-end transmission path between two points at which application-specific equipment is connected.

commercial building: A building or portion thereof that is intended for office use.

connecting hardware: A device providing mechanical cable terminations.

connector (plug), duplex; optical fiber: A remateable device that terminates two fibers and mates with a duplex receptacle.

consolidation point: A connection facility within Cabling Subsystem 1 for interconnection of cables extending from building pathways to the equipment outlet.

cord (telecommunications): An assembly of cord cable with a plug on one or both ends.

cord cable: A cable used to construct patch, work area, and equipment cords.

cross-connect: A facility enabling the termination of cable elements and their interconnection or cross-connection.

cross-connection: A connection scheme between cabling runs, subsystems, and equipment using patch cords or jumpers that attach to connecting hardware on each end.

customer premises: Building(s), grounds and appurtenances (belongings) under the control of the customer.

demarcation point: A point where the operational control or ownership changes.

Distributor A: Optional connection facility in a hierarchical star topology that is cabled between the equipment outlet and Distributor B or Distributor C.

Distributor B: Optional intermediate connection facility in a hierarchical star topology that is cabled to Distributor C.

Distributor C: Central connection facility in a hierarchical star topology.

drop cable: Cable linking a drop terminal (e.g. from a service provider) to a premises terminal.

earth: See **ground**.

earthing: See **grounding**.

electromagnetic compatibility: The ability of electronic systems to operate in their intended electromagnetic environment without suffering performance degradation and without causing performance degradation in other equipment.

electromagnetic interference: Radiated or conducted electromagnetic energy that has an undesirable effect on electronic equipment or signal transmissions.

end user: The owner or user of the premises cabling system.

equipment cord: See **cord**.

equipment outlet: Outermost connection facility in a hierarchical star topology.

fiber optic: See **optical fiber**.

ground: A conducting connection, whether intentional or accidental, between an electrical circuit (e.g., telecommunications) or equipment and the earth, or to some conducting body that serves in place of earth.

grounding: The act of creating a ground.

grounding conductor: A conductor used to connect the grounding electrode to the building's main grounding busbar.

horizontal cross-connect: A cross-connect of horizontal cabling to other cabling, e.g., horizontal, backbone, equipment.

identifier: An item of information that links a specific element of the telecommunications infrastructure with its corresponding record.

infrastructure (telecommunications): A collection of those telecommunications components, excluding equipment, that together provide the basic support for the distribution of information within a building or campus.

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).

interconnection: A connection scheme that employs connecting hardware for the direct connection of a cable to another cable without a patch cord or jumper.

intermediate cross-connect: Distributor B.

jumper: 1) An assembly of twisted-pairs without connectors, used to join telecommunications circuits/links at the cross-connect. 2) A length of optical fiber cable with a connector plug on each end.

keying: The mechanical feature of a connector system that guarantees correct orientation of a connection, or prevents the connection to a jack, or to an optical fiber adapter of the same type intended for another purpose.

link: A transmission path between two points, not including equipment and cords.

main cross-connect: Distributor C.

media (telecommunications): Wire, cable, or conductors used for telecommunications.

mode: A path of light in an optical fiber.

modular jack: A female telecommunications connector that may be keyed or unkeyed and may have 6 or 8 contact positions, but not all the positions need be equipped with jack contacts.

modular plug cord: A length of cable with a modular plug on both ends.

multimode optical fiber: An optical fiber that carries many paths of light.

multipair cable: A cable having more than four pairs.

optical fiber: Any filament made of dielectric materials that guides light.

optical fiber cable: An assembly consisting of one or more optical fibers.

optical fiber duplex connection: A mated assembly of two duplex connectors and a duplex adapter.

outlet/connector (telecommunications): An equipment outlet used in commercial and residential cabling.

outside plant: Telecommunications infrastructure designed for installation exterior to buildings.

patch cord: 1) A length of cable with a plug on one or both ends. 2) A length of optical fiber cable with a connector on each end.

patch panel: A connecting hardware system that facilitates cable termination and cabling administration using patch cords.

pathway: A facility for the placement of telecommunications cable.

plug: A male telecommunications connector.

pull strength: See **pull tension**.

pull tension: The pulling force that can be applied to a cable.

record: A collection of detailed information related to a specific element of the telecommunications infrastructure.

screen: An element of a cable formed by a shield.

service provider: The operator of any service that furnishes telecommunications content (transmissions) delivered over access provider facilities.

sheath: See **cable sheath**.

shield: 1) A metallic layer placed around a conductor or group of conductors. 2) The cylindrical outer conductor with the same axis as the center conductor that together form a coaxial transmission line.

single-mode optical fiber: An optical fiber that carries only one path of light.

splice: A joining of conductors, meant to be permanent.

star topology: A topology in which telecommunications cables are distributed from a central point.

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 infrastructure: See **infrastructure (telecommunications)**.

topology: The physical or logical arrangement of a telecommunications system.

transition, optical fiber: An assembly of optical fibers and connectors, with an array connector on one end and simplex or duplex connectors on other end.

transition point: A connection between round cable and flat undercarpet cable in Cabling Subsystem 1.

wire: An individually insulated solid or stranded metallic conductor.

3.3 Acronyms and abbreviations

ADSL	asymmetrical digital subscriber line
AHJ	authority having jurisdiction
ANSI	American National Standards Institute
ATM	asynchronous transfer mode
BRI	basic rate interface
CPR	coupled power ratio
EIA	Electronic Industries Alliance
EMI	electromagnetic interference
EO	equipment outlet
FCC	Federal Communications Commission
FDDI	fiber distributed data interface
FOCIS	Fiber Optic Connector Intermateability Standard
FTR	Federal Telecommunications Recommendation
HC	horizontal cross-connect
IC	intermediate cross-connect

ANSI/TIA-568-C.0

IEC	International Electrotechnical Commission
IEEE	The Institute of Electrical and Electronics Engineers
ISDN	integrated services digital network
LAN	local area network
LED	light emitting diode
LSA	least squares analysis
MC	main cross-connect
MICE	mechanical, ingress, climatic/chemical, electromagnetic
NCS	National Communications System
NEC [®]	National Electrical Code [®]
NESC [®]	National Electrical Safety Code [®]
NFPA [®]	National Fire Protection Association
NIST	National Institute of Standards and Technology
OLTS	optical loss test set
OTDR	optical time domain reflectometer
PRI	primary rate interface
RF	radio frequency
ScTP	screened twisted-pair
TGB	telecommunications grounding busbar
TIA	Telecommunications Industry Association
TMGB	telecommunications main grounding busbar
TSB	Telecommunications System Bulletin
US	United States
UTP	unshielded twisted-pair
VDSL	very-high-speed digital subscriber line
VFL	visual fault locator

3.4 Units of measure

dB	decibel
dBm	decibel (referenced to milliwatts)
°C	degrees Celsius
ft	foot
Hz	hertz
in	inch
J	joule
kb/s	kilobit per second
kHz	kilohertz
km	kilometer

kV	kilovolt
lbf	pound force
m	meter
Mb/s	megabits per second
MHz	megahertz
mm	millimeter
m/s ²	acceleration of gravity in SI (1g = 9.7536 m/s ²)
N	Newton
nm	nanometer
μm	micrometer (micron)
V	volt
V/m	volts per meter
V rms	volts root mean square

4 TELECOMMUNICATIONS CABLING SYSTEM STRUCTURE

4.1 General

Figure 2 illustrates a representative model of functional elements that comprise a generic cabling system. It depicts the relationship between the elements and how they may be configured to create a total system. The functional elements are "equipment outlets", "Distributors" and "Cabling Subsystems", which together comprise a generic telecommunications cabling system.

NOTE – As an example, in a typical commercial building where ANSI/TIA-568-C.1 applies, Distributor C represents the main cross-connect (MC), Distributor B represents the intermediate cross-connect (IC), Distributor A represents the horizontal cross-connect (HC), and the equipment outlet (EO) represents the telecommunications outlet/connector.

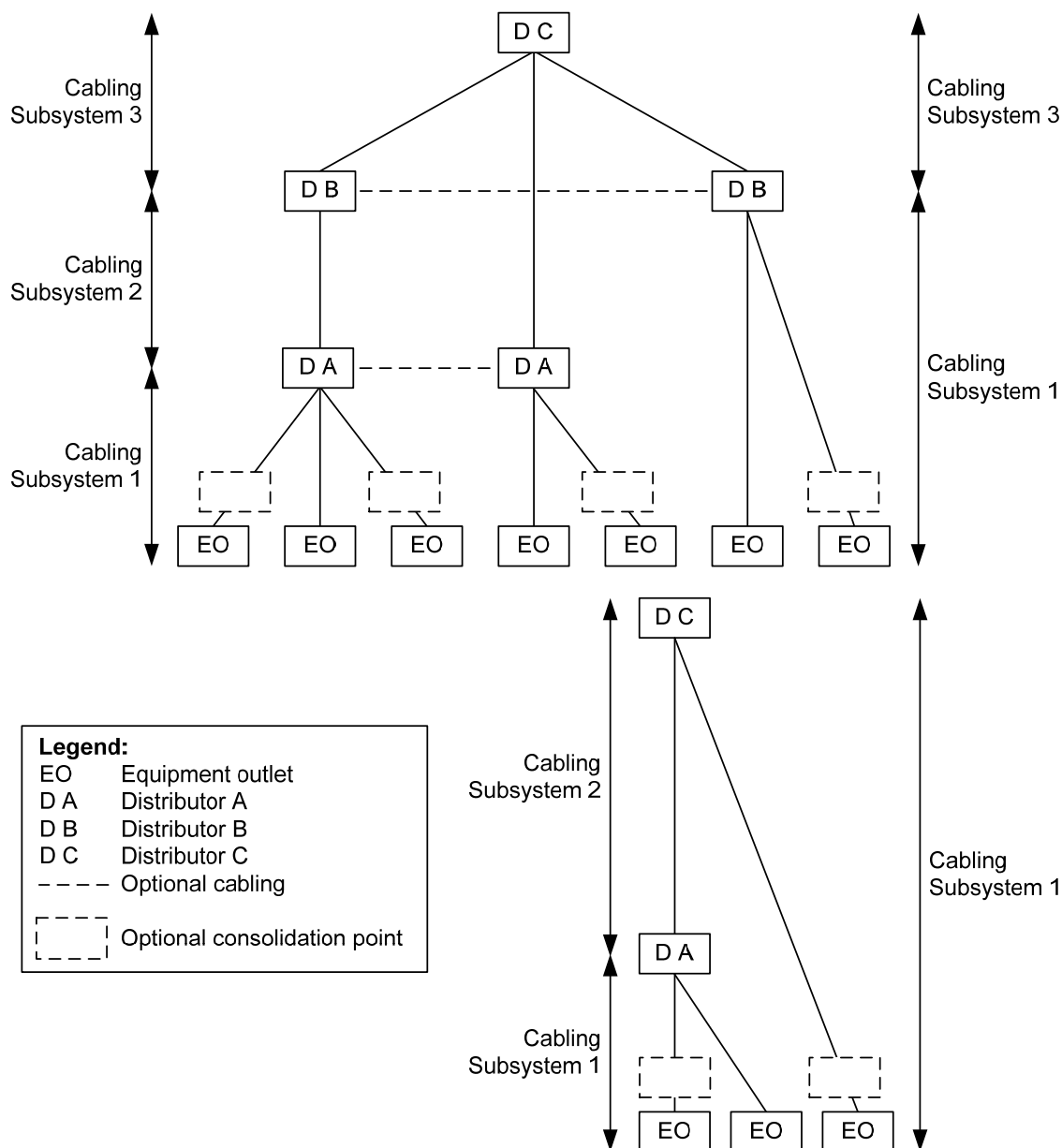


Figure 2 – Functional elements that comprise a generic cabling system

4.2 Topology

4.2.1 General

Generic cabling shall be installed in a hierarchal star topology. There shall be no more than two Distributors between Distributor C and an EO. Centralized optical fiber cabling is a hierarchal star topology that extends from Distributor B or Distributor C, through Distributor A (if present) to an EO. See annex A for additional optical fiber centralized cabling information.

NOTES

1 – The topology specified by this Standard has been selected because of its acceptance and flexibility.

2 – It may be necessary to divide the facility (e.g., a campus) into smaller areas within the scope of this Standard and then connect these areas together.

4.2.2 Accommodation of non-star configurations

The use of appropriate interconnections, electronics, or adapters can often accommodate systems that are designed for non-star configurations such as ring, bus, or tree.

4.3 Equipment outlets

EOs provide the outermost location to terminate the cable in a hierarchal star topology. It is also a location for administration, reconfigurations, connection of equipment and for testing.

4.4 Distributors

Distributors provide a location for administration, reconfiguration, connection of equipment, and for testing. Distributors can be configured as interconnections or cross-connections (see figure 3). The various premises cabling standards (e.g., those listed in the Foreword) may contain additional types of implementations at a Distributor.

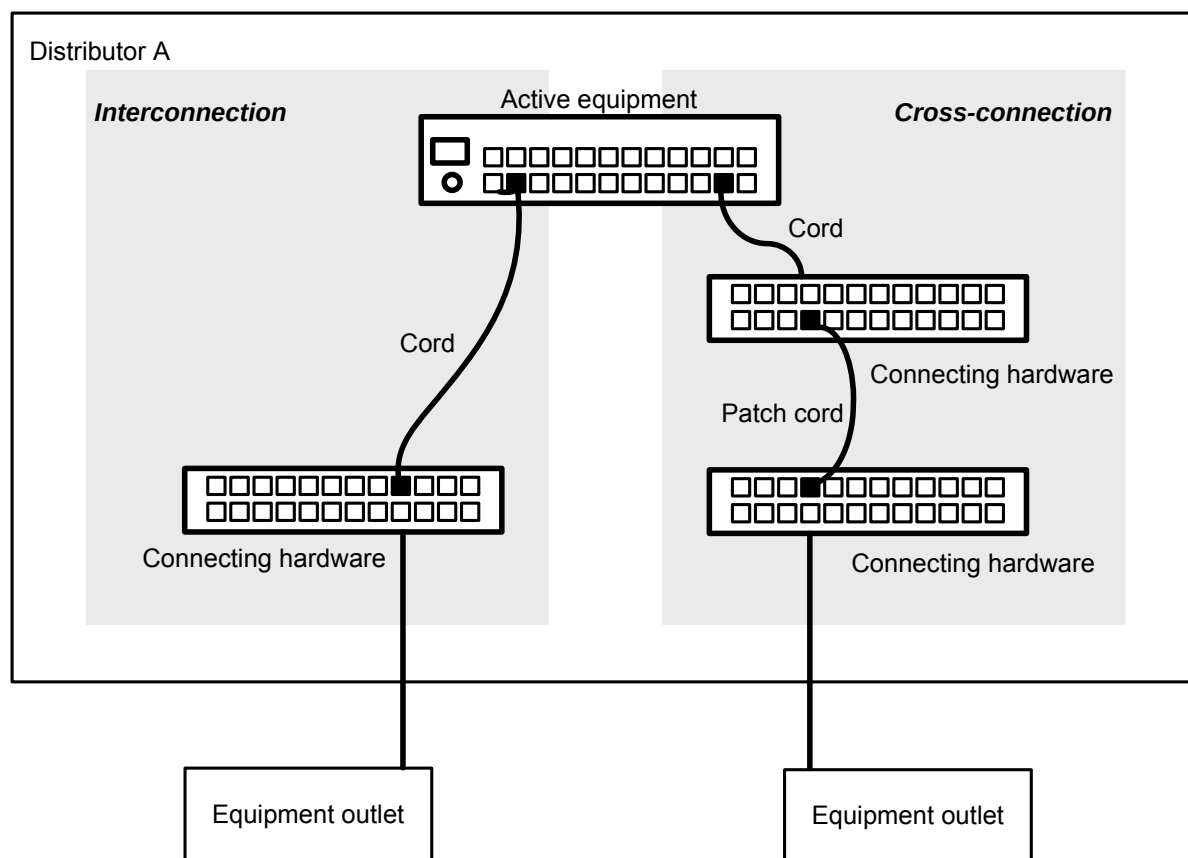


Figure 3 – Illustration of interconnection and cross-connection

4.5 Cabling Subsystem 1

The function of Cabling Subsystem 1 is to provide a signal path between Distributor A, Distributor B or Distributor C and an EO (see figure 2). Cabling Subsystem 1 shall contain no more than one transition point or consolidation point. Splices shall not be installed as part of balanced twisted-pair Cabling Subsystem 1. Splitters shall not be installed as part of optical fiber Cabling Subsystem 1.

4.6 Cabling Subsystem 2 and Cabling Subsystem 3

Cabling Subsystem 2 and Cabling Subsystem 3 provide signal paths between Distributors (see figure 2). See annex C for information regarding multi-tenant Cabling Subsystem 2 and Cabling Subsystem 3.

NOTE – The use of Distributor B is optional. It may be used, for example, to overcome distance limitations of the application or media. The use of Distributor B may allow a greater selection of media types for Cabling Subsystem 2 and Cabling Subsystem 3.

4.7 Recognized cabling

The recognized media, which shall be used individually or in combination, are:

- 100-ohm balanced twisted-pair cabling (ANSI/TIA/EIA-568-B.1 and ANSI/TIA/EIA-568-B.2);
- multimode optical fiber cabling (ANSI/TIA-568-C.3); and,
- single-mode optical fiber cabling (ANSI/TIA-568-C.3).

Cabling media other than those recognized above may be specified by the appropriate premises cabling standards (e.g., those listed in the foreword).

Recognized cabling components shall meet applicable requirements specified in ANSI/TIA/EIA-568-B.2, ANSI/TIA-568-C.3 and, if applicable, the specific premises cabling standard.

4.8 Cabling lengths

4.8.1 General

Cabling lengths are dependent upon the application and upon the specific media chosen (see annex D). Specific premises cabling standards (e.g., those listed in the foreword) may specify additional cabling length limitations.

4.8.2 Demarcation point

The cabling length between the demarcation point and Distributor C shall be included in the total distance calculations. The length and type of media (including gauge size for balanced twisted-pair cabling) shall be recorded in administration documentation. For more details on administration see ANSI/TIA/EIA-606-A.

4.9 Grounding and bonding considerations

Grounding and bonding systems are an integral part of the signal or telecommunications cabling system. In addition to helping protect personnel and equipment from hazardous voltages, a proper grounding and bonding system will improve the electromagnetic compatibility performance of the cabling system. Improper grounding and bonding can allow induced voltages and conducted noise, which can disrupt signal transmission. The media should be chosen or the cabling pathways should be designed to meet the specified transmission performance in the environment where installed (see annex F). The telecommunications grounding and bonding system shall conform to local codes and ANSI-J-STD-607-A requirements.

5 CABLING INSTALLATION REQUIREMENTS

5.1 General

Cabling and its installation shall comply with the authority having jurisdiction (AHJ) and applicable regulations.

Cable stress, such as that caused by tension in suspended cable runs and tightly cinched bundles, should be minimized. Cable bindings, if used to tie multiple cables together, should be irregularly spaced and should be loosely fitted (easily moveable).

The cable shall not be subjected to pulling tension exceeding the pulling strength rating of the cable. The cable bend radius shall be greater than or equal to the minimum bend radius requirement during and after installation.

5.2 Environmental compatibility

The cabling system should be designed to be compatible with its worst case environment. Compatibility of the cabling with the environment can be achieved with enhanced cabling components or by means of separation or isolation. Separation and isolation methods can be used to convert the environment to be compatible with the cabling system. In some cases, a combination of component enhancements, isolation and separation may be used (see annex F).

5.3 Balanced twisted-pair cabling

5.3.1 Maximum pulling tension

The pulling tension for a 4-pair balanced twisted-pair cable shall not exceed 110 N (25 lbf) during installation. For multipair cable, manufacturer's pulling tension guidelines shall be followed.

5.3.2 Minimum bend radius

5.3.2.1 Cable

Cable bend radius may vary depending on the cable condition during installation (tensile load) and after installation when the cable is at rest (no-load).

The minimum inside bend radius, under no-load or load, for 4-pair balanced twisted-pair cable shall be four-times the cable diameter. For example, a cable diameter of 9 mm (0.354 in) requires a minimum bend radius of 36 mm (1.5 in).

The minimum bend radius, under no-load or load, for multipair cable shall follow the manufacturer's guidelines.

5.3.2.2 Cord cable

The minimum inside bend radius for 4-pair balanced twisted-pair cord cable shall be one-times the cord cable diameter.

5.3.3 Cable termination

5.3.3.1 General

Cables should be terminated with connecting hardware of the same performance (category) or higher. The installed transmission performance of cabling where components of different performance category requirements are used shall be classified by the least-performing component. The category of the installed link should be suitably marked and noted in the administration records.

It is essential to maintain the design performance of connecting hardware when terminated to a balanced twisted-pair cable, and this shall be achieved by terminating the appropriate connecting hardware for that balanced twisted-pair cable in accordance with the connecting hardware manufacturer's instructions. Where no connecting hardware manufacturer's instructions exist, then

the cable geometry shall be maintained as close as possible to the connecting hardware, and its cable termination points and the maximum pair un-twist for the balanced twisted-pair cable termination shall be in accordance with table 1.

Table 1 – Maximum pair un-twist for category cable termination

Category	Maximum pair un-twist mm (in)
3	75 (3)
5e	13 (0.5)
6	13 (0.5)
6A	13 (0.5)

5.3.3.2 Eight-position modular jack pin-pair assignments

Pin/pair assignments shall be as shown in figure 4 or, optionally, per figure 5 if necessary to accommodate certain 8-pin cabling systems. The colors shown are associated with 4-pair cable.

NOTE - The choice of pin/pair assignment designation can be customer specific. For example, see US Federal Government publication NCS, FTR 1090-1997 for US Federal Government installations.

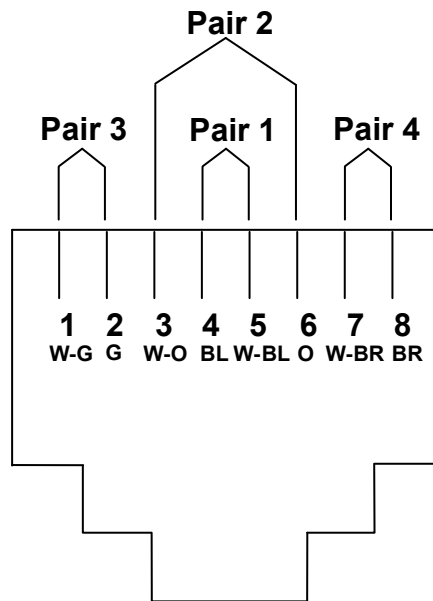


Figure 4 – Front view of eight position jack pin/pair assignments (T568A)

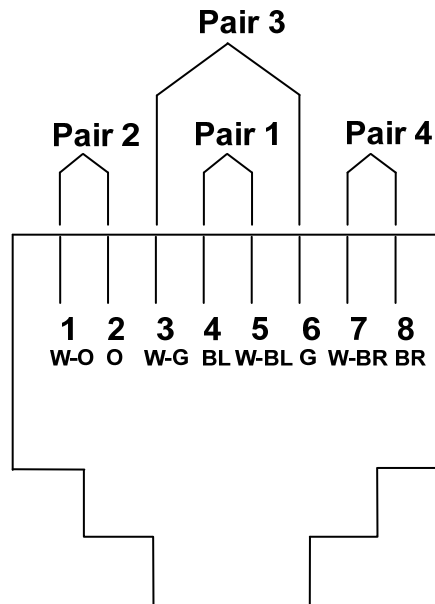


Figure 5 – Front view of optional eight-position jack pin/pair assignment (T568B)

5.3.4 Cords and jumpers

Cross-connect jumpers and modular plug cords should be of the same category or higher as the category of the cabling to which they connect. Due to performance and testing requirements, it is recommended that modular cords be factory manufactured.

5.3.5 Grounding and bonding requirements for screened cabling

Grounding and bonding of the screen and associated connecting hardware shall meet the requirements of this Standard and the manufacturer installation instructions.

Equipment is usually grounded through the equipment power connection. The screen of screened twisted-pair (ScTP) cables shall be bonded to the telecommunications grounding busbar (TGB) or telecommunications main grounding busbar (TMGB). To extend the screen of Cabling Subsystem 1 at the equipment outlet (EO) to the equipment, use an ScTP cord. Voltage of greater than 1.0 V rms between the screen of Cabling Subsystem 1 at the EO and the ground wire of the corresponding electrical outlet expected to provide power to the equipment indicates improper grounding and is not recommended. The bonding and grounding infrastructure should be modified so that this voltage is less than 1.0 V rms.

5.3.6 Separation of power and telecommunications cables

Lack of separation between power and telecommunications cabling may have transmission performance implications. Refer to TIA-569-B for pathway separation from electromagnetic interference (EMI) sources guidelines and the specific premises cabling standard (e.g., those listed in the foreword) for additional performance considerations.

5.3.7 Electrostatic discharge

Electrostatic charges are generated when different materials come into contact and are then separated. This charging effect is made even greater by friction such as the rubbing of two materials together. A good conducting path will allow this stored charge to dissipate rapidly.

Cables can acquire an electrostatic charge during installation when they are unreel from a cable reel, or dragged across a floor. Before connecting equipment to installed cabling, discharge the electrostatic charges to ground.

5.4 Optical fiber cabling

5.4.1 Minimum bend radius and maximum pulling tension

Non-circular cable bend diameter requirements are to be determined using the minor axis as the cable diameter and bending in the direction of the preferential bend. See table 2 for maximum tensile load and minimum bend radius.

Table 2 – Maximum tensile load and minimum bend radius

Cable type and installation details	Maximum tensile load during installation	Minimum bend radii while subjected to	
		maximum tensile load (during installation)	no tensile load (after installation)
Inside plant cable with 2 or 4 fibers installed in Cabling Subsystem 1	220 N (50 lbf)	50 mm (2 in)	25 mm (1 in)
Inside plant cable with more than 4 fibers	Per manufacturer	20-times the cable outside diameter	10-times the cable outside diameter
Indoor/outdoor cable with up to 12 fibers	1335 N (300 lbf)	20-times the cable outside diameter	10-times the cable outside diameter
Indoor/outdoor cable with more than 12 fibers	2670 N (600 lbf)	20-times the cable outside diameter	10-times the cable outside diameter
Outside plant cable	2670 N (600 lbf)	20-times the cable outside diameter	10-times the cable outside diameter
Drop cable installed by pulling	1335 N (300 lbf)	20-times the cable outside diameter	10-times the cable outside diameter
Drop cable installed by directly buried, trenched or blown into ducts	440 N (100 lbf)	20-times the cable outside diameter	10-times the cable outside diameter

5.4.2 Cord cable

Optical fiber cord cable shall have the same fiber type as the optical fiber cabling and meet the requirements of ANSI/TIA-568-C.3.

5.4.3 Polarity

To support bi-directional communication systems that use separate optical fibers in each direction, the cabling system shall provide means to maintain correct signal polarity so that the transmitter on one end of the channel will connect to the receiver on the other end of the channel. Maintaining the correct transmit-to-receive polarity throughout the cabling system is crucial for system operation. annex B describes methods for maintaining polarity.

6 CABLING TRANSMISSION PERFORMANCE AND TEST REQUIREMENTS

6.1 General

Transmission performance depends on cable characteristics, length, connecting hardware, cords, cross-connect wiring, the total number of connections, and the care with which they are installed and maintained. This clause addresses field-test specifications for post-installation performance measurements of cabling.

6.2 Field-test instrument calibration

The test instrument documentation shall include certification of calibration according to the manufacturer's requirements. Additionally, the test instrument shall report the date and time of its current calibration.

6.3 Balanced twisted-pair transmission performance and test requirements

Cabling requirements (permanent link and channel) for category 3 and category 5e 100-ohm balanced twisted-pair cabling are specified in ANSI/TIA/EIA-568-B.1. Cabling requirements (permanent link and channel) for category 6 and category 6A 100-ohm balanced twisted-pair cabling are specified in ANSI/TIA/EIA-568-B.2. For balanced twisted-pair cabling and component transmission performance, and associated field test equipment requirements, see ANSI/TIA/EIA-568-B.2.

6.4 Optical fiber transmission performance and test requirements

6.4.1 General

This clause contains the performance measurement specifications for field testing premises optical fiber cabling. See annex E for guidelines when field-testing length, loss and polarity of optical fiber cabling.

6.4.2 Field-test instruments

6.4.2.1 Multimode

Field-test instruments for multimode fiber cabling shall meet the requirements of TIA-526-14-A. The light source shall meet the launch requirements of ANSI/TIA-455-78B. This launch condition can be achieved either within the field-test instrument or by use of an external mandrel wrap with a Category 1 light source.

When using a mandrel wrap, the source reference jumper should be wrapped in five non-overlapping turns around a smooth round mandrel (rod) during the reference calibration of the source to the detector and for all loss measurements. The mandrel diameter size is dependent upon the fiber core size and shall be chosen as specified in table 3.

Table 3 – Acceptable mandrel diameters for common multimode cable types (five wraps)

Fiber core/cladding size (µm)	900 µm buffered fiber mm (in)	2.0 mm jacketed cable mm (in)	2.4 mm jacketed cable mm (in)	3.0 mm jacketed cable mm (in)
50/125	25 (0.98)	23 (0.91)	23 (0.91)	22 (0.87)
62.5/125	20 (0.79)	18 (0.71)	18 (0.71)	17 (0.67)

NOTE – The mandrel diameters are based on nominal values of 20 mm (0.79 in) and 25 mm (0.98 in)) reduced by the cable diameter and rounded up.

6.4.2.2 Single-mode

Field test instruments for single-mode fiber cabling shall meet the requirements of TIA-526-7.

6.4.3 Link segment performance measurements**6.4.3.1 General**

Link attenuation is measured using the reference methods specified by TIA-526-14-A for multimode and TIA-526-7 for single-mode. The one cord reference method is preferred for both multimode and single-mode. Other methods as detailed in the above standards may be applied. Test documentation should include the test method applied.

Link attenuation does not include any active devices or passive devices other than cable, connectors, and splices (i.e., link attenuation does not include such devices as optical bypass switches, couplers, repeaters or optical amplifiers).

6.4.3.2 Cabling Subsystem 1 link segment

Cabling Subsystem 1 link segments need to be tested in one direction at one wavelength, either 850 nm or 1300 nm for multimode, and either 1310 nm or 1550 nm for single-mode.

6.4.3.3 Cabling Subsystem 2 and Cabling Subsystem 3 link segment

Cabling Subsystem 2 and Cabling Subsystem 3 link segments shall be tested in at least one direction at both operating wavelengths to account for attenuation differences associated with wavelength. Cabling Subsystem 2 and Cabling Subsystem 3 multimode link segments shall be tested at 850 nm and 1300 nm. Cabling Subsystem 2 and Cabling Subsystem 3 single-mode link segments shall be tested at 1310 nm and 1550 nm.

6.4.3.4 Link attenuation allowance calculation

The link attenuation allowance is calculated as:

$$\begin{aligned} \text{Link Attenuation Allowance (dB)} &= \text{Cable Attenuation Allowance (dB)} + \text{Connector} \\ &\text{Insertion Loss Allowance (dB)} + \text{Splice Insertion Loss Allowance (dB)} \end{aligned} \quad (1)$$

where:

$$\text{Cable Attenuation Allowance (dB)} = \text{Maximum Cable Attenuation Coefficient (dB/km)} \times \text{Length (km)}$$

$$\text{Connector Insertion Loss Allowance (dB)} = \text{Number of Connector Pairs} \times \text{Connector Loss Allowance (dB)}$$

$$\text{Splice Insertion Loss Allowance (dB)} = \text{Number of Splices} \times \text{Splice Loss Allowance (dB)}$$

NOTE – Component loss allowances are provided in ANSI/TIA-568-C.3.

ANNEX A (NORMATIVE) CENTRALIZED OPTICAL FIBER CABLING

This annex is normative and is considered part of this Standard.

A.1 General

Centralized optical fiber cabling is intended for users who desire to deploy centralized electronics. Centralized cabling provides connections from the equipment outlet to centralized cross-connects by allowing the use of pull-through cables (continuous sheath cables), an interconnect, or a splice (see figure 6).

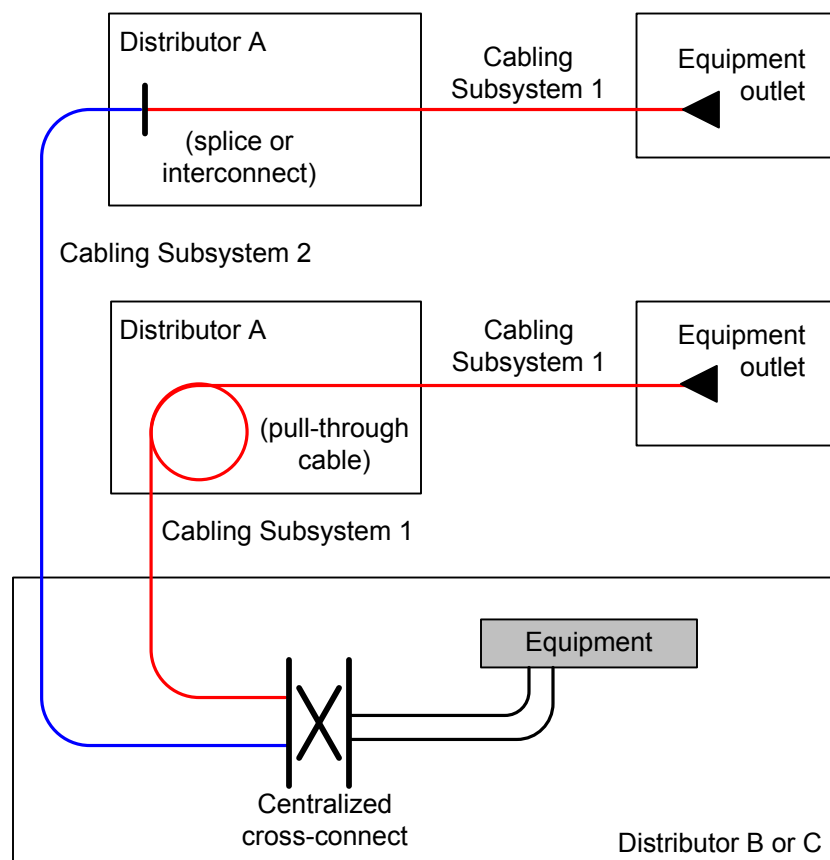


Figure 6 – Illustration of centralized optical fiber cabling

A.2 Implementation

Implementation of centralized cabling shall be within the same building as the areas served.

Centralized cabling design shall allow for migration (in part or in total) of the pull-through, interconnect, or splice implementation to a cross-connection implementation. The design 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.

ANNEX B (NORMATIVE) MAINTAINING OPTICAL FIBER POLARITY

B.1 General

Several methods are used to maintain polarity for optical fiber cabling systems. The guidelines described and illustrated in this annex are separated into clauses to portray duplex connector systems and array connector systems. Following one duplex polarity method and one array polarity method consistently will simplify channel connectivity in an installation.

Optical fiber cable shall be color-coded or marked as specified in ANSI/TIA-598-C. For illustrative purposes, the figures throughout this document depict the 568SC duplex connector and the 12-position MPO array connector. Other connector types are permitted, provided the fiber ordering arrangement is maintained relative to the plug's keying features, as shown in the figures.

B.2 Component descriptions

Component requirements for duplex and array connector systems, as described in this clause, are specified in ANSI/TIA-568-C.3.

B.3 Duplex polarity systems

B.3.1 General

The two positions of the 568SC connector and adapter shall be identified as Position A and Position B as specified in ANSI/TIA-568-C.3. Alternative connector designs shall employ similar labeling and identification schemes to that of the 568SC. For alternative connector designs utilizing latches, the latch defines the positioning in the same manner as the key and keyways of the 568SC connector. Labeling may be either field or factory installed. Duplex systems shall use A-to-B patch cords illustrated in figure 7.

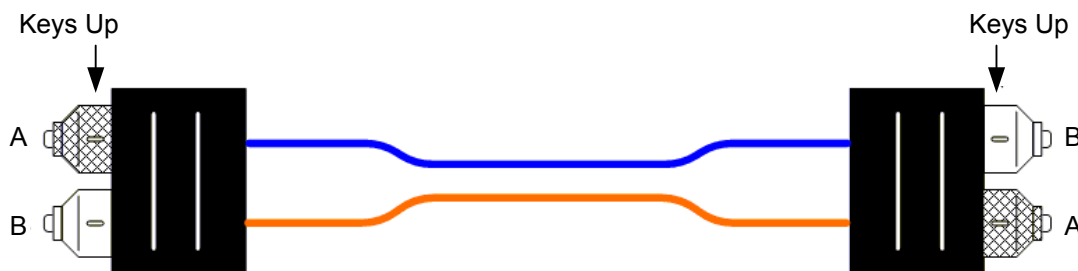


Figure 7 – A-to-B duplex optical fiber patch cord

Fibers shall be grouped in pairs following the color-coding or numbering sequence specified in ANSI/TIA-598-C. The pairs form 2-fiber transmission paths that shall be associated with Position A and Position B of a duplex adapter at each end of the cable. The first fiber of a pair shall be attached to Position A at one end and Position B at the other end. The second fiber of the pair shall be attached to Position B at one end and Position A at the other end.

Two methods of implementation are defined for these requirements. One is called consecutive-fiber positioning and the other is called reverse-pair positioning.

B.3.2 Consecutive-fiber positioning

Consecutive-fiber positioning shall be implemented by installing the adapters in opposite orientations on each end of the link (i.e., A-B, A-B... on one end and B-A, B-A... on the other) and then attaching fibers to the adapters in consecutive order (i.e., 1,2,3,4...) on both ends. This implementation is illustrated in figure 8 and figure 9.

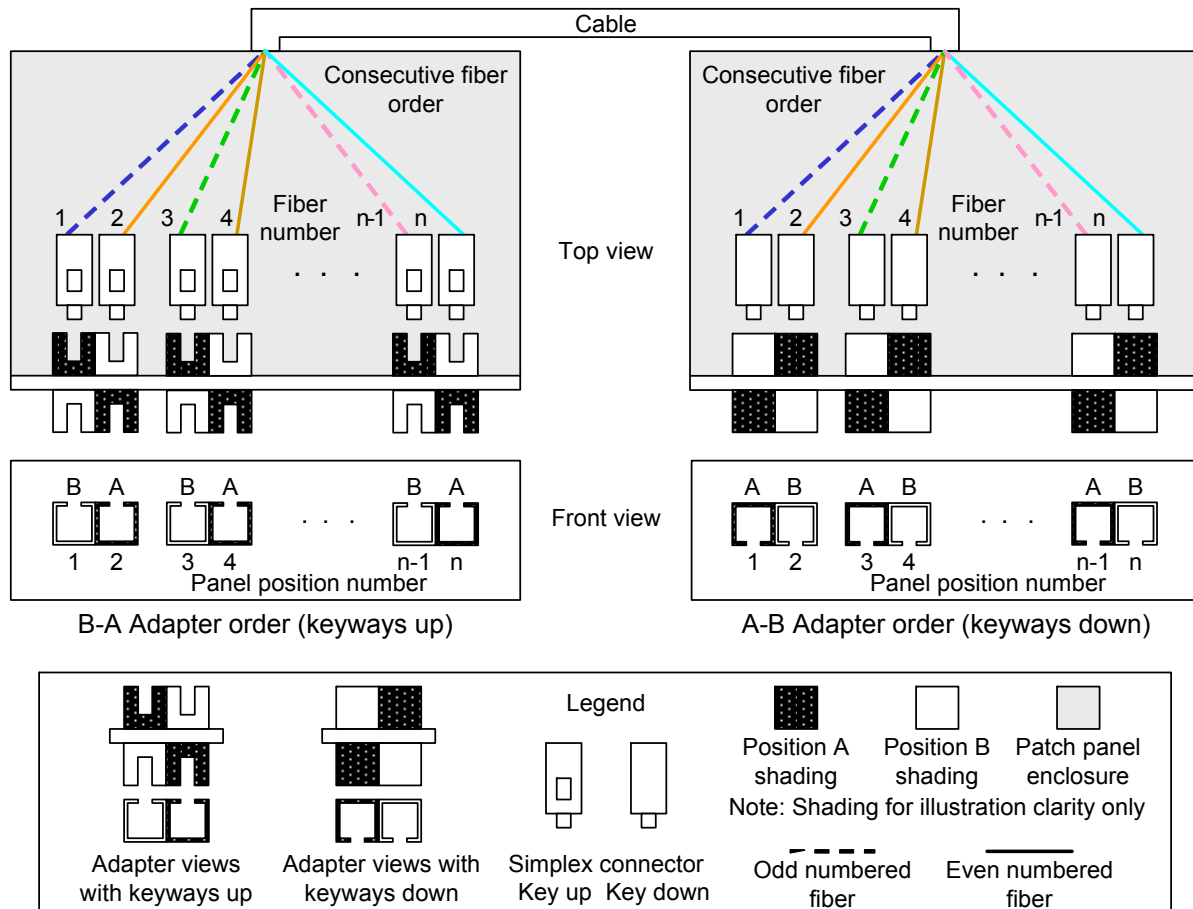


Figure 8 – Consecutive-fiber positioning shown with horizontally mounted hardware

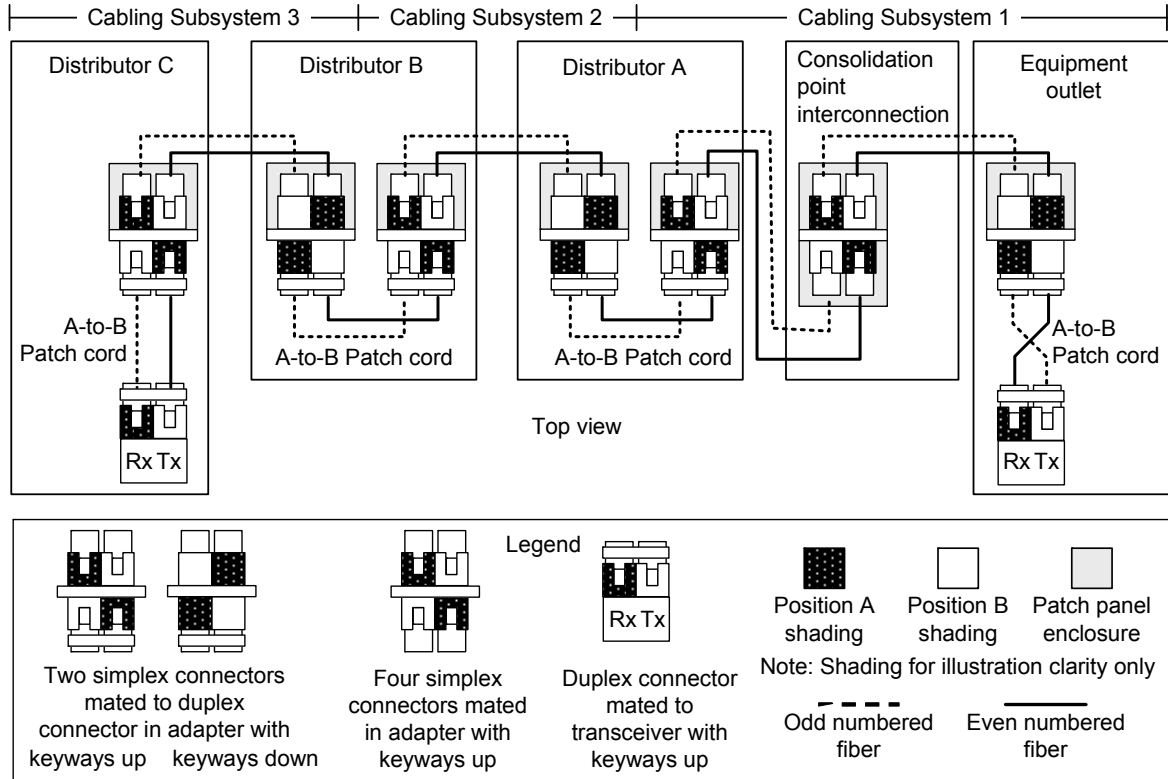


Figure 9 – Consecutive-fiber positioning cabling system example shown with horizontally mounted hardware

B.3.3 Reverse-pair positioning

Reverse-pair positioning shall be implemented by installing the adapters in the same orientation on each end of the link (i.e., A-B, A-B... or B-A, B-A...) and then attaching fibers to the adapters in consecutive order (i.e., 1,2,3,4...) on one end and in reverse-pair order (i.e., 2,1,4,3...) on the other end. This implementation is illustrated in figure 10 and figure 11.

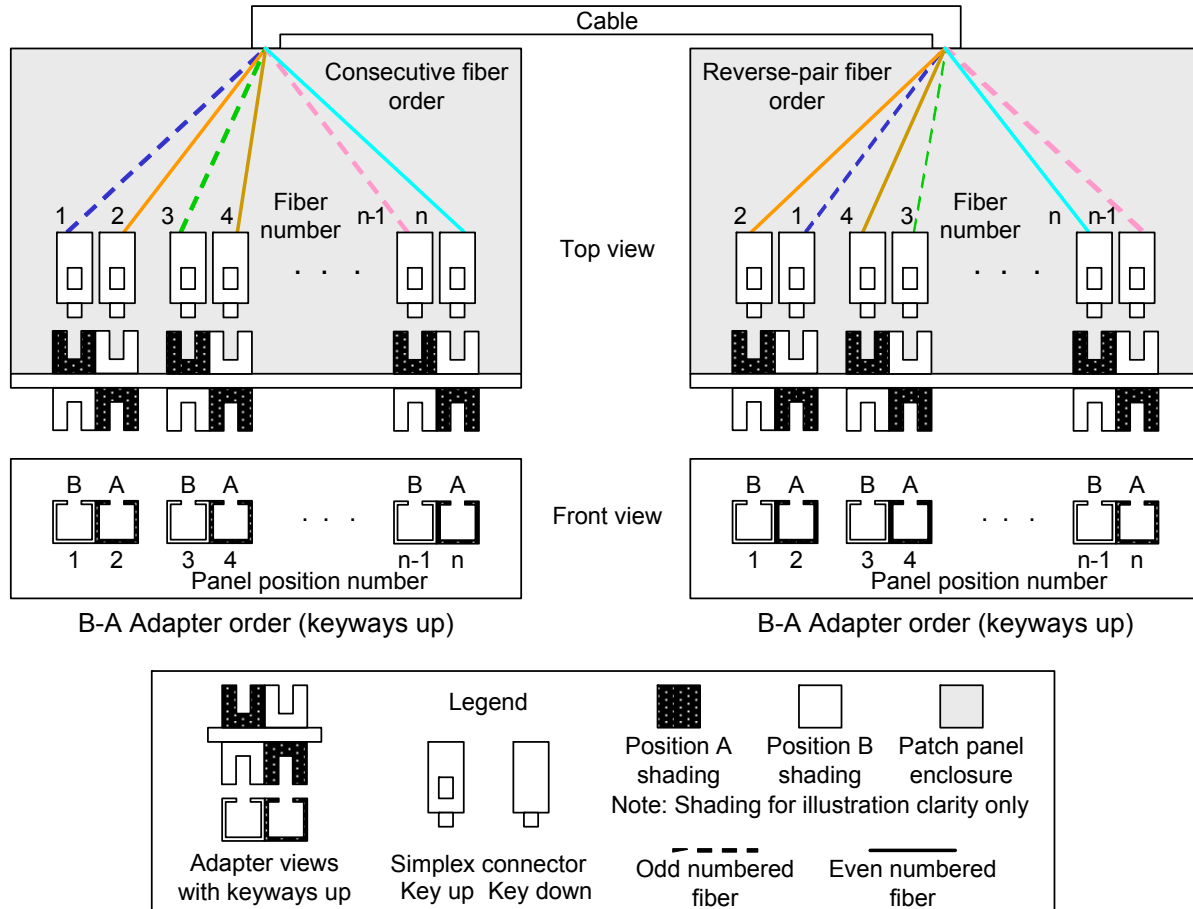


Figure 10 – Reverse-pair positioning shown with horizontally mounted hardware

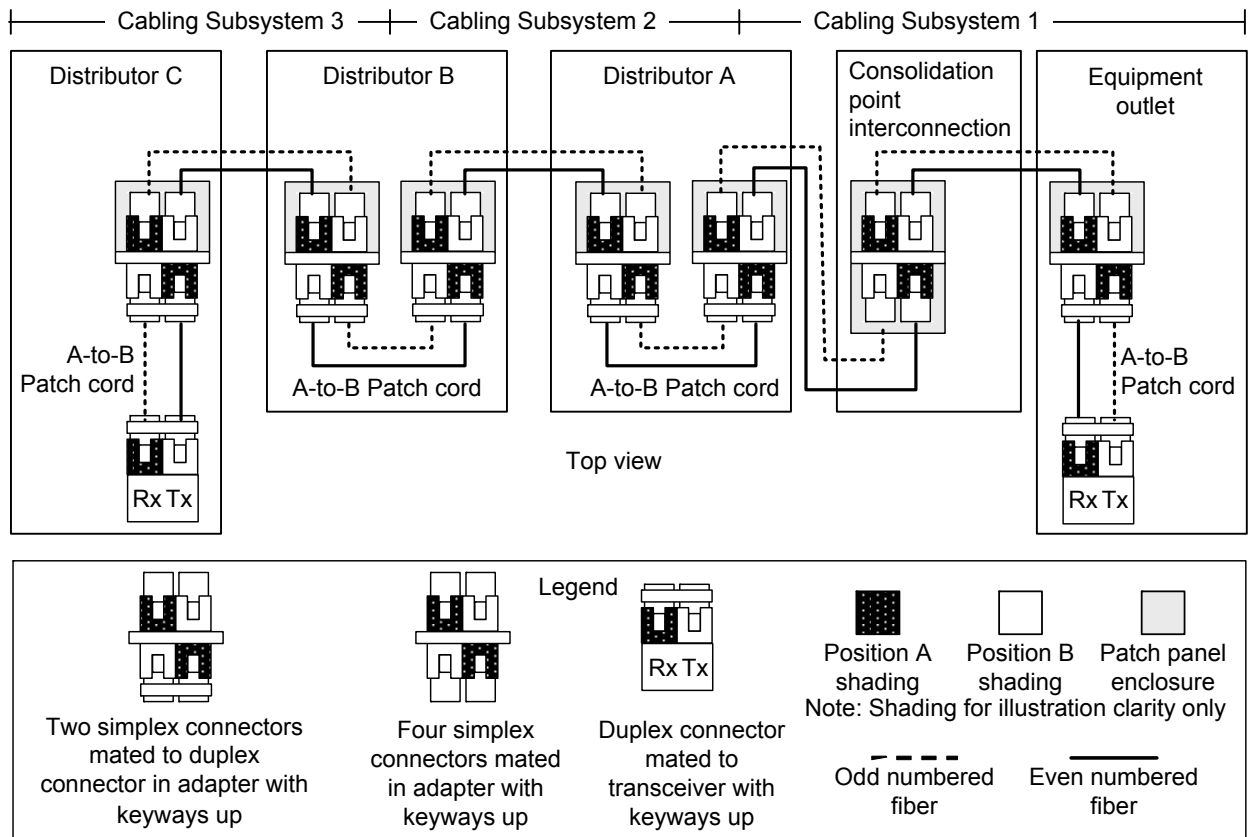


Figure 11 – Reverse-pair positioning cabling system example shown with horizontally mounted hardware

B.4 Array polarity systems

B.4.1 General

All array connectivity methods have the same goal: to create an optical path from the transmit port of one device to the receive port of another device. Different methods to accomplish this goal may be implemented; however these different methods may not be interoperable. It is recommended that a method be selected in advance and maintained consistently throughout an installation. While many methods are available to establish polarity, this Standard outlines sample methods that may be employed for array cabling systems where the connectors have one row of fibers only. For convenience, these sample methods are referred to as Methods A, B, and C. No preference or priority is implied by this notation.

Any connectivity method requires a specific combination of components to maintain polarity. Some of the components may be common to other connectivity methods. The components associated with the three illustrated array polarity methods are given in table 4 and table 5.

Table 4 – Summary of components used for duplex signals

Connectivity method	Array connector cable Type	Array adapter Type	Duplex patch cord type
A	A	A	One A-to-B and one A-to-A per duplex channel
B	B	B	A-to-B
C	C	A	A-to-B

Table 5 – Summary of components used for parallel signals

Connectivity method	Array connector cable Type	Array adapter Type	Array patch cord type
A	A	A	One Type-A and one Type-B
B	B	B	Type-B

Parallel optical fiber links integrate multiple transmitters in one transmitter module, multiple fibers in fiber array connectors, and multiple receivers in one receiver module. Multiple transmitters and receivers may also be integrated together in a transceiver module.

When mating connectors that use alignment pins (e.g., MPO, MT-RJ), it is critical that one plug is pinned and the other plug is unpinned. The pinned connector is typically located inside the panel (i.e., the fixed connector is pinned and the connector that is frequently removed and handled is unpinned). As MPO and MT-RJ transceivers typically have pins, this convention leads to the following implementation on initial build out:

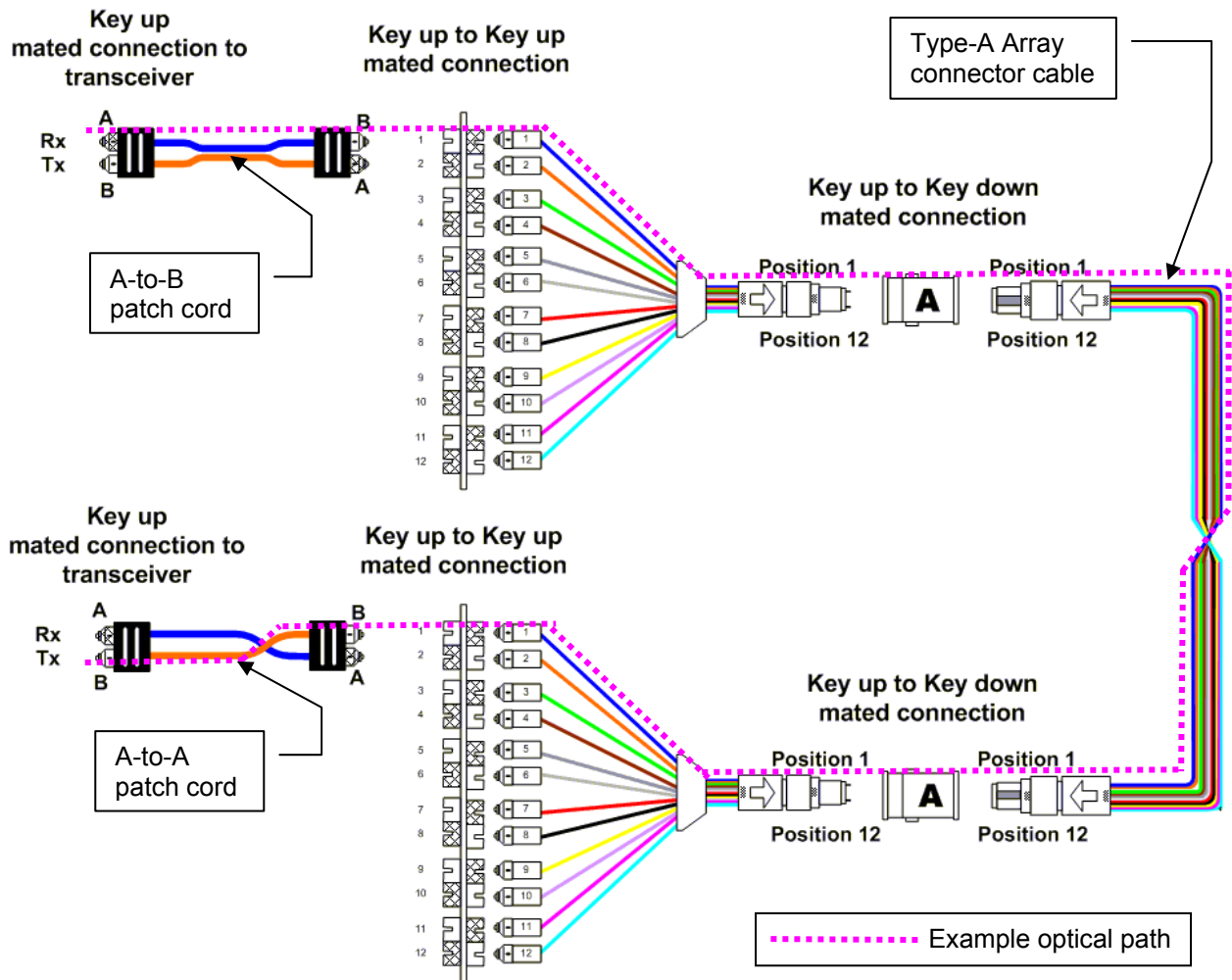
- Patch cords from transceiver to panel are typically unpinned on both ends.
- Transitions (mounted behind the panel) are typically pinned.
- Cables from rack to rack are typically unpinned on both ends.

B.4.2 Connectivity Method A

B.4.2.1 Connectivity Method A for duplex signals

Figure 12 illustrates connectivity Method A for duplex signals.

When connecting multiple duplex optical transceiver ports, the Type-A backbone (composed of one or many Type-A array connector cables mated in Type-A adapters) is connected on each end to a transition. On one end of the optical link, A-to-B patch cords are used to connect ports on the transition to their respective duplex transceiver ports. On the other end of the optical link, A-to-A patch cords are used to connect ports on the transition to their respective duplex transceiver ports. In each duplex optical path there shall be one A-to-A patch cord.



NOTE – The Type-A cable is illustrated with a twist.

Figure 12 – Connectivity Method A for duplex signals

B.4.2.2 Connectivity Method A for parallel signals

Figure 13 illustrates connectivity Method A for parallel signals.

When connecting arrays for parallel signals, the Type-A backbone (composed of one or many Type-A array connector cables mated in Type-A adapters) is connected on each end to a patch panel. On one end of the optical link, a Type-A array patch cord is used to connect patch panel ports to their respective parallel transceiver ports. On the other end of the optical link, a Type-B array patch cord is used to connect panel ports to their respective parallel transceiver ports. In each optical path there shall be only one Type-B array patch cord.

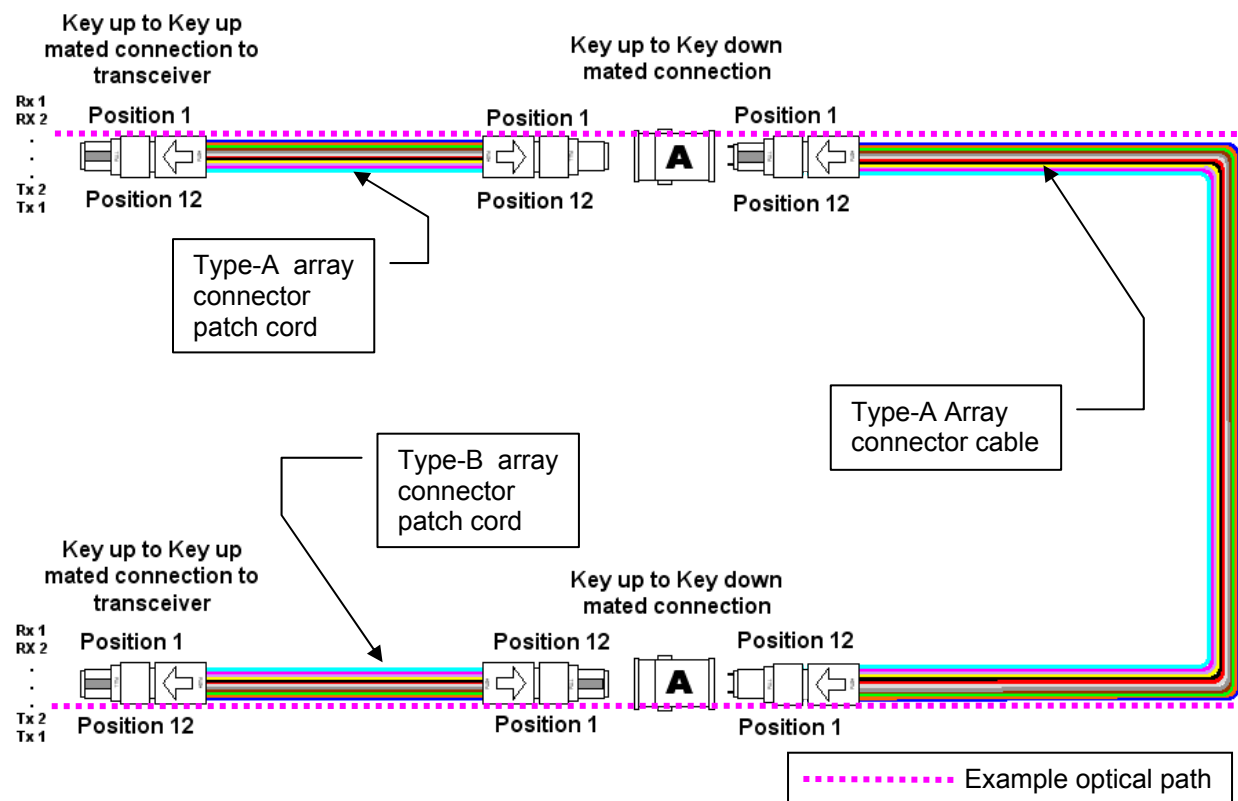


Figure 13 – Connectivity Method A for parallel signals

B.4.3 Connectivity Method B

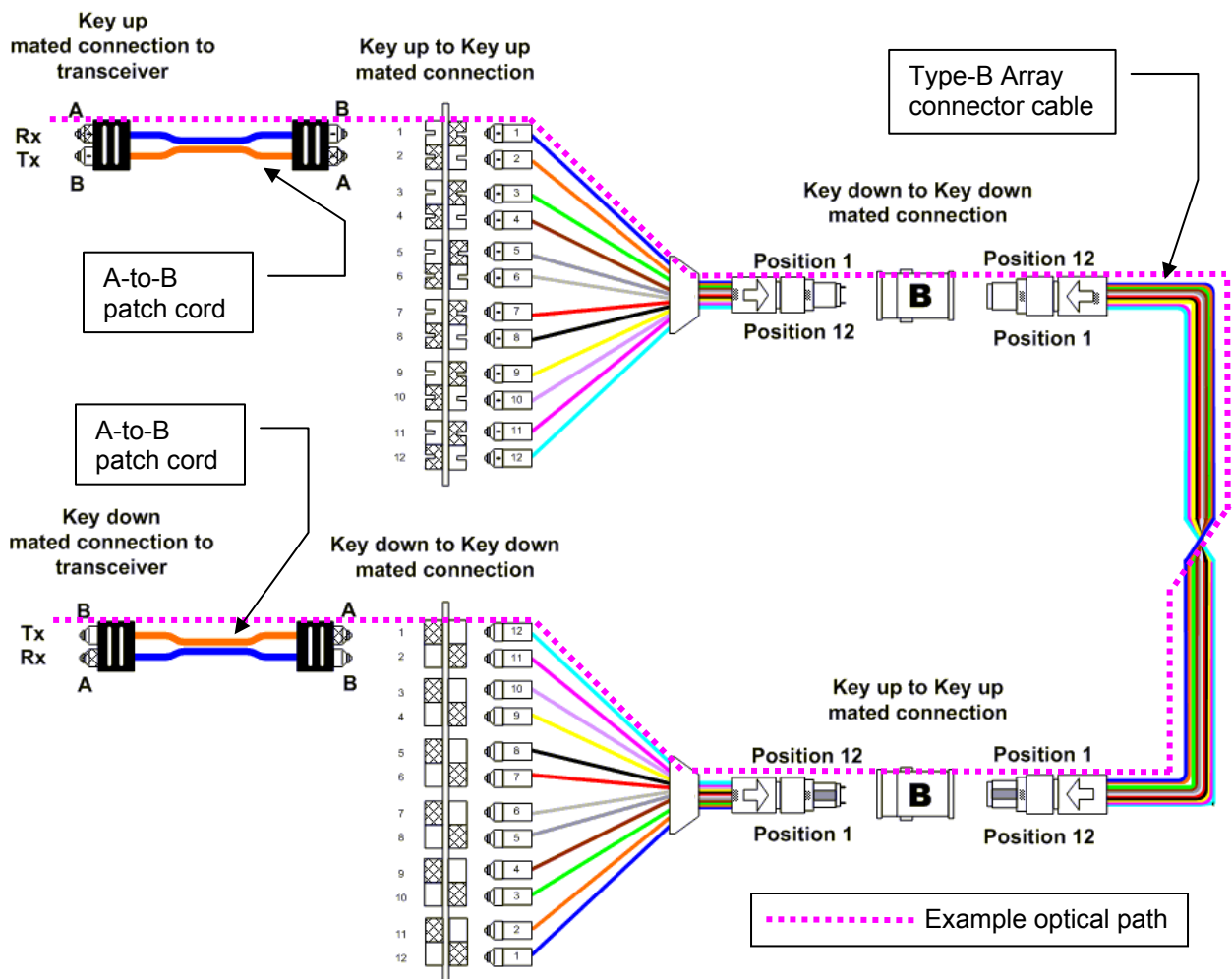
B.4.3.1 General

MPO connectors shall be be 0° contact angle (or “flat”) when connectivity Method B is deployed.

B.4.3.2 Connectivity Method B for duplex signals

Figure 14 illustrates connectivity Method B for duplex signals.

When connecting multiple duplex optical transceiver ports, the Type-B backbone (composed of one or many Type-B array connector cables mated in Type-B adapters) is connected on each end to a transition. The transitions are mounted in two orientations such that their duplex adapter key orientation on one end of the backbone is rotated 180-degrees relative to their adapter key orientation on the other end of the backbone. For example, one transition is installed with keyways up and the other with keyways down. A-to-B patch cords are then used to connect ports on the transition to their respective duplex transceiver ports.



NOTES

1 – The Type-B cable is illustrated with a twist.

2 – For ease of illustration, the lower transceiver connection is shown inverted (key down); the transceiver would be mounted key up as normal.

Figure 14 – Connectivity Method B for duplex signals

B.4.3.3 Connectivity Method B for parallel signals

Figure 15 illustrates connectivity Method B for parallel signals.

When connecting parallel signals, the Type-B backbone (composed of one or many Type-B array connector cables mated in Type-B adapters) is connected on each end to a patch panel. Type-B array patch cords are then used to connect the patch panel ports to their respective parallel transceiver ports.

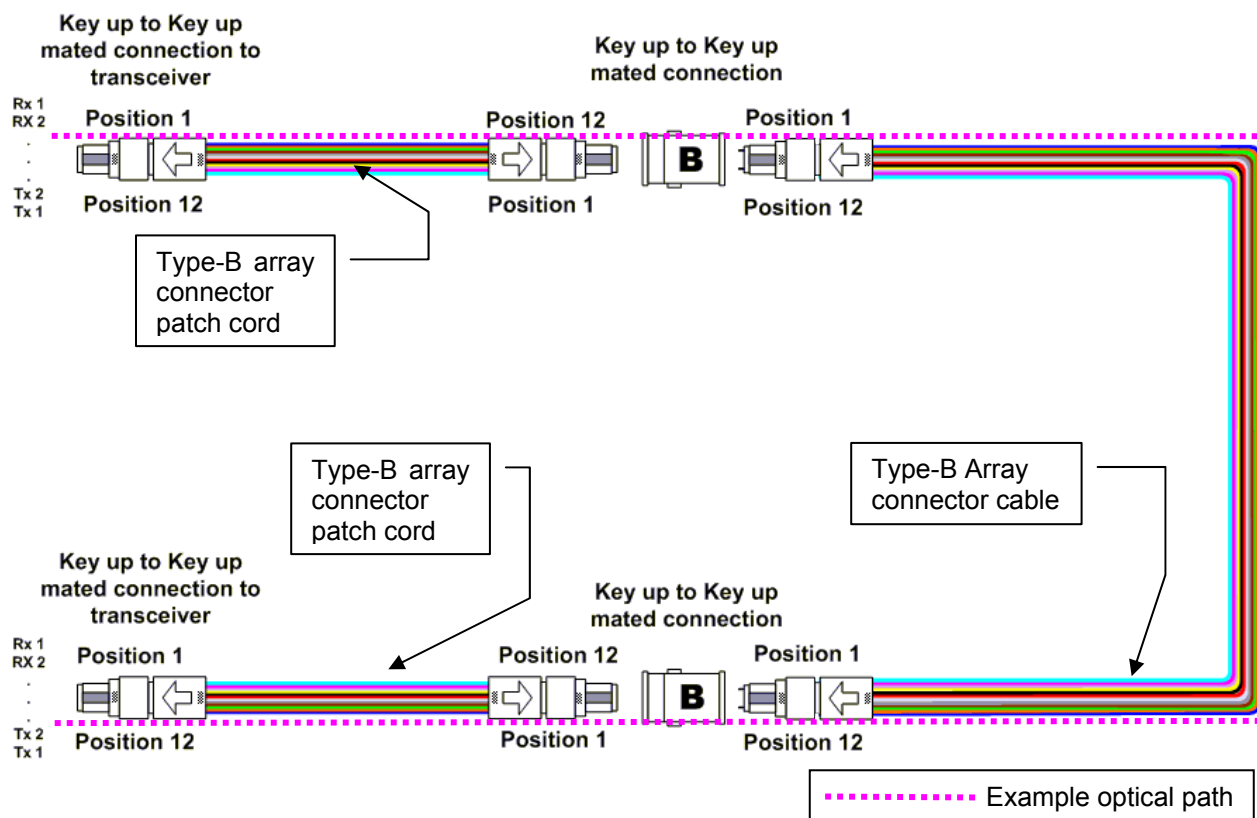
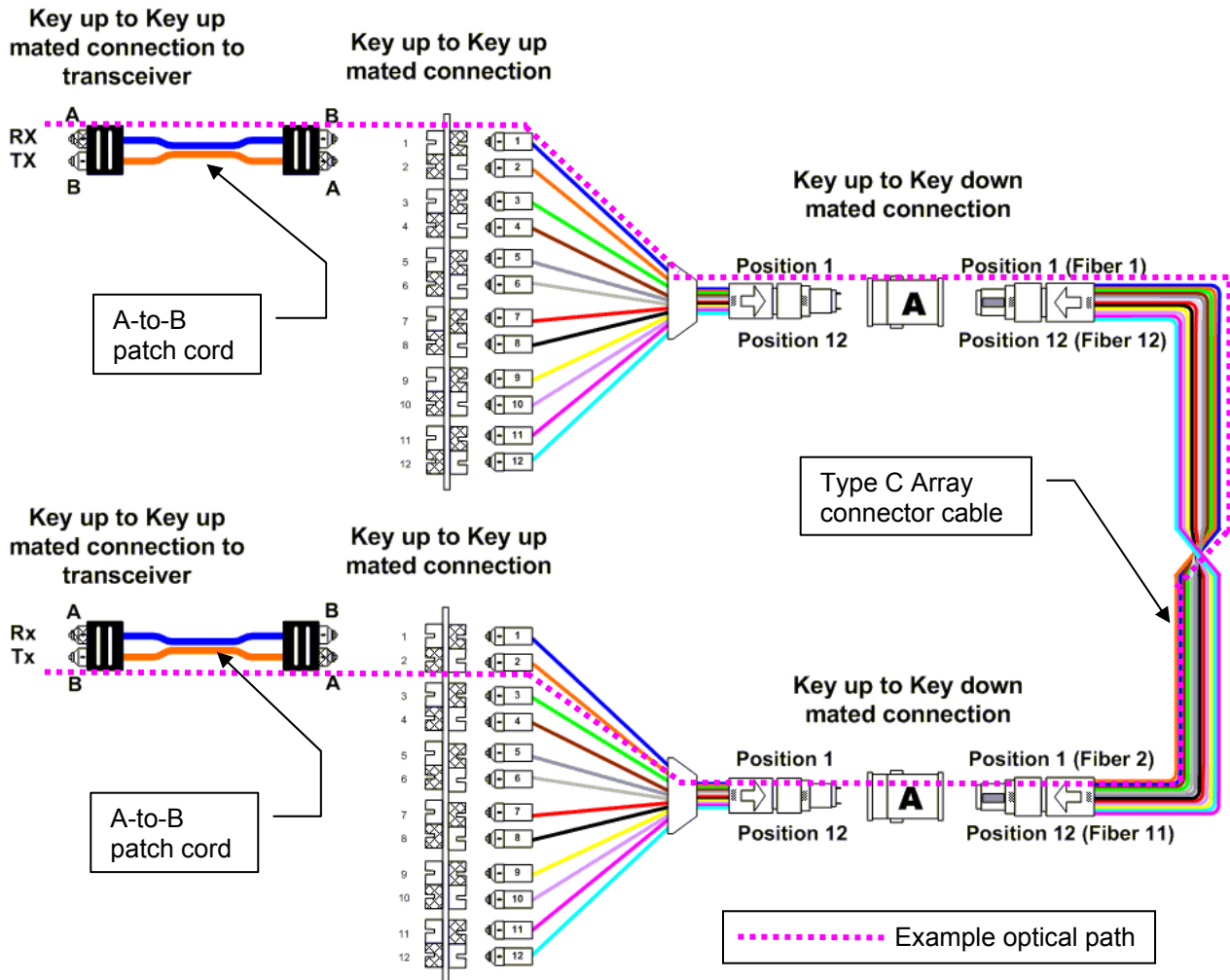


Figure 15 – Connectivity Method B for parallel signals

B.4.4 Connectivity Method C for duplex signals

Figure 16 illustrates connectivity Method C for duplex signals.

When connecting multiple duplex optical transceiver ports, one and only one Type-C array connector cable is connected on each end to a transition. A Type-C array connector cable uses reverse pair positioning so that on one end the fiber strands are 1,2,3,4... while at the other end, the fiber strands are 2,1,4,3...for proper polarity. A-to-B patch cords are then used to connect ports on the transition to their respective duplex transceiver ports.



NOTE – The Type-C cable is illustrated with a twist.

Figure 16 – Connectivity Method C for duplex signals

ANNEX C (INFORMATIVE) MULTI-TENANT CABLING SUBSYSTEM 2 AND CABLING SUBSYSTEM 3

This annex is informative and not part of this Standard.

C.1 General

Responsibility and ownership of multi-tenant Cabling Subsystem 2, Cabling Subsystem 3 or both may vary by region. It is incumbent on the owner to become familiar with local conditions before making relevant decisions.

C.2 Existing Cabling Subsystem 2, Cabling Subsystem 3, or both cabling

Existing Cabling Subsystem 2, Cabling Subsystem 3, or both cabling may be owned and administered by an access provider, or by the building owner or their agents depending upon regulatory conditions. In some locations, ownership and responsibility for the cabling has been transferred to the building owner or their agents. In other localities, the ownership and responsibility for the cabling has been retained by the entity that installed the cable.

C.3 New Cabling Subsystem 2, Cabling Subsystem 3, or both cabling

Ownership of new multi-tenant Cabling Subsystem 2, Cabling Subsystem 3, or both is determined at the time that the decision is made to build, and may be constrained by regulatory conditions.

When the decision is made to deploy a multi-tenant Cabling Subsystem 2, Cabling Subsystem 3, or both, the selection of media type should be based on the following criteria:

- User type (e.g., residential, commercial) – initial and forecast
- Frequency of tenant changes
- Applications supported – initial and forecast
- Design
- Cabling distances

The deployment of an appropriate range of media types is recommended.

New multi-tenant Cabling Subsystem 2, Cabling Subsystem 3, or both will typically serve tenant needs for many years. They should be sized to accommodate anticipated growth in user demand, and in a configuration that supports the limitations and requirements of the anticipated medium.

See annex D for application support information regarding media types.

ANNEX D (INFORMATIVE) APPLICATION SUPPORT INFORMATION

This annex is informative and not part of this Standard.

D.1 General

This clause provides information regarding applications support for many of the available applications across media types recognized in this Standard. This compilation allows the user to easily access enough basic information to make informed decisions about media choices and system design. With a predetermined knowledge of the required distances, the anticipated applications, and the cabling system design, the user can determine the most appropriate media for their needs. Still, this information is not intended to constitute a design guideline. Application standards and cabling system manufacturers should be consulted to establish complete requirements and capabilities of specific cabling alternatives.

NOTE – Premises standards may impose distance limitations shorter than those listed due to the scope of the standard.

D.2 Balanced twisted-pair cabling supportable distances

Table 6 lists maximum supportable distances for applications using copper cabling. The table is based on the minimum performance requirements of specific balanced twisted-pair cabling established by ANSI/TIA/EIA-568-B.2. Applications are identified using both industry standard and common names.

Table 6 – Maximum supportable distances for balanced twisted-pair cabling applications

Application	Media	Distance m (ft)	Comments
Ethernet 10BASE-T	category 3, 5e, 6, 6A	100 (328)	
Ethernet 100BASE-TX	category 5e, 6, 6A	100 (328)	
Ethernet 1000BASE-T	category 5e, 6, 6A	100 (328)	
Ethernet 10GBASE-T	category 6A	100 (328)	
ADSL	category 3, 5e, 6, 6A	5,000 (16404)	1.5 Mb/s to 9 Mb/s
VDSL	category 3, 5e, 6, 6A	5,000 (16404)	1500 m (4900 ft) for 12.9 Mb/s; 300 m (1000 ft) for 52.8 Mb/s
Analog Phone	category 3, 5e, 6, 6A	800 (2625)	
FAX	category 3, 5e, 6, 6A	5,000 (16404)	
ATM 25.6	category 3, 5e, 6, 6A	100 (328)	
ATM 51.84	category 3, 5e, 6, 6A	100 (328)	
ATM 155.52	category 5e, 6, 6A	100 (328)	
ATM 1.2G	category 6, 6A	100 (328)	
ISDN BRI	category 3, 5e, 6, 6A	5,000 (16404)	128 kb/s
ISDN PRI	category 3, 5e, 6, 6A	5,000 (16404)	1.472 Mb/s

D.3 Optical fiber cabling supportable distances

Table 7 lists maximum supportable distances and maximum channel attenuation for applications using optical fiber cabling. The table is based on the minimum performance requirements of 62.5/125 μm , 50/125 μm , 850 nm laser-optimized 50/125 μm , and single-mode fiber established by ANSI/TIA-568-C.3. Applications are identified using industry standard names.

Table 7 – Maximum supportable distances and attenuation for optical fiber applications by fiber type

		Multimode						Single-mode	
		62.5/125 μm TIA 492AAAA (OM1)		50/125 μm TIA 492AAAB (OM2)		850 nm laser- optimized 50/125 μm TIA 492AAAC (OM3)		TIA 492CAAA (OS1)	TIA 492CAAB (OS2)
Application	Parameter Nominal wavelength (nm)	850	1300	850	1300	850	1300	1310	1550
Ethernet 10/100BASE-SX	Channel attenuation (dB)	4.0	-	4.0	-	4.0	-	-	-
	Supportable distance m (ft)	300 (984)	-	300 (984)	-	300 (984)	-	-	-
Ethernet 100BASE-FX	Channel attenuation (dB)	-	11.0	-	6.0	-	6.0	-	-
	Supportable distance m (ft)	-	2000 (6560)	-	2000 (6560)	-	2000 (6560)	-	-
Ethernet 1000BASE-SX	Channel attenuation (dB)	2.6	-	3.6	-	4.5	-	-	-
	Supportable distance m (ft)	275 (900)	-	550 (1804)	-	800 (2625)	-	-	-
Ethernet 1000BASE-LX	Channel attenuation (dB)	-	2.3	-	2.3	-	2.3	4.5	-
	Supportable distance m (ft)	-	550 (1804)	-	550 (1804)	-	550 (1804)	5000 (16405)	-
Ethernet 10GBASE-S	Channel attenuation (dB)	2.4	-	2.3	-	2.6	-	-	-
	Supportable distance m (ft)	33 (108)	-	82 (269)	-	300 (984)	-	-	-
Ethernet 10GBASE-LX4	Channel attenuation (dB)	-	2.5	-	2.0	-	2.0	6.3	-
	Supportable distance m (ft)	-	300 (984)	-	300 (984)	-	300 (984)	10000 (32810)	-
Ethernet 10GBASE-L	Channel attenuation (dB)	-	-	-	-	-	-	6.2	-
	Supportable distance m (ft)	-	-	-	-	-	-	10000 (32810)	-
Ethernet 10GBASE-LRM	Channel attenuation (dB)	-	1.9	-	1.9	-	1.9	-	-
	Supportable distance m (ft)	-	220 (720)	-	220 (720)	-	220 (720)	-	-
Fibre Channel 100-MX-SN-I (1062 Mbaud)	Channel attenuation (dB)	3.0	-	3.9	-	4.6	-	-	-
	Supportable distance m (ft)	300 (984)	-	500 (1640)	-	860 (2822)	-	-	-

Table 7 (Concluded)

		Multimode						Single-mode	
		62.5/125 μm TIA 492AAAA (OM1)		50/125 μm TIA 492AAAB (OM2)		850 nm laser- optimized 50/125 μm TIA 492AAAC (OM3)		TIA 492CAAA (OS1)	TIA 492CAAB (OS2)
	Parameter								
Application	Nominal wavelength (nm)	850	1300	850	1300	850	1300	1310	1550
Fibre Channel 100-SM-LC-L (1062 Mbaud)	Channel attenuation (dB)	-	-	-	-	-	-	7.8	-
	Supportable distance m (ft)	-	-	-	-	-	-	10000 (32810)	-
Fibre Channel 200-MX-SN-I (2125 Mbaud)	Channel attenuation (dB)	2.1	-	2.6	-	3.3	-	-	-
	Supportable distance m (ft)	150 (492)	-	300 (984)	-	500 (1640)	-	-	-
Fibre Channel 200-SM-LC-L (2125 Mbaud)	Channel attenuation (dB)	-	-	-	-	-	-	7.8	-
	Supportable distance m (ft)	-	-	-	-	-	-	10000 (32810)	-
Fibre Channel 400-MX-SN-I (4250 Mbaud)	Channel attenuation (dB)	1.8	-	2.1	-	2.5	-	-	-
	Supportable distance m (ft)	70 (230)	-	150 (492)	-	270 (886)	-	-	-
Fibre Channel 400-SM-LC-L (4250 Mbaud)	Channel attenuation (dB)	-	-	-	-	-	-	7.8	-
	Supportable distance m (ft)	-	-	-	-	-	-	10000 (32810)	-
Fibre Channel 1200-MX-SN-I (10512 Mbaud)	Channel attenuation (dB)	2.4	-	2.2	-	2.6	-	-	-
	Supportable distance m (ft)	33 (108)	-	82 (269)	-	300 (984)	-	-	-
Fibre Channel 1200-SM-LL-L (10512 Mbaud)	Channel attenuation (dB)	-	-	-	-	-	-	6.0	-
	Supportable distance m (ft)	-	-	-	-	-	-	10000 (32810)	-
FDDI PMD ANSI X3.166	Channel attenuation (dB)	-	11.0	-	6.0	-	6.0	-	-
	Supportable distance m (ft)	-	2000 (6560)	-	2000 (6560)	-	2000 (6560)	-	-
FDDI SMF-PMD ANSI X3.184	Channel attenuation (dB)	-	-	-	-	-	-	10.0	-
	Supportable distance m (ft)	-	-	-	-	-	-	10000 (32810)	-

ANNEX E (INFORMATIVE) GUIDELINES FOR FIELD-TESTING LENGTH, LOSS AND POLARITY OF OPTICAL FIBER CABLING

E.1 General

Accurate characterization and testing of installed optical fiber cabling is crucial to ensuring overall network integrity and performance. An optical fiber cabling link may consist of a fiber or concatenated fibers (spliced, cross-connected or interconnected) with a connector or adapter on each end. The fiber type, link length, the number and quality of terminations and splices, cable stresses, and wavelength can all affect attenuation measurements. For example, link attenuation can be negatively influenced by severe cable bends, poorly installed connectors or even the presence of dirt on the endface of connectors. The attenuation measurement result should always be less than the designed link attenuation allowance (also known as loss budget) that is based on the number of terminations, the number of splices and cable length. Documenting the test results provides the information that demonstrates the acceptability of the cabling system or support of specific networking technologies.

Testing installed optical fiber cabling for attenuation with an optical loss test set (OLTS), as described in cabling standards, and verifying the cabling length and polarity constitutes Tier 1 testing. Tier 2 testing, which is optional, includes the Tier 1 tests plus the addition of an optical time domain reflectometer (OTDR) trace. An OTDR trace can be used to characterize the installed fiber link resulting in an indication of the uniformity of cable attenuation and connector insertion loss. See clause E.5 for descriptions of test measurement methods.

Testing conducted on optical fiber cabling should be in accordance with a published standard (see table 7 for examples of applications). This annex describes field-testing of length, optical attenuation and polarity in optical fiber cabling using an OLTS, OTDR and a visible light source such as a visual fault locator (VFL). The purpose of this annex is to clarify, not replace, TIA-526-7 and TIA-526-14-A.

Tier 1 criteria, unless otherwise instructed or requested, constitutes testing in accordance with this annex.

WARNING – All tests performed on optical fiber cabling that use a laser or light emitting diode (LED) in a test set are to be carried out with safety precautions in accordance with ANSI Z136.2.

E.2 Test criteria

E.2.1 General

Optical fiber link attenuation, the optical power loss measured between two points, is a result of the effects of the cable type, cable length and condition, quality and quantity of splices and connectors, and the wavelength of transmission. Cabling designers generally provide the link attenuation allowance criteria for optical fiber links that are eventually installed and tested.

E.2.2 Tier 1

When conducting Tier 1 testing, each optical fiber link is measured for its attenuation with an OLTS. Fiber length verification may be obtained from cable sheath markings or via the OLTS (if the OLTS has length measurement capability). Polarity can be verified with the OLTS while performing attenuation tests. A visible light source, such as a VFL, can also be used to verify polarity.

NOTE – The optical lengths of certain cables (e.g., stranded loose tube) may be longer than the cable sheath due to the fiber lay within the cable sheath.

For multimode cabling, cabling standards describe that attenuation measurements are taken according to TIA-526-14-A, Method B. Additionally, the light source is to meet the launch requirements of ANSI/TIA-455-78B. This launch condition can be achieved either within the field-test

instrument by the manufacturer, or by use of an external mandrel wrap (see table 3 and clause E.7) applied to the source test jumper with a Category 1 Coupled Power Ratio (CPR) light source.

NOTE – Refer to TIA-526-14-A for details on measuring source CPR.

For single-mode cabling, cabling standards describe that attenuation measurements be taken in accordance to TIA-526-7, Method A.1. When performing single-mode attenuation measurements, a single 30 mm (1.2 in) diameter loop applied to the source test jumper is often used to ensure single-mode operation (see ANSI/TIA-455-78B).

NOTE – TIA-526-14-A and TIA-526-7 contain a discussion of three reference methods. The one jumper reference methods (Method B and Method A.1, respectively) provide test results inclusive of the connections made at the test jumpers to the cabling link and all connections and splices that may be within the cabling link. Certain fiber optic connector types, including array connectors, cannot be tested using Method B or Method A.1. In such cases, the two or three jumper methods may be required. Such testing is permitted but the test method should be documented with the measurement results.

Testing can be conducted at one or more wavelengths and in one or both directions. A published standard should be referenced to identify the wavelength(s) and direction(s) required for the test.

The polarity of duplex or multi-fiber cabling systems can be verified to ensure that a transmitter on one end of the fiber connects to a corresponding receiver on the other end. See annex B for information that describes maintaining polarity.

E.2.3 Tier 2 (Optional)

Tier 2 testing supplements Tier 1 testing with the addition of an OTDR trace of the cabling link. The wavelength(s) 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 a fiber link, including fiber segment length, attenuation uniformity and attenuation rate, connector location and insertion loss, splice location and splice loss, and other power loss events such as a sharp bend that may have been incurred during cable installation. The OTDR trace does not replace the need for OLTS testing, but is used for supplemental evaluation of the cabling link.

E.3 Test instruments

E.3.1 General

This clause describes the functional use of the OLTS, OTDR, and visible light source. Although these functions are described as separate instruments, they can be combined into a single test instrument. For example, a VFL can be contained within an OLTS or OTDR to facilitate multi-functional use. Calibration of these instruments should be performed at intervals specified by the manufacturer.

E.3.2 Optical loss test set

The most basic optical fiber measurement is that of received optical power. An OLTS includes an optical power meter to measure received optical power and a light source that closely resembles a system transmitter (e.g., an LED for multimode optical links, a laser for single-mode optical links). An OLTS may be a single instrument or separable optical power meter and light source.

E.3.3 Visible light source

A visible light source is a visible incandescent, LED or laser source used to trace fibers. Applications of using a visible light source include end-to-end continuity verification, identification of connectors in patch panels or outlets, and identification of fibers. One such visible light source is a VFL. The VFL is a visible red laser source (630-665 nm) that, in addition to identifying or tracing cabled fibers, can aid in troubleshooting faults on optical fiber cables. The VFL can often identify breaks or bends in cables (if the jacket is not opaque to the laser), faulty connectors or some types of splices, and other causes of signal loss.

NOTE – A VFL normally uses a Class 2 light source and should not be directly viewed. Safe usage of the tool requires indirect viewing of the light source by pointing the end of the fiber at an adjacent surface (or introducing another surface in front of a fixed mounted connector) until the presence of light is determined.

E.3.4 Optical time domain reflectometer

An OTDR can be used to measure fiber length, to characterize anomalies or damaged areas along installed fiber, and to evaluate uniformity of connections (connectors and splices). An OTDR sends high-powered pulses of light into an optical fiber and measures the strength of the power returned to the instrument as a function of time. This returned power is produced by backscattering of light from the fiber material (Rayleigh scattering) and by changes in the index of refraction at fiber joints. Light pulses injected into the fiber by the OTDR are attenuated outbound and on the return to the OTDR. An OTDR characterizes optical fiber links with a graphical signature (trace) on a display screen, which may be interpreted into a table and subsequently downloaded to a personal computer. The OTDR, by use of movable cursors on the display or software, has the capability to measure the length of the fiber and estimate the power loss between any two points along the optical fiber link.

E.4 Precautions to measurement testing

Several precautions should be taken when measuring the performance of optical fiber cabling. Some of these precautions include:

- Using appropriate mating adapters to interface test jumpers (used with OLTSS) or launch fibers (used with OTDRs) with the cabling and instrumentation.
- Ensuring that all connectors, mating adapters, and test jumpers or launch fibers are clean prior to and during the test measurement.
- Ensuring that all test jumpers are verified per clause E.5.1.2.
- Using test jumpers that are of acceptable quality as they are subject to heavy use. Replace test jumpers when no longer meeting the criteria established in clause E.5.1.2.
- Keeping endface inspection equipment nearby to help ascertain connector quality.
- Ensuring that the power meter and light source are set to the same wavelength.
- Ensuring that optical sources are turned on for sufficient time prior to testing to stabilize per manufacturer recommendations.
- Ensuring that test jumpers and launch fibers are of recommended length for the OLTSS and the OTDR, and are of the same fiber core size as the cable under test (e.g., use 50/125 μm test jumpers with 50/125 μm cable).

NOTE – When an overfilled light launch is transmitted from a 62.5/125 μm fiber into a 50/125 μm fiber, a coupling loss increase of about 4.7 dB is possible.

E.5 Test measurement methods

E.5.1 Optical link attenuation

E.5.1.1 General

The link attenuation of optical fiber cabling, whether multimode or single-mode, should be measured with an OLTS to ensure acceptable overall quality and performance of the installed components. The use of an OLTS requires the use of quality test jumpers, referencing the light source output to an optical power meter, and access to both ends of the cabling under test. The measured cabling attenuation is then compared to the reference for calculating the resulting link attenuation – so it is important to properly set and maintain the reference measurement.

NOTES

1 – Absolute optical power levels are measured in dBm [$\text{dBm} = 10 \log (\text{mW})$], calibrated to NIST or other appropriate standards. 0 dBm is equivalent to 1 mW of power, hence the “m” in dBm. Loss in dB is a relative measurement equal to input power minus output power represented in dBm. The loss of passive networks will be greater than 0 dB.

2 – On test equipment where loss is represented by a positive value, a negative value may represent an improper reference. However, some test equipment represents loss with negative values, in which case a positive value may indicate an improper reference. In either case, consult equipment manufacturer documentation to determine how the loss results are presented.

3 – It is important to leave the test jumper connected to the source after referencing so as not to adversely influence the attenuation measurement. Removal and reattachment of the test jumper connection from the source may result in a change of coupled power that affects the referenced power level. Re-referencing is to be performed if the test jumper is disconnected from the light source.

4 – Proper cleaning of each connector is essential for meaningful attenuation measurements. If higher than expected losses are measured, clean the connectors and retest. If the test jumpers continue to test high, replace each test jumper with a new one until the measured attenuation is in the appropriate range.

5 – Mated connector insertion loss is also a function of the mating adapter. Mating adapters are a potential source of additional insertion loss as they become dirty or wear out. Choose high quality mating adapters and limit the number of uses per manufacturer recommendations.

E.5.1.2 Verifying test jumper quality

The following procedure will verify that test jumpers are in acceptable condition for either multimode or single-mode cabling. The example herein describes the process for verifying the quality of multimode fiber test jumpers with the jumper connected to the source having five non-overlapping wraps of multimode fiber on a mandrel (see table 3 and clause E.7). The procedure is also applicable to single-mode cabling, however, the five non-overlapping wraps of multimode fiber would be replaced with a single 30 mm (1.2 in) diameter loop of single-mode fiber.

To verify that the test jumpers are in acceptable condition, first reference the light source to the optical power meter (see figure 17). Disconnect test jumper (J1) from the power meter (only) and insert a second test jumper (J2) by connecting it to the power meter and to (J1) with a mating adapter (see figure 18) and record the measurement. Disconnect both ends of J2, interchange the ends, and reconnect it and record the measurement. The resulting measurements, P_{verify} , should be within the appropriate connector loss specification. For example, if the connector used is specified at 0.75 dB, the reading on the power meter should be within 0.75 dB of P_1 .

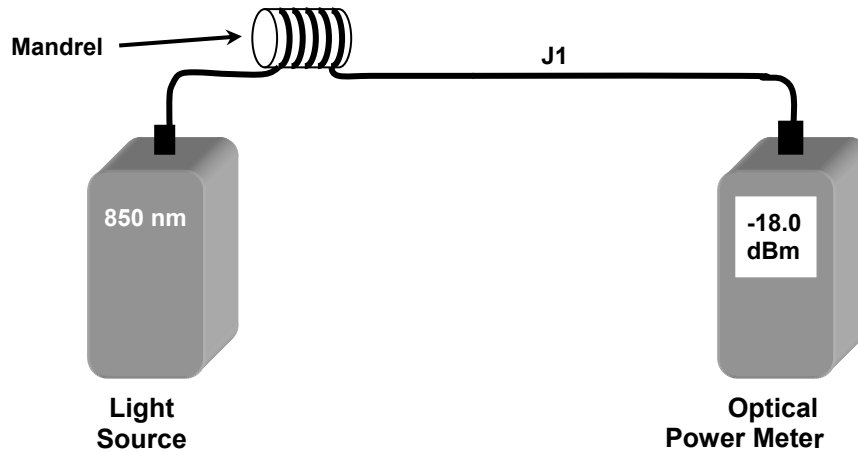


Figure 17 – Example of OLTS reference measurement (P_1) with one test jumper (multimode)

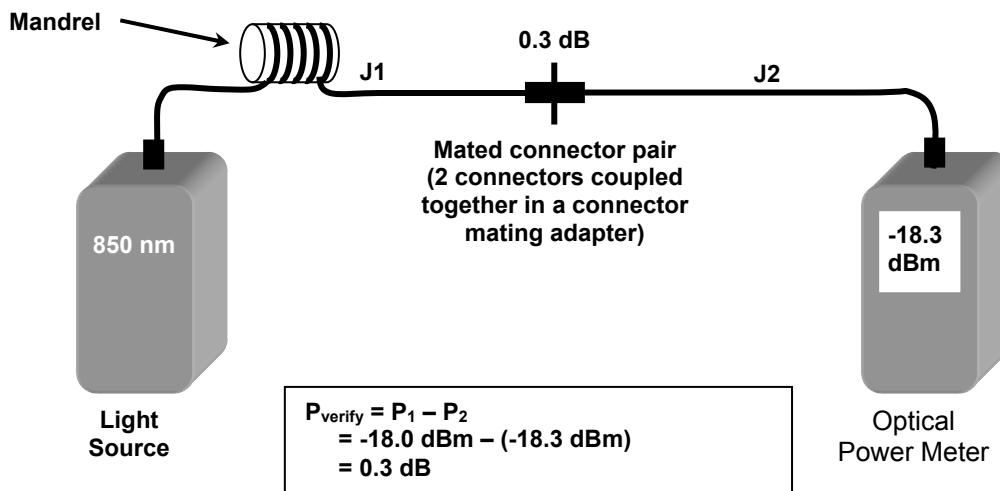


Figure 18 – Example of a measurement (P_2) when verifying OLTS test jumpers (multimode)

E.5.1.3 Multimode

E.5.1.3.1 General

TIA-526-14-A, Method B is used to test multimode cabling attenuation. This method references the optical power source to the optical power meter by connecting them with one test jumper (J1) that meets the conditions of clause E.5.1.2. The link measurement is then performed by disconnecting this test jumper from the optical meter (only), placing a second jumper (J2) that meets the conditions of clause E.5.1.2 on the meter, and then measuring the link attenuation by connecting the test jumper of the source to one end of the cabling link and the test jumper of the meter to the other end of the cabling link. The test jumpers should be 1 m (3.3 ft) to 5 m (16.4 ft) in length and should be verified to ensure they are of acceptable quality.

The basic steps taken to measure and calculate multimode cabling attenuation include:

1. Verifying test jumper quality (once before testing; see clause E.5.1.2)
2. Setting the reference (once before testing; see clause E.5.1.3.2)
3. Measuring link attenuation (each link; see clause E.5.1.3.3)
4. Calculating link attenuation (each link; see clause E.5.1.5)

E.5.1.3.2 Setting the reference

When referencing the light source to the power meter, one test jumper (J1) is to be connected between the light source and the power meter (see figure 19) and a reference measurement taken (P_1 [dBm]). When the test source is a Category 1 CPR source, a mandrel wrap “mode filter” (see table 3 and clause E.7) is applied to the test jumper (J1) prior to setting the reference and for all subsequent measurements.

NOTE – To improve the stability of the reference reading and for easier handling, it may be helpful to secure the mandrel to the light source by some means such as a cable tie or tape. Care should be taken to ensure that the fiber jacket is not deformed or damaged when using a cable tie or tape.

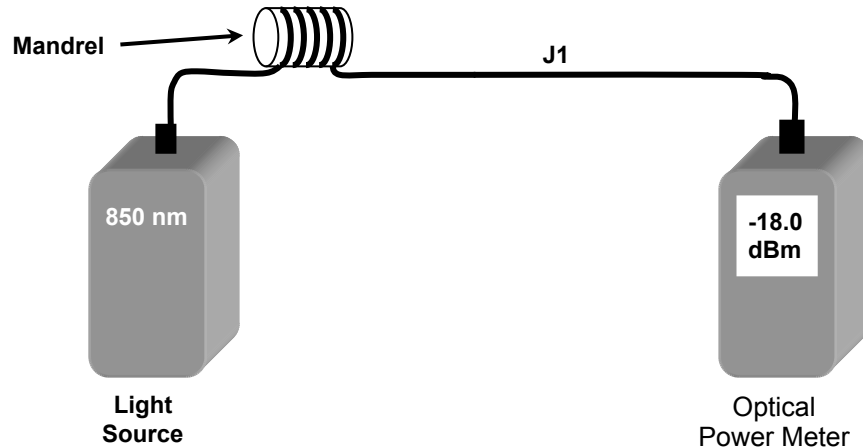


Figure 19 – Example of OLTS reference measurement (P_1) with one test jumper (multimode)

E.5.1.3.3 Measuring link attenuation

Connect the end of test jumper (J1) (source end) to one end of the link, and connect an acceptable test jumper (J2) between the other end of the link and the meter (see figure 20). The optical power reading is P_2 (dBm).

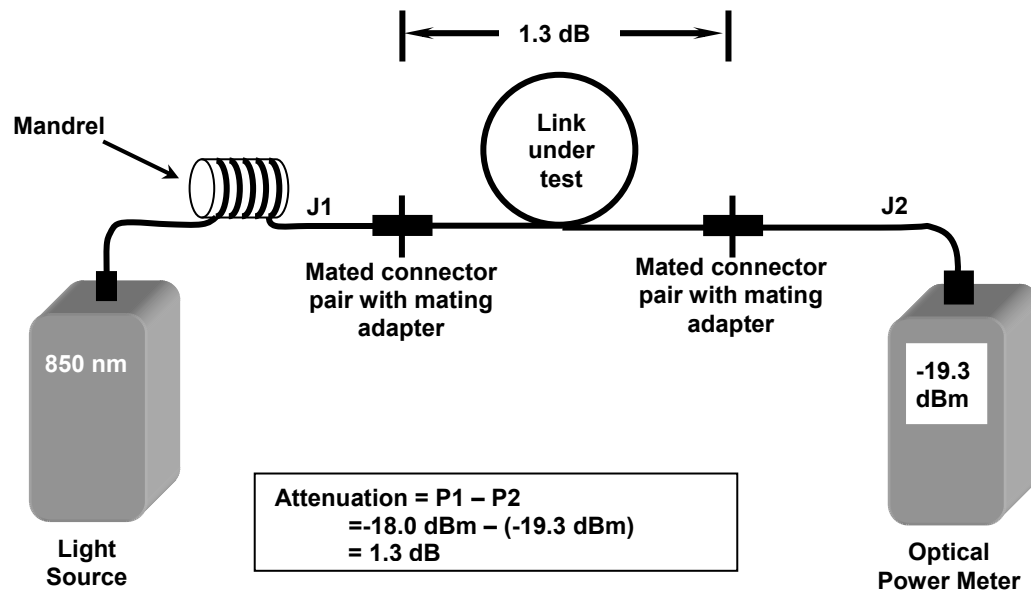


Figure 20 – Example of a multimode link attenuation measurement (P_2)

E.5.1.4 Single-mode**E.5.1.4.1 General**

TIA-526-7, Method A.1 is used for testing single-mode cabling attenuation. This method references the optical power source to the optical power meter by connecting them with one test jumper (J1) that meets the conditions of clause E.5.1.2. The link measurement is then performed by disconnecting this test jumper from the optical meter (only) and placing a second jumper (J2) that meets the conditions of clause E.5.1.2 on the meter, and then measuring the link attenuation by connecting the test jumper of the source to one end of the cabling link and the test jumper of the meter to the other end of the cabling link. The test jumpers should be 1 m (3.3 ft) to 5 m (16.4 ft) in length and should be verified to ensure they are of acceptable quality.

The basic steps taken to measure and calculate single-mode cabling attenuation include:

1. Verifying test jumper quality (once before testing; see clause E.5.1.2)
2. Setting the reference (once before testing; see clause E.5.1.4.2)
3. Measuring link attenuation (each link; see clause E.5.1.4.3)
4. Calculating link attenuation (each link; see clause E.5.1.5)

E.5.1.4.2 Setting the reference

When referencing the light source to the power meter, a single 30 mm (1.2 in) diameter loop is applied to the test jumper (J1) prior to setting the reference and for all subsequent measurements to ensure single-mode operation (see ANSI/TIA-455-78B). The test jumper (J1) is to be connected between the light source and the power meter (see figure 21) and a reference measurement taken (P_1 [dBm]).

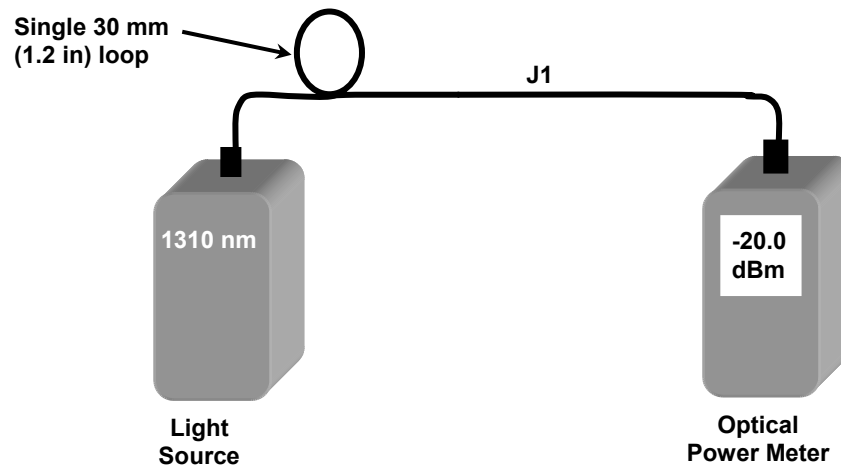


Figure 21 – Example of OLTS reference measurement (P_1) one test jumper (single-mode)

E.5.1.4.3 Measuring link attenuation

Connect the end of test jumper (J1) (source end) to one end of the link, and connect an acceptable test jumper (J2) between the other end of the link and the meter (see figure 22). The optical power reading is P_2 (dBm).

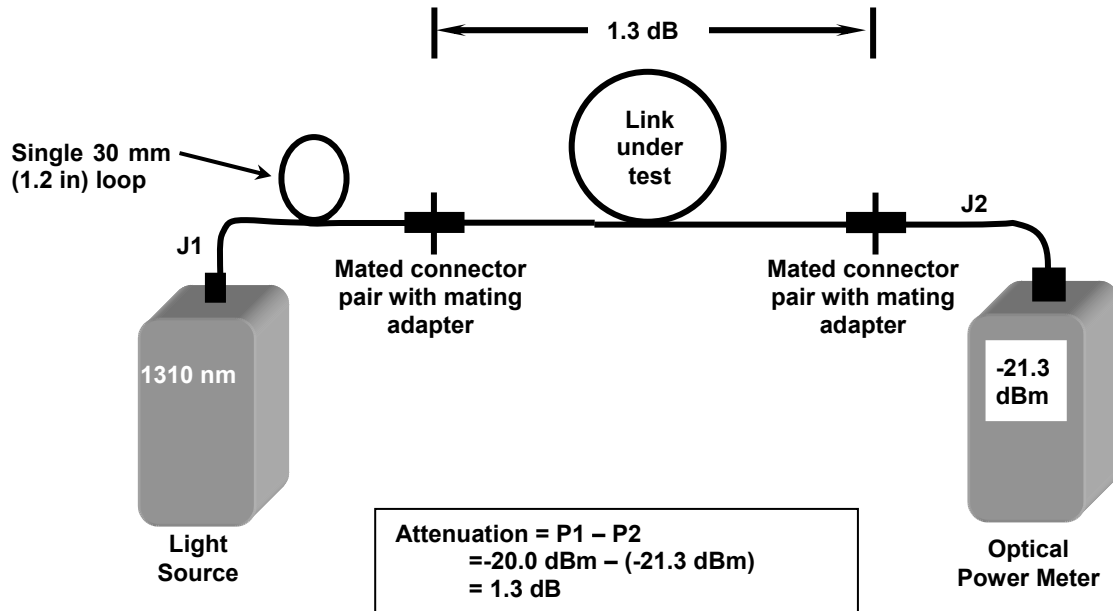


Figure 22 – Example link attenuation measurement of single-mode cabling using an OLTS

E.5.1.5 Calculating link attenuation

Equation E.1 is used to determine the fiber cabling link loss (attenuation).

$$\text{Attenuation (dB)} = P_1 (\text{dBm}) - P_2 (\text{dBm}) \quad (\text{E.1})$$

where:

P_1 = Reference power measurement

P_2 = Cabling test power measurement

E.5.2 Length

Fiber length verification may be obtained from cable sheath markings or may be estimated by the OLTS (if the OLTS has length measurement capability and assuming equipment is capable of measuring the fiber length under test) or an OTDR.

NOTE – The optical lengths of certain cables (e.g., stranded loose tube) may be longer than the cable sheath due to the fiber lay within the cable sheath.

E.5.3 Polarity

Polarity can be verified with an OLTS while performing attenuation tests, by checking the labeling or identifying marks, or by using a visible light source, such as a VFL. A visible light source connects directly to the cable under test or to one end of a test jumper and the other end of the test jumper connected to the cable under test. The light can be used to visually identify polarity of fiber pairs or fibers that may be transposed in a patch panel. As an example, an equipment outlet identified as “3” could be transposed with the patch panel position identified as “7”.

NOTE – A VFL normally uses a Class 2 light source and should not be directly viewed. Safe usage of the tool requires indirect viewing of the light source by

pointing the end of the fiber at an adjacent surface (or introducing another surface in front of a fixed mounted connector) until the presence of light is determined.

E.5.4 OTDR trace

The OTDR takes multiple measurements and presents the results on a display as a “trace”. The vertical scale provides relative power level measured in dB while the horizontal scale provides length. The trace can identify fiber length, and loss events such as connectors, splices and fiber bends.

An OTDR is connected to the optical fiber link with a length of cable that has commonly been called a ‘launch fiber’, ‘dead zone cable’, ‘pulse suppressor’, ‘test fiber box’ or ‘access jumper’. The length of the launch fiber should follow the OTDR manufacturer’s recommendation. In the absence of manufacturer recommendations a launch fiber length of 100 m (328 ft) for multimode and 300 m (984 ft) for single-mode is usually acceptable. The launch fiber allows the OTDR receiver to recover from the overload caused by the back reflection from the connection on the OTDR to the launch fiber and allows measuring the insertion loss of the initial connector on the cable being tested. To view the far-end connector of the link, a sufficient length of fiber may be coupled to the far-end connector (also known as a ‘receive fiber’). Where additional fiber is coupled to the far-end connector as a receive fiber, it should be recorded in the documentation. Figure 23 illustrates the connection setup for an OTDR.

NOTE – An OTDR has a more controlled launch condition over that of an OLTS and does not need a mandrel wrap.

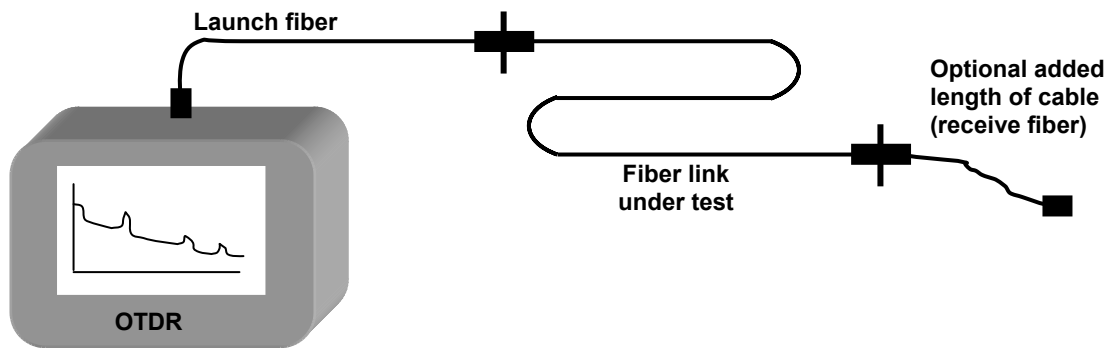


Figure 23 – OTDR setup illustration of fiber link testing

Selectable parameters affecting the OTDR measurement may include the test source wavelength, pulse duration or signal strength, length range, backscatter coefficient, signal averaging (time or count) and the group index of the fiber (also known as the index of refraction or the refractive index). The display should be adjusted to view the region of interest on the trace on both the horizontal and vertical axes. Cursors on the display can be used to determine length or power loss between any two points along the trace of the fiber link. See clause E.8 for basic information on interpreting a trace.

E.6 Documentation

Test results documentation are generally recorded and stored by the test instrument for subsequent downloading to a personal computer.

Documentation that should be recorded for OLTS test results include:

- Date of the test
- Test personnel
- Description of the field-test instrument used (including the source CPR Category for multimode measurements); manufacturer model number and serial number
- Date of the latest field-test instrument calibration
- Type and length of test jumpers
- Fiber identifier (ID)
- Test procedure and method used (TIA-526-14-A, Method B for multimode; TIA-526-7, Method A.1 for single-mode) to include launch condition description (for multimode, record the mandrel diameter and number of turns; for single-mode, record the diameter of the mode suppression loop and number of turns)
- Link loss results (including direction) at tested wavelength(s)

Documentation that should be recorded for OTDR test results include:

- Date of the test
- Test personnel
- Description of the field-test instrument used; manufacturer model number and serial number
- Date of the latest field-test instrument calibration
- Type and length of launch fiber
- Fiber identifier (ID)
- Trace file including OTDR selectable parameters
- Tested wavelength(s)

E.7 Mandrel wrap usage for multimode fiber testing with an OLTS LED source

Multimode optical fiber has a core surrounded by a cladding layer. A plastic buffer coating, that both protects the glass fiber and removes any light that enters the cladding, covers the fiber. The index of refraction profile of the core is designed to confine and propagate multiple modes or “paths” of light within the core.

Overfilled or Category 1 CPR light sources, including some LED sources used in OLTSs, launch light at a spot size and numerical aperture greater than that of standard multimode fiber, exciting both low-order (tightly coupled) and high-order (loosely coupled) modes. Low-order modes have low angles relative to the core and are confined to the inner region of the core. High-order modes have high angles relative to the core and travel throughout the core. Light launched into the core at angles greater than the numerical aperture of the fiber, as well as light launched directly into the cladding, are quickly absorbed by the buffer coating.

Because they are loosely coupled, the highest order modes excited by overfilled LED sources experience higher loss in the fiber, at fiber bends, and connections than low order modes. A mandrel wrap placed on the test jumper that is attached to the source during referencing and during testing of the cabling serves as a “high-order mode filter” and will provide greater consistency of measurements than using a Category 1 CPR source without a mandrel wrap. The effect of a mandrel-wrap on an overfilled light source is illustrated in figure 24.

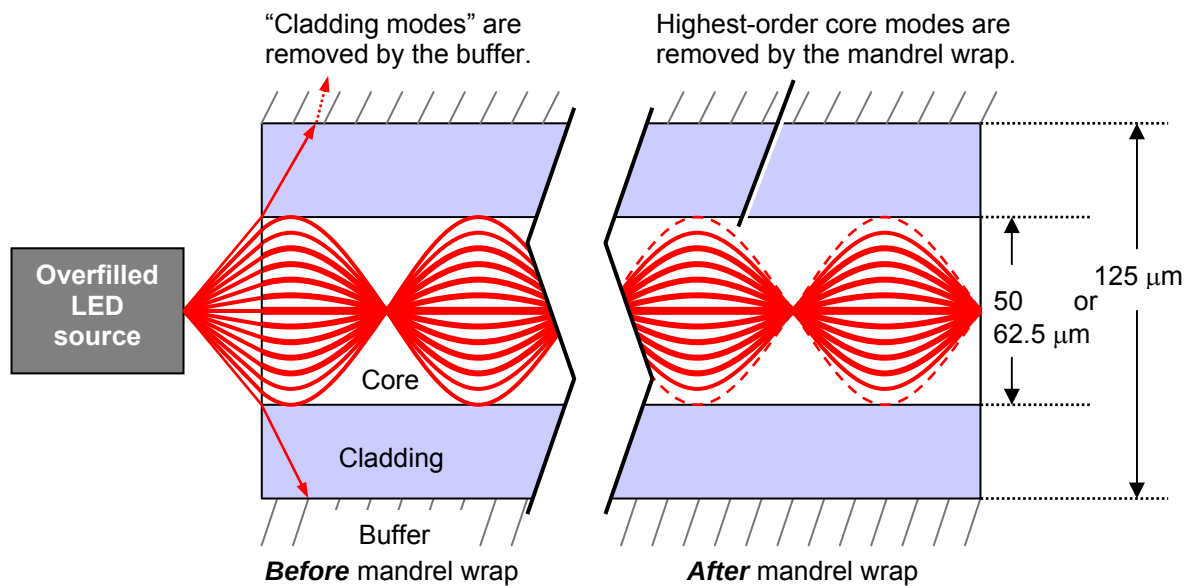


Figure 24 – Effect of mandrel wrap

The mandrel-wrap is installed on the transmit test jumper of an OLTS having an overfilled launch when it is used to measure the link loss of multimode fiber links. The installation of the mandrel wrap is performed by wrapping a length of fiber around a smooth round mandrel (rod) for a total of five (5) non-overlapping wraps. A mandrel wrap is never installed on the receive test jumper (optical power meter). Table 3 shows mandrel diameters for typical cabled fiber types.

The advantage of using the overfilled LED source to test multimode fiber is that the same light source or OLTS can be used to test either 62.5 μm or 50 μm fiber links by using the appropriate core size test jumpers with a mandrel.

E.8 Interpreting length, attenuation rate, and insertion loss from an OTDR trace

E.8.1 Length

When measuring length, observe the OTDR manufacturer's recommendations for optimum settings. To measure the length of any segment except the first segment attached to an OTDR, place two cursors on the trace. For reflective events, such as connectors or mechanical splices, the first cursor is placed at the lowest point of the trace before the peak which indicates the reflective event at the beginning of the segment (Z_0 , in figure 25). The second cursor is placed at the lowest point of the next straight line trace, again before the peak of a reflective event (Z_1) which indicates the end of the same segment. The fiber length is the difference between these two distances ($Z_1 - Z_0$).

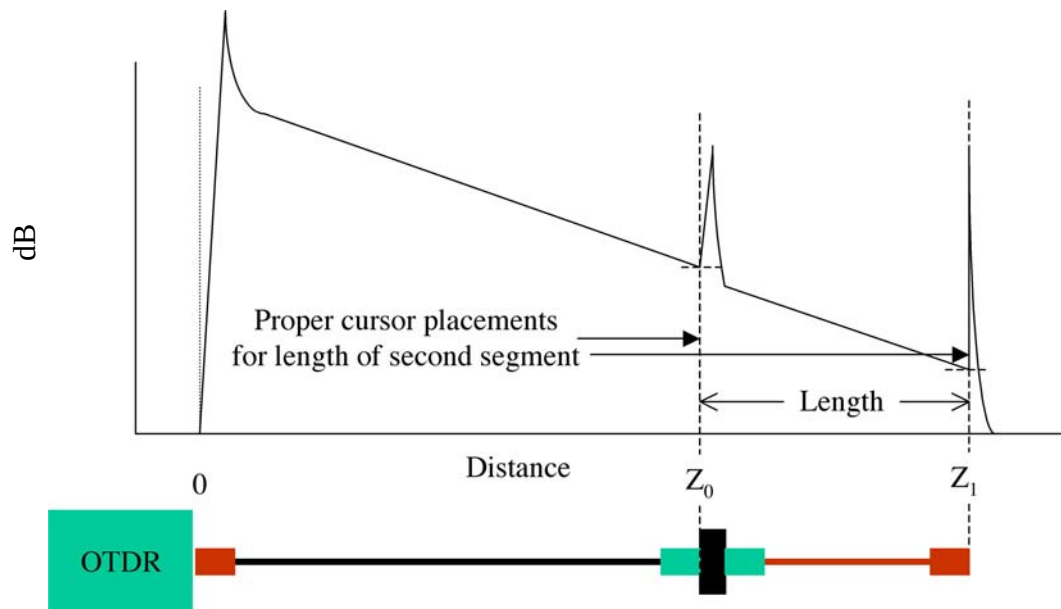


Figure 25 – Example OTDR trace illustrating length

E.8.2 Attenuation rate

When estimating attenuation rate, observe the OTDR manufacturer's recommendations for optimum settings. To measure the attenuation rate of a cable segment or link terminated with reflective connections (connectors or mechanical splices), place two cursors on the trace. Both cursors are placed in the same straight-line trace with no features (i.e., reflections or drops) between the cursors. The first cursor is placed near the beginning of the straight-line trace but not in the decay of the peak (Z_1 , figure 26). The second cursor is placed at or near the end of the same straight-line trace (Z_2). The attenuation rate, calculated by the OTDR in dB/km, is the power difference ($P_1 - P_2$) divided by the distance between the cursors, $Z_2 - Z_1$. Note that the two cursors can be moved slightly closer to one another to avoid being in either peak. Such movement will change the value of the attenuation rate slightly, but not the interpretation of the rate (acceptable or unacceptable).

NOTE – Most OTDRs can also measure the attenuation coefficient using a statistical method called “least squares analysis” (LSA). The OTDR calculates the best straight line between the two cursors reducing the errors caused by non-linearities of reflective events or noisy traces.

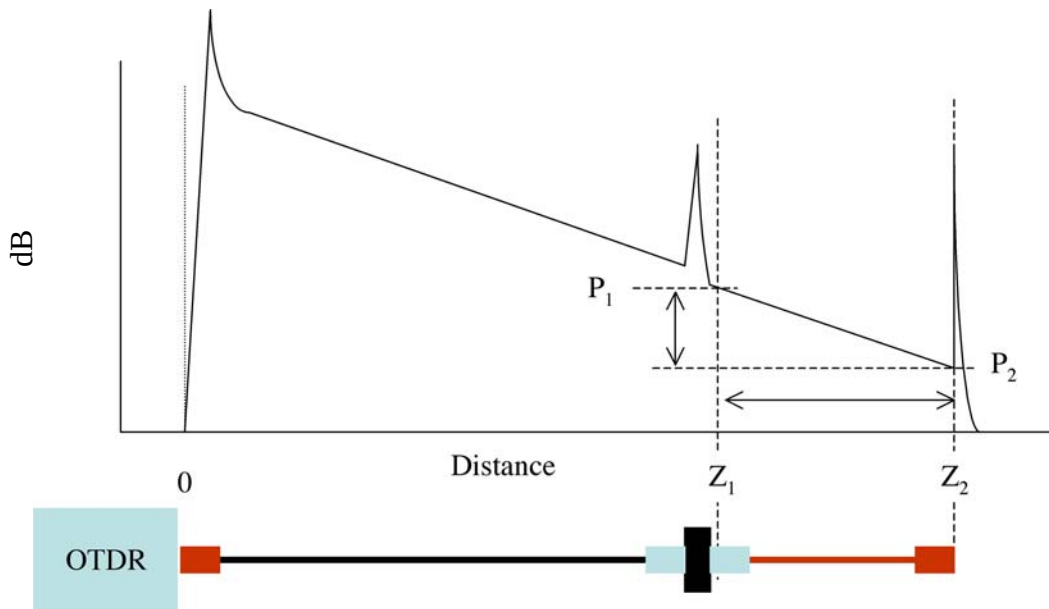


Figure 26 – Example OTDR trace illustrating attenuation rate

E.8.3 Insertion loss

When measuring insertion loss (connector pair or splice), observe the OTDR manufacturer's recommendations for optimum settings. To measure the insertion loss using the "two point method", place two cursors on the trace at opposite sides of the event (connector pair or splice). The cursors are placed in the straight-line trace and not in the peak or drop. The first cursor is placed near the end of the straight-line trace before the peak of a reflective event; e.g., a connection (Z_1 , figure 27) or drop if the event is non-reflective; e.g., a splice. The second cursor is placed at or near the beginning of the straight-line trace (Z_2) after the peak or drop. The insertion loss is the power difference, ($P_1 - P_2$).

NOTE – A method to measure insertion loss, which is built into many OTDRs, uses "least squares analysis" (LSA).

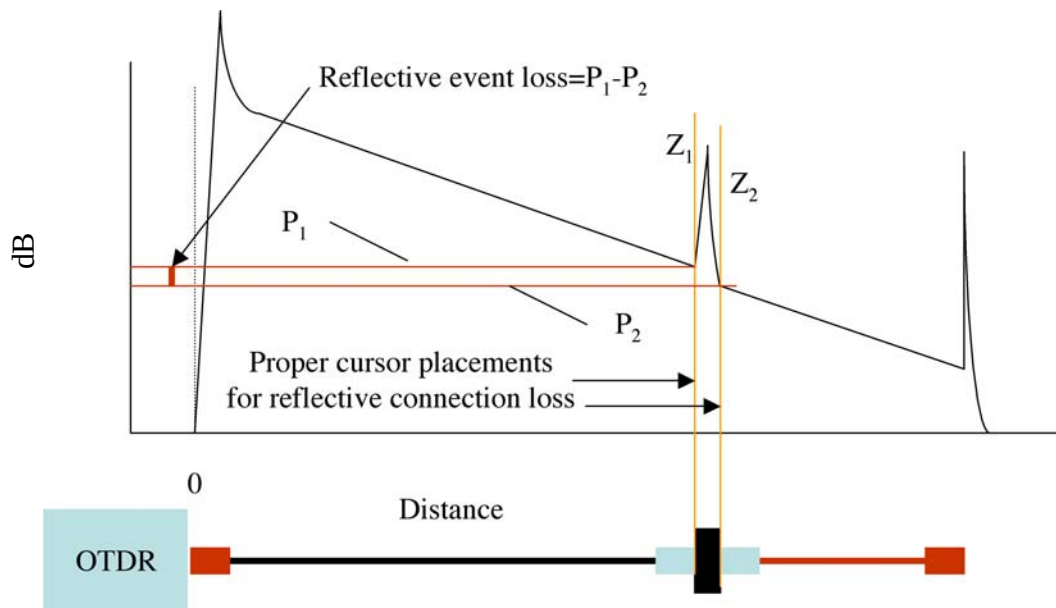


Figure 27 – Example OTDR trace illustrating insertion loss measurement

NOTES

- 1 – OTDRs rely on fiber backscatter for measurements. Connections between two fibers of different backscatter coefficients may cause connection or splice loss errors. Testing in both directions and averaging will reduce this error.
- 2 – Large backscatter differences in fibers can cause connectors or splices to show a "gain" instead of a loss. Testing in the reverse direction and averaging will provide a more accurate measurement.
- 3 – When testing short cables with an OTDR, large reflections from connectors may cause anomalous events called "ghosts" which can be confused with actual connections. Refer to OTDR instructions regarding ghosts.

ANNEX F (INFORMATIVE) ENVIRONMENTAL CLASSIFICATIONS

Environmental classifications have been developed for the purpose of describing areas in which cabling is placed. The specifications of MICE include: M - mechanical; I - ingress; C - climatic; and, E - electromagnetic. Compatibility with the environment can be achieved with enhanced cabling components or through protection, separation or isolation. Table 8 provides thresholds for environmental conditions. MICE 1 ($M_1I_1C_1E_1$) generally relates to environmentally controlled areas such as commercial building offices, MICE 2 ($M_2I_2C_2E_2$) generally relates to a light industrial environment and MICE 3 ($M_3I_3C_3E_3$) generally relates to an industrial environment. The classification for areas with mixed environments may be described by including the classification level for each variable as a subscript (e.g., $M_1I_2C_3E_1$). If a cabling system component crosses an environmental boundary, the component or mitigation technique should be selected to be compatible with the worst case environment to which it is exposed.

Table 8 – M, I, C, E environmental conditions

Mechanical	M₁	M₂	M₃
Shock/bump (see a)			
Peak acceleration	40 m/s ⁻²	100 m/s ⁻²	250 m/s ⁻²
Vibration			
Displacement amplitude (2 Hz to 9 Hz)	1.5 mm	7.0 mm	15.0 mm
Acceleration amplitude (9 Hz to 500 Hz)	5 m/s ⁻²	20 m/s ⁻²	50 m/s ⁻²
Tensile force	See b)	See b)	See b)
Crush	45 N over 25 mm (linear) min.	1 100 N over 150 mm (linear) min.	2 200 N over 150 mm (linear) min.
Impact	1 J	10 J	30 J
Bending, flexing and torsion	See b)	See b)	See b)

Ingress	I₁	I₂	I₃
Particulate ingress (dia. max)	12.5 mm	50 µm	50 µm
Immersion	None	Intermittent liquid jet ≤ 12.5 l/min ≥ 6.3 mm jet > 2.5 m distance	Intermittent liquid jet ≤ 12.5 l/min ≥ 6.3 mm jet > 2.5 m distance and immersion (≤1 m for ≤30 minutes)

Table 8 (Continued)

Climatic and chemical	C ₁	C ₂	C ₃
Ambient temperature	-10 °C to +60 °C	-25 °C to +70 °C	-40 °C to +70 °C
Rate of change of temperature	0.1 °C per minute	1.0 °C per minute	3.0 °C per minute
Humidity	5 % to 85 % (non-condensing)	5 % to 95 % (condensing)	5 % to 95 % (condensing)
Solar radiation	700 Wm ⁻²	1 120 Wm ⁻²	1 120 Wm ⁻²
Liquid pollution (see c)) Contaminants	Concentration x 10 ⁻⁶	Concentration x 10 ⁻⁶	Concentration x 10 ⁻⁶
Sodium chloride (salt/sea water)	0	<0,3	<0,3
Oil (dry-air concentration) (for oil types see b)	0	<0,005	<0,5
Sodium stearate (soap)	None	>5 x 10 ⁴ aqueous non-gelling	>5 x 10 ⁴ aqueous gelling
Detergent	None	ffs	ffs
Conductive materials	None	Temporary	Present
Gaseous pollution (see Note 3) Contaminants	Mean/Peak (Concentration x 10 ⁻⁶)	Mean/Peak (Concentration x 10 ⁻⁶)	Mean/Peak (Concentration x 10 ⁻⁶)
Hydrogen sulphide	<0.003/<0,01	<0.05/<0,5	<10/<50
Sulphur dioxide	<0.01/<0.03	<0.1/<0,3	<5/<15
Sulphur trioxide (ffs)	<0.01/<0.03	<0.1/<0.3	<5/<15
Chlorine wet (>50 % humidity)	<0.000 5/<0.001	<0.005/<0.03	<0.05/<0.3
Chlorine dry (<50 % humidity)	<0.002/<0.01	<0.02/<0.1	<0.2/<1.0
Hydrogen chloride	-/<0.06	<0.06/<0.3	<0.6/3.0
Hydrogen fluoride	<0.001/<0.005	<0.01/<0.05	<0.1/<1.0
Ammonia	<1/<5	<10/<50	<50/<250
Oxides of Nitrogen	<0.05/<0.1	<0.5/<1	<5/<10
Ozone	<0.002/<0.005	<0.025/<0.05	<0.1/<1

Table 8 (Concluded)

Electromagnetic	E ₁	E ₂	E ₃
Electrostatic discharge – Contact (0,667 µC)	4 kV	4 kV	4 kV
Electrostatic discharge – Air (0,132 µC)	8 kV	8 kV	8 kV
Radiated RF - AM	3 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz)	3 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz)	10 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz)
Conducted RF	3 V at 150kHz to 80MHz	3 V at 150kHz to 80MHz	10 V at 150kHz to 80MHz
EFT/B (comms)	500 V	1 kV	1 kV
Surge (transient ground potential difference) - signal, line to earth	500 V	1 kV	1 kV
Magnetic Field (50/60 Hz)	1 Am ⁻¹	3 Am ⁻¹	30 Am ⁻¹
Magnetic Field (60 Hz to 20 000 Hz)	ffs	ffs	ffs
NOTES 1 – Bump: the repetitive nature of the shock experienced by the channel shall be taken into account. 2 – This aspect of environmental classification is installation-specific and should be considered in association with IEC 61918 and the appropriate component specification. 3 – A single dimensional characteristic, i.e. Concentration x 10⁻⁶, was chosen to unify limits from different standards.			

ANNEX G (INFORMATIVE) BIBLIOGRAPHY

This annex is informative only and is not part of this Standard.

The following is a list of some generally applicable basic standards and guides that are relevant to the requirements of this Standard. Other American National Standards also may be relevant.

- ANSI Z136.2, *ANS For Safe Use Of Optical Fiber Communication Systems Utilizing Laser Diode And LED Sources*
- ANSI/TIA-568-C.1, *Commercial Building Telecommunications Cabling Standard*
- ANSI/TIA-568-C.2, *Balanced Twisted-Pair Telecommunications Cabling and Components Standard*
- ANSI/TIA-604-3, *FOCIS 3, Fiber Optic Connector Intermateability Standard, Type SC and SC-APC*
- ANSI/TIA-604-5, *FOCIS-5, Fiber optic Intermateability Standard, Type MPO*
- Federal Communications Commission (FCC) Washington D.C., *The Code of Federal Regulations, FCC 47 CFR 68*
- Federal Telecommunications Recommendation 1090-1997, *Commercial Building Telecommunications Cabling Standard*, 11 August 1997, by National Communications System (NCS).
- IEEE C2-2007, *National Electrical Safety Code® (NESC®)*
- IEEE 802.3-2005, *Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*
- IEC 61918-2007, *Industrial Communication Networks - Installation of Communication Networks in Industrial Premises*
- NFPA 70, *National Electrical Code®*
- TIA-492AAAA, *Detail Specification For 62.5-μm Core Diameter/125-μm Cladding Diameter Class IA Graded-Index Multimode Optical Fibers*
- TIA-492AAAB, *Detail Specification For 50-μm Core Diameter/125-μm Cladding Diameter Class IA Graded-Index Multimode Optical Fibers*
- TIA-492AAAC, *Detail Specification For 850-nm Laser-optimized, 50-μm Core Diameter/125-μm Cladding Diameter Class IA Graded-Index Multimode Optical Fibers*
- TIA-492CAAA, *Detail Specification For Class IVA Dispersion-Unshifted Single-Mode Optical Fibers*
- TIA-492CAAB, *Detail Specification For Class IVA Dispersion-Unshifted Single-Mode Optical Fibers With Low Water Peak*
- TIA TSB-31-C, *Telephone Terminal Equipment Rationale and Measurement Guidelines for US Network Protection*

ANSI/TIA-568-C.0

The organizations listed below can be contacted to obtain reference information.

ANSI

American National Standards Institute (ANSI)
11 W 42 St.
New York, NY 10032
USA
(212) 642-4900
www.ansi.org

BICSI

BICSI
8610 Hidden River Parkway
Tampa, FL 33637-1000
USA
(800) 242-7405
www.bicsi.org

FCC

Federal Communications Commission (FCC)
Washington, DC 20554
USA
(301) 725-1585
www.fcc.org

Federal and Military Specifications

National Communications System (NCS)
Technology and Standards Division
701 South Court House Road Arlington, VA 22204-2198
USA
(703) 607-6200
www.ncs.gov

IEC

International Electrotechnical Commission (IEC)
Sales Department
PO Box 131
3 rue de Varembe
CH-1211 Geneva 20
Switzerland
+41 22 919 02 11
www.iec.ch

IEEE

The Institute of Electrical and Electronic Engineers, Inc (IEEE)
IEEE Service Center
445 Hoes Ln., PO Box 1331
Piscataway, NJ 08855-1331
USA
(732) 981-0060
www.ieee.org

NFPA

National Fire Protection Association (NFPA)
Batterymarch Park
Quincy, MA 02269-9101
USA
(617) 770-3000
www.nfpa.org

TIA

Telecommunications Industry Association (TIA)
2500 Wilson Blvd., Suite 300
Arlington, VA 22201-3836
USA
(703) 907-7700
www.tiaonline.org

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