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TIA/EIA-568-A

TIA/EIA STANDARD

Commercial Building Telecommunications Cabling Standard

TIA/EIA-568-A

(Revision of EIA/TIA-568)

OCTOBER 1995

TELECOMMUNICATIONS INDUSTRY ASSOCIATION

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(From Standards Proposal Nos. 2840-A and 2840-A-1, formulated under the cognizance of the TR-41.8 Subcommittee on Commercial and Residential Building Cabling Systems.)

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COMMERCIAL BUILDING TELECOMMUNICATIONS CABLING STANDARD

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FOREWORD

This forward is not considered part of the standard.

Early in 1985, a large number of companies representing the telecommunications and computer industry expressed concern over the lack of a standard for building telecommunications cabling systems. The Computer Communications Industry Association (CCIA) asked the Electronic Industries Association (EIA) to undertake the task of developing the required standard. EIA accepted the task and the project was assigned to TR-41.8 under Engineering Committee TR-41. The TR-41 Committee established several working groups related to this activity.

- a) TR-41.8.1 - Working Group on Commercial and Industrial Building Wiring
- b) TR-41.8.2 - Working Group on Residential and Light Commercial Building Wiring
- c) TR-41.8.3 - Working Group on Telecommunications Pathways and Spaces/Administration
- d) TR-41.8.4 - Working Group on Backbone Cabling Systems for Residential and Light Commercial Buildings
- e) TR-41.8.5 - Working Group for Definitions
- f) TR-41.7.2 - Working Group for Grounding and Bonding
- g) TR-41.7.3 - Working Group on Electromagnetic Compatibility Considerations

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In 1988 the Telecommunications sector of the EIA (specifically the TR and FO Committees and Subcommittees) became the TIA (Telecommunications Industry Association) under the TIA technical council. While TIA is a separate corporation, it conducts the standards activities through the EIA organization. Throughout this document these organizations are referred to as ANSI/TIA/EIA.

ANSI/TIA/EIA reviews most standards every 5 years. At that time standards are reaffirmed, rescinded or revised according to the submitted updates.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/EIA.

This standard has been prepared by the Working Group TR-41.8.1 under the jurisdiction of the Sub Committee TR-41.8 and approved by the Technical Committee TR-41.

This standard replaces ANSI/EIA/TIA-568 standard dated July 1991. Since the publication of ANSI/EIA/TIA-568, the office environment has undergone a period of rapid change marked by the growth of increasingly powerful personal computers, the access to more sophisticated applications and the need to interconnect different systems. These changes place increased demands on the transmission capacity of premises cabling. This has led to the development of

twisted-pair copper cables and connecting hardware with enhanced transmission characteristics and the use of optical fiber cabling for system interconnection.

This standard incorporates and refines the technical content of EIA/TIA TSB 36, TIA/EIA TSB 40, and TIA/EIA TSB 40A, which covered additional specifications for categories 3, 4 and 5 Unshielded Twisted-Pair (UTP) cables and compatible connecting hardware. Cables and connecting hardware for categories 1 and 2 are not a recognized part of this standard and therefore are not covered. This standard also incorporates and refines the technical content of the draft TSB 53 which covered additional specifications for 150 Ω Shielded Twisted-Pair (STP-A) cables and compatible connectors. This document takes precedence over the technical contents of TSB 36, TSB 40, and TSB 40A. New specifications for 62.5/125 μm optical fiber and single-mode optical fiber cables, connectors and cabling practices have also been included.

Annexes A, B, and C are normative and considered a mandatory part of this standard. Annexes D through J are informative and not considered as requirements of this standard.

Commercial Building Telecommunications Cabling Standard

1 INTRODUCTION

1.1 Purpose

This standard specifies a generic telecommunications cabling system for commercial buildings that will support a multiproduct, multivendor environment. It also provides information that may be used for the design of telecommunications products for commercial enterprises.

The purpose of this standard is to enable the planning and installation of a structured cabling system for commercial buildings. Installation of cabling systems during building construction or renovation is significantly less expensive and less disruptive than after the building is occupied.

This standard establishes performance and technical criteria for various cabling system configurations for interfacing and connecting their respective elements. In order to determine the requirements of a generic cabling system, a review of the performance requirements for various telecommunications services was conducted. 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 and regulations, equipment vendors, and system and service suppliers for applicability, limitations, and ancillary requirements.

1.2 Related Standards

This standard is one of a series of technical standards that address building cabling for telecommunications products and services. This document, together with its companion standards, listed below, fills a recognized need in the telecommunications industry brought about by the evolving industry structure.

ANSI/EIA/TIA-569, Commercial Building Standard for Telecommunications Pathways and Spaces

ANSI/EIA/TIA-570, Residential and Light Commercial Telecommunications Wiring Standard

ANSI/TIA/EIA-606, Administration Standard for the Telecommunications Infrastructure of Commercial Buildings

ANSI/EIA/TIA-607, Commercial Building Grounding/Bonding Requirements

This document contains references to national and international standards. Where appropriate, international standards are used.

1.3 Specification of Criteria

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

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

Where both a mandatory and an advisory level are specified for the same criterion, the advisory level represents a goal currently identifiable as having distinct compatibility or performance advantages, or both, toward which future designs should strive.

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

Citations of other documents refer to the latest revision unless specifically dated or otherwise noted.

This standard is a living document. The criteria contained in this document are subject to revision and updating as warranted by advances in network, terminal equipment, or cabling technology.

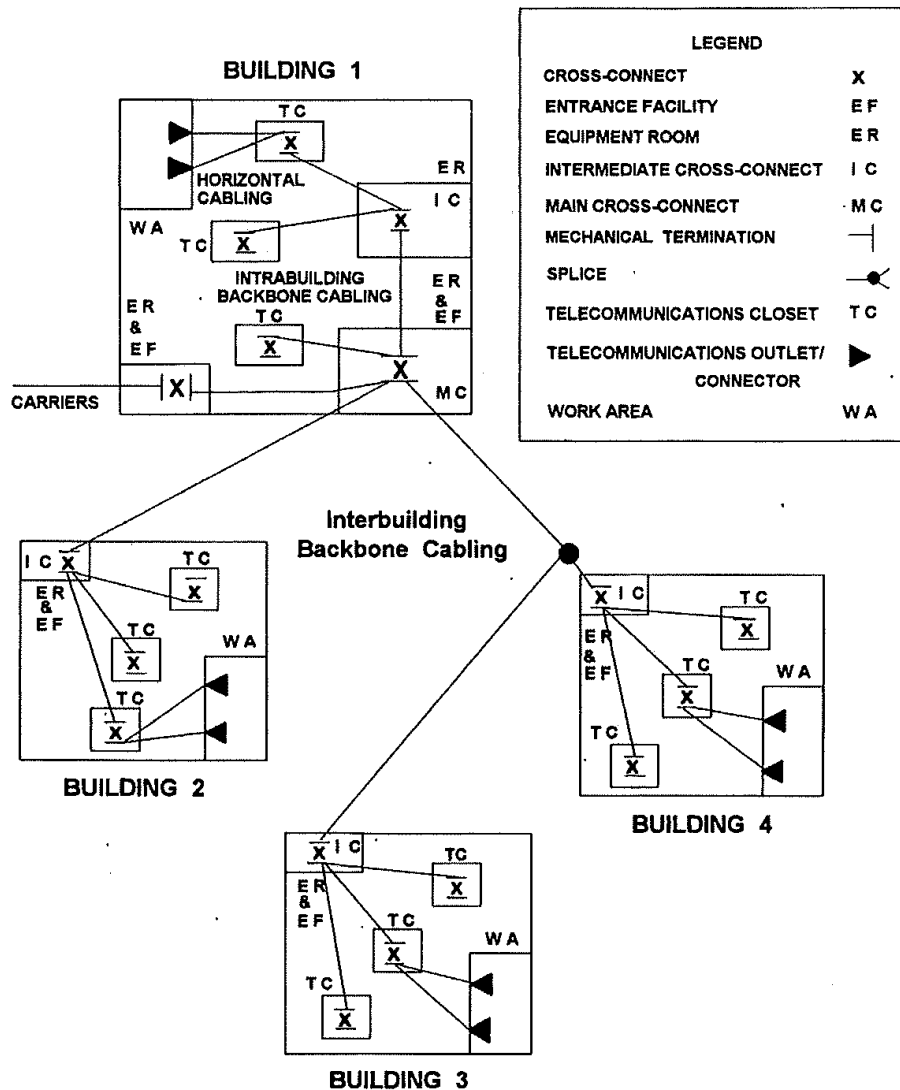
1.4 Telecommunications Cabling System Structure

Figure 1-1 illustrates a model for the various functional elements that comprise a modern cabling system. It depicts the relationship between the elements and how they interface to each other to create the total system.

The elements of the telecommunications cabling system structure are:

- a) Horizontal Cabling (Section 4),
- b) Backbone Cabling (Section 5),
- c) Work Area (Section 6),
- d) Telecommunications Closets (Section 7),
- e) Equipment Rooms (Section 8),
- f) Entrance Facilities (Section 9) and
- g) Administration (NOTE)

NOTE - Basic administration information is covered in various places throughout this document. The reader of this document should refer to ANSI/TIA/EIA-606 for more information regarding administration.



NOTES:

1. This figure is not meant as an all-inclusive representation of the telecommunications cabling system but only as a typical example.
2. All cross-connects located in TCs in this figure are horizontal cross-connects (HCs).

Figure 1-1 Typical Telecommunications Cabling System

ANSI/TIA/EIA-568-A

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2 SCOPE

This standard specifies minimum requirements for telecommunications cabling within a commercial building, up to and including the telecommunications outlet/connector, and between buildings in a campus environment. It specifies component requirements, cabling distances, telecommunications outlet/connector configurations, and a recommended topology.

Building telecommunications cabling specified by this standard is intended to support a wide range of different commercial building sites and applications (e.g., voice, data, text, video, and image). Typically, this includes sites with a geographical extent up to 3,000 m (approximately 10,000 ft), up to 1,000,000 m² (approximately 10,000,000 ft²) of office space, and with a population of up to 50,000 individual users.

Telecommunications cabling systems specified by this standard are intended to have a useful life in excess of ten years.

This standard applies to the telecommunications cabling systems of buildings for commercial enterprises that are office oriented.

2.1 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; parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated. ANSI and TIA maintain registers of currently valid national standards published by them.

- ANSI/EIA/TIA-492AAAA, *Detail Specification for 62.5 μ m Core Diameter/125 μ m Cladding Diameter Class Ia Multimode, Graded-Index Optical Waveguide Fibers*
- ANSI/EIA/TIA-492BAAA, *Detail Specification for Class IVa Dispersion-Unshifted Single-mode Optical Waveguide Fibers Used in Communication Systems*
- ANSI/EIA/TIA-455, *Test Procedures for Fiber Optic Fibers, Cables and Transistors*
- ANSI/EIA/TIA-569 Standard, *Commercial Building Standard for Telecommunications Pathways and Spaces*
- ANSI/EIA/TIA-570 Standard, *Residential and Light Commercial Telecommunication Wiring Standard*
- ANSI/EIA/TIA-598, *Color Coding of Optical Fiber Cables*
- ANSI/EIA/TIA-604-3, *FOCIS 3 Fiber Optic Connector Interchangeability Standard*
- ANSI/EIA/TIA-607, *Commercial Building Grounding/Bonding Requirements*
- ANSI/ICEA S-80-576-1988, *Communications Wire and Cable for Wiring Premises*
- ANSI/ICEA S-83-596-1988, *Fiber Optic Premises Distribution Cable*
- ANSI/ICEA S-83-640-1992, *Fiber Optic Outside Plant Communications Cable*

- ANSI/ICEA S-84-608-1988, *Filled Telecommunications Cable*
- ANSI/IPC-FC-211, *Performance Specification for Flat Undercarpet Data Transmission Cable*
- ANSI/TIA/EIA-472CAAA, *Detail Specification for All Dielectric (Construction 1) Fiber Optic Communications Cable for Indoor Plenum Use, Containing Class Ia, 62.5 μm Core Diameter/125 μm Cladding Diameter Optical Fiber(s)*
- ANSI/TIA/EIA-472DAAA, *Detail Specification for All Dielectric Fiber Optic Communications Cable for Outside Plant Use Containing Class Ia, 62.5 μm Core Diameter/125 μm Cladding Diameter/250 μm Coating Diameter Optical Fiber(s)*
- ANSI/TIA/EIA-606, *Administration Standard For The Telecommunications Infrastructure Of Commercial Buildings*
- ANSI Z136.2, *American Standard for the Safe Operation of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources*
- ASTM D 4565-94, *Physical and Environmental Properties of Insulation and Jackets for Telecommunications Wire and Cable*
- ASTM D 4566-94, *Electrical Performance Properties of Insulations and Jackets for Telecommunications Wire and Cable*
- IEC 68-1:1982, *Basic Environmental Testing Procedures, Part1.1: General and Guidance*
- IEC 68-2-2:1974, *Basic Environmental Testing Procedures, Part2: Tests, Test B: Dry Heat*
- IEC 68-2-6:1982, *Basic Environmental Testing Procedures, Part2: Tests, Test Fc and Guidance: Vibration*
- IEC 68-2-14:1984, *Basic Environmental Testing Procedures, Part2: Tests, Test N: Change of Temperature*
- IEC 68-2-38:1974, *Basic Environmental Testing Procedures, Part2: Tests, Test Z/AD: Composite Temperature/Humidity Cycle Test*
- IEC 512-2, *Electromechanical Components for Electronic Equipment; Basic Testing Procedures and Measuring Methods, Part 2: General Examination, Electrical Continuity and Contact Resistance Tests, Insulation Tests and Voltage Stress Tests*
- IEC 603-7, *Connectors for frequencies below 3 MHz for use with printed boards*
- IEC 807-8, *Rectangular Connectors for Frequencies Below 3 MHz Part 8: Detail Specification for Connectors, Four-Signal Contacts and Earthing Contacts for Cable Screen, First Edition*
- ITU-T G.117, *Transmission Aspects of Unbalance About Earth (Definitions and Methods)*

- ITU-T G 0.9, *Measuring Arrangements To Assess The Degree Of Unbalance About Earth*
- ISO 8802.5-92, *Information Technology - Local and Metropolitan Area Networks*
- NQ-EIA/IS-43, *EIA Interim Standard Omnibus Specification, Local Area Network Twisted Pair Data Communications Cable, September 1987*
- NQ-EIA/IS-43AA, *Cable for LAN Twisted Pair Data Communications-Detail Specification for Type 1, Outdoor Cable, September 1988*
- NQ-EIA/IS-43AB, *Cable for LAN Twisted Pair Data Communications-Detail Specification for Type 1, Non-Plenum Cable, September 1988*
- NQ-EIA/IS-43AC, *Cable for LAN Twisted Pair Data Communications-Detail Specification for Type 1, Riser Cable, September 1988*
- NQ-EIA/IS-43AD, *Cable for LAN Twisted Pair Data Communications-Detail Specification for Type 1, Plenum Cable, September 1988*
- NQ-EIA/IS-43AE, *Cable for LAN Twisted Pair Data Communications-Detail Specification for Type 2, Non-Plenum Cable, September 1988*
- NQ-EIA/IS-43AF, *Cable for LAN Twisted Pair Data Communications-Detail Specification for Type 2, Plenum Cable, September 1988*
- NQ-EIA/IS-43AG, *Cable for LAN Twisted Pair Data Communications-Detail Specification for Type 6 Office Cable, September 1988*
- UL 1863-90, *UL Standard for Safety Communication Circuit Accessories*

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3 DEFINITIONS, ACRONYMS & ABBREVIATIONS

This section contains the definitions of terms, acronyms, and abbreviations that have special technical meaning or that are unique to the technical content of the standard. Special definitions that are appropriate to individual technical sections are included.

3.1 Definitions

The generic definitions in this section have been formulated for use by the entire family of telecommunications infrastructure standards. As such, the definitions do not contain mandatory requirements of the standard. Specific requirements are found in the normative sections of the standard.

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

- a) different sizes or types of plugs to mate with one another or to fit into a telecommunications outlet/connector,
- b) the rearrangement of leads,
- c) large cables with numerous wires to fan out into smaller groups of wires, and
- d) interconnection between cables.

adapter, optical fiber duplex: see optical fiber duplex adapter.

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

backbone: a facility (e.g., pathway, cable or conductors) between telecommunications closets, or floor distribution terminals, the entrance facilities, and the equipment rooms within or between buildings.

backbone cable: see backbone.

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

bridged tap: the multiple appearances of the same cable pair at several distribution points.

building entrance area: see entrance room or space, telecommunications.

cable: an assembly of one or more conductors or optical fibers within an enveloping sheath, constructed so as to permit use of the conductors singly or in groups.

cable sheath: a covering over the conductor assembly that may include one or more metallic members, strength members, or jackets.

cabling: a combination of all cables, wire, cords, and connecting hardware.

campus: the buildings and grounds of a complex; e.g., a university, college, industrial park or military establishment.

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

closet, telecommunications: an enclosed space for housing telecommunications equipment, cable terminations, and cross-connect cabling. The closet is the recognized location of the cross-connect between the backbone and horizontal facilities.

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

conduit: a raceway of circular cross-section of the type permitted under the appropriate electrical code.

connecting hardware: a device providing mechanical cable terminations.

cord, telecommunications: a cable using stranded conductors for flexibility, as in distribution cords or line cords. Line cords can also use tinsel conductors.

cross-connect: a facility enabling the termination of cable elements and their interconnection, and/or cross-connection, primarily by means of a patch cord or jumper.

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) with grounds and appurtenances (belongings) under the control of the customer.

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

device, (as related to a work station): an item such as a telephone, personal computer, or graphic or video terminal.

device, (as related to protection): a protector, a protector mount, a protector unit, or a protector module.

distribution frame: a structure with terminations for connecting the permanent cabling of a facility in such a manner that inter-connection or cross-connections may be readily made.

duct:

- a) a single enclosed raceway for wires or cables. See also conduit, raceway;
- b) a single enclosed raceway for wires or cables usually used in soil or concrete;
- c) an enclosure in which air is moved. Generally part of the HVAC system of a building.

entrance facility, telecommunications: an entrance to a building for both public and private network service cables (including antennae) including the entrance point at the building wall and continuing to the entrance room or space.

entrance point, telecommunications: the point of emergence of telecommunications conductors through an exterior wall, a concrete floor slab, or from a rigid metal conduit or intermediate metal conduit.

entrance room or space, telecommunications: a space in which the joining of inter- or intra-building telecommunications backbone facilities takes place. An entrance room may also serve as an equipment room.

equipment cable (cord): a cable or cable assembly used to connect telecommunications equipment to horizontal or backbone cabling.

equipment room, telecommunications: a centralized space for telecommunications equipment that serves the occupants of the building. An equipment room is considered distinct from a telecommunications closet because of the nature or complexity of the equipment.

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 the earth.

horizontal cabling: the cabling between and including the telecommunications outlet/connector and the horizontal cross-connect.

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

hybrid cable: an assembly of two or more cables (of the same or different types or categories) covered by one overall sheath.

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

interconnection: a connection scheme that provides for the direct connection of a cable to another cable or to an equipment cable without a patch cord or jumper.

intermediate cross-connect: a cross-connect between first level and second level backbone cabling.

jumper: an assembly of twisted pairs without connectors, used to join telecommunications circuits/links at the cross-connect.

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.

light commercial building: a building or portion thereof that is intended for use with one to four (1-4) non-residential exchange access lines per tenant.

link: a transmission path between two points, not including terminal equipment, work area cables, and equipment cables.

listed: equipment included in a list published by an organization, acceptable to the authority having jurisdiction, that maintains periodic inspection of production of listed equipment, and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

main cross-connect: a cross-connect for, first level backbone cables, entrance cables, and equipment cables.

media, telecommunications: wire, cable, or conductors used for telecommunications.

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

modular plug: a telecommunications male connector for wire or cords. A modular plug may be keyed or unkeyed and may have six or eight contact positions, but not all the positions need be equipped with contacts.

multimode optical fiber: an optical fiber that will allow many bound modes to propagate. The fiber may be either a graded-index or step-index fiber. See also: optical fiber cable.

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

optical fiber duplex adapter: a mechanical media termination device designed to align and join two duplex connectors.

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

optical fiber duplex connector: a mechanical media termination device designed to transfer optical power between two pairs of optical fibers.

outlet box, telecommunications: a metallic or nonmetallic box mounted within a wall, floor, or ceiling and used to hold telecommunications outlet/connectors or transition devices.

outlet/connector, telecommunications: a connecting device in the work area on which horizontal cable terminates.

patch cord: a length of cable with connectors on one or both ends used to join telecommunications circuits/links at the cross-connect.

patch panel: a cross-connect system of mateable connectors that facilitates administration.

pathway: a facility for the placement of telecommunications cable.

pull strength: see pull tension.

pull tension: the pulling force that can be applied to a cable without effecting specified characteristics for the cable.

raceway: any channel designed for holding wires or cables, e.g., conduit, electrical metallic tubing, sleeves, slots, underfloor raceways, cellular floors, surface raceways, lighting fixture raceways, wireways, cable troughs, busways, auxiliary gutters, and ventilated flexible cableways.

screen: see shield.

sheath: see cable sheath.

shield (screen): a metallic layer placed around a conductor or group of conductors.

NOTE - The shield may be the metallic sheath of the cable or the metallic layer inside a nonmetallic sheath.

single-mode optical fiber: an optical fiber that will allow only one mode to propagate; this fiber is typically a step index fiber.

space, telecommunications: an area used for housing the installation and termination of telecommunications equipment and cable, e.g., telecommunications closets, work areas, and manhole/handholes.

splice: a joining of conductors generally from separate sheaths.

splice closure: a device used to protect a cable or wire splice.

star topology: a topology in which each telecommunications outlet/connector is directly cabled to the distribution device.

telecommunications: any transmission, emission, or reception of signs, signals, writings, images, and sounds, that is information of any nature by cable, radio, optical, or other electromagnetic systems.

telecommunications closet: see closet, telecommunications.

telecommunications entrance facility: see entrance facility, telecommunications.

telecommunications entrance point: see entrance point, telecommunications.

telecommunications entrance room or space: see entrance room or space, telecommunications.

telecommunications equipment room: see equipment room, telecommunications.

telecommunications grounding busbar: a common point of connection for telecommunications system and bonding to ground, and located in the telecommunications closet or equipment room.

telecommunications infrastructure: see infrastructure, telecommunications.

telecommunications outlet/connector: see outlet/connector, telecommunications.

terminal:

- a) a point at which information may enter or leave a communications network; or
- b) the input-output associated equipment; or
- c) a device by means of which wires may be connected to each other.

termination hardware: this term is outmoded, use connecting hardware.

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

transfer impedance: the ratio of the induced voltage of the conductors enclosed by the shield to the shield of the cable, connector, or cable assembly.

transition point: a location in the horizontal cabling where flat undercarpet cable connects to round cable.

work area (work station): a building space where the occupants interact with telecommunications terminal equipment.

work area cable (cord): a cable assembly connecting the telecommunications outlet/connector to the terminal equipment.

3.2 Acronyms and Abbreviations

ACR	Attenuation-to-Crosstalk Ratio
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
AWG	American Wire Gauge
BER	Bit Error Rate
BICSI	Building Industry Consulting Service International
CSA	Canadian Standards Association
dB	decibel
dc	direct current
EIA	Electronic Industries Association
EMI	electromagnetic interference
EP	entrance point
ER	equipment room
FCC	Federal Communications Commission
FDDI	fiber distributed data interface
FIPS PUB	Federal Information Processing Standard Publication
FOCIS	Fiber Optic Connector Intermateability Standard
ft	foot
HC	horizontal cross-connect
HVAC	heating, ventilation, and air conditioning
Hz	hertz
IC	intermediate cross-connect
ICEA	Insulated Cable Engineers Association
IDC	insulation displacement connector
IEC	International Electrotechnical Commission
IEEE	The Institute of Electrical and Electronics Engineers
in	inch
ISDN	integrated services digital network
ISO	International Organization for Standardization
ITU-T	International Telecommunications Union-Telecommunications Standardization Section
J	joule
kHz	kilohertz
km	kilometer
kV	kilovolt

LAN	local area network
lbf	pound force
LED	light emitting diode
m	meter
Mb/s	Megabits per second
MC	main cross-connect
MDF	main distribution frame
MHz	megahertz
mm	millimeter
N	Newton
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NEXT	near end crosstalk
NIR	Near-end Crosstalk-to-Insertion Loss Ratio
nF	nanofarad
nm	nanometer
pF	picofarad
PVC	polyvinyl chloride
RH	relative humidity
rms	root mean square
SRL	structural return loss
STP	shielded twisted-pair
TC	telecommunications closet
TIA	Telecommunications Industry Association
TSB	Telecommunications System Bulletin
UL	Underwriters Laboratories
UTP	unshielded twisted-pair
WA	work area
X	cross-connect
μm	micron or micrometer

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4 HORIZONTAL CABLING

4.1 General

The horizontal cabling is the portion of the telecommunications cabling system that extends from the work area telecommunications outlet/connector to the horizontal cross-connect in the telecommunications closet. The horizontal cabling includes the horizontal cables, the telecommunications outlet/connector in the work area, the mechanical termination, and patch cords or jumpers located in the telecommunications closet.

NOTE - The term "horizontal" is used since typically the cable in this part of the cabling system runs horizontally along the floor(s) or ceiling(s) of a building.

The following list of common services and systems should be considered when the horizontal cabling is designed. (The list is not intended to be complete.)

- a) Voice telecommunications service
- b) Premises switching equipment
- c) Data communications
- d) Local area networks (LAN)
- e) Other building signaling systems

In addition to satisfying today's telecommunications requirements, the horizontal cabling should facilitate ongoing maintenance and relocation. It should also accommodate future equipment and service changes. The horizontal cabling contains the greatest quantity of individual cables in the building. After construction of the building, the horizontal cabling is often much less accessible than the backbone cabling. The time, effort, and skills required for changes can be extremely high. In addition, access to the horizontal cabling frequently causes disruption to occupants and their work. These factors make the choice and layout of horizontal cable types very important to the design of the building cabling. Consideration should be given to accommodating a diversity of user applications in order to reduce or eliminate the probability of requiring changes to the horizontal cabling as user needs evolve.

The proximity of horizontal cabling to electrical facilities that generate high levels of electromagnetic interference (EMI) shall be taken into account for metallic cabling. Motors and transformers used to support the building's mechanical requirements and copiers used in the work area are examples of these types of sources. ANSI/EIA/TIA-569 specifies separation of horizontal cabling pathways from typical sources of EMI.

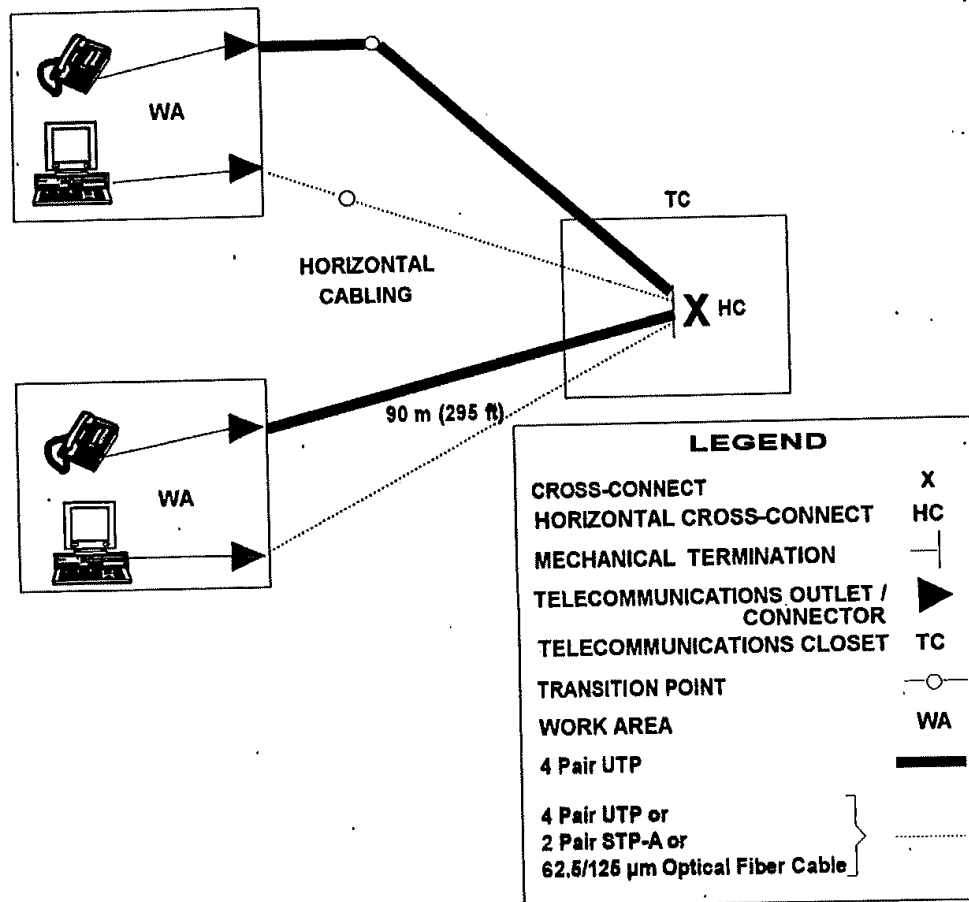
4.2 Topology

The horizontal cabling shall be a star topology as shown in figure 4-1. Each work area telecommunications outlet/connector shall be connected to a horizontal cross-connect in the telecommunications closet. Each work area should be served by a telecommunications closet located on the same floor. Some networks or services require application-specific electrical components (such as impedance matching devices) on the telecommunications outlet/connector of the horizontal cabling. These application-specific electrical components shall not be installed

as part of the horizontal cabling. When needed, such electrical components shall be placed external to the telecommunications outlet/connector. Keeping application-specific components external to the telecommunications outlet/connector will facilitate the use of the horizontal cabling for varying network and service requirements.

Horizontal cabling shall contain no more than one transition point between flat under carpet cable and one of the equivalent horizontal cables recognized in 4.4.

Bridged taps and splices shall not be permitted as part of the copper horizontal cabling.



NOTE:

Cabling between telecommunications closets for the purpose of creating "bus" and "ring" topologies is considered part of the backbone cabling. The direct connections between nearby telecommunications closets are covered in 5.2.3.

Figure 4-1 Typical Horizontal and Work Area Cabling

4.3 Horizontal Distances

The maximum horizontal distance shall be 90 m (295 ft), independent of media type (figure 4-1). This is the cable length from the mechanical termination of the media at the horizontal cross-connect in the telecommunications closet to the telecommunications outlet/connector in the work area.

Length limitations for cross-connect jumpers and patch cords in the cross-connect facilities, including horizontal cross-connects, jumpers, and patch cords that connect horizontal cabling with equipment or backbone cabling, should not exceed 6 m (20 ft) in length.

NOTE - In establishing maximum distance, for each horizontal channel, an allowance was made for 3 additional meters (9.8 ft) from the telecommunications outlet/connector to the work station. For each horizontal channel, a total of 10 m (33 ft) is allowed for cords in the work area, and for patch cords or jumpers, and for equipment cables or cords in the telecommunications closet. It is recommended that cables and connectors used for equipment cords meet or exceed performance requirements found in sections 10, 11 and 12.

4.4 Recognized Cables

Three types of cables are recognized for use in the horizontal cabling system. These cables are:

- a) four-pair 100 Ω unshielded twisted-pair (UTP) cables (10.2);
- b) two-pair 150 Ω shielded twisted-pair (STP-A) cables (11.2);
- c) two-fiber, 62.5/125 μm optical fiber cable (12.2).

At this time, 50 Ω coaxial cable is a recognized media type (See informative Annex G). It is not, however, recommended for new cabling installations and is expected to be removed from the next revision of this standard.

The specific performance characteristics for the recognized cables, associated connecting hardware, and cross-connect jumpers and patch cords are described in sections 10, 11, 12, and informative Annex G.

Hybrid cables, consisting of more than one of the recognized cables listed herein, under a common sheath, may be used in the horizontal cabling provided that they meet the requirements of 13.1.

NOTES:

- 1 The use of a generic name does not guarantee that the requirements of this standard are met.
- 2 Informative Annex G provides a brief description of a number of other horizontal cables that have been used in telecommunications. These cables, as well as others, may be effective for specific applications, and are not part of the requirements of this standard, but may be used in addition to the minimum requirements of this standard.

4.5 Choosing Media

This standard recognizes the importance of both voice and data telecommunications in a commercial building. A minimum of two telecommunications outlet/connectors shall be provided for each individual work area as shown in figure 4-1 (it is not necessary that they be on separate faceplates). One telecommunications outlet/connector may be associated with voice and the other with data. Consideration should be given to install additional outlets/connectors based on present and projected needs.

The two telecommunications outlet/connectors shall be configured as:

- a) One telecommunications outlet/connector shall be supported by a four-pair 100 Ω UTP cable, category 3 or higher.
- b) The other/second telecommunications outlet/connector shall be supported by a minimum of one of the following horizontal media. This media choice should be based upon present and projected needs.
 - 1) Four-pair 100 Ω UTP cable (category 5 recommended)
 - 2) Two-pair 150 Ω STP-A cable
 - 3) Two-fiber, 62.5/125 μm optical fiber cable

NOTE - See 10.4, 11.4, and 12.4 for requirements on compatible connectors.

4.6 Cabling Installation Practices

Proper practices should be observed for horizontal cabling to ensure initial and continuing performance of the cabling system over its life cycle. This is especially true for higher performance cables, including both copper and optical fiber cabling. Additional information regarding cabling installation practices can be found in sections 10, 11, and 12.

4.7 Grounding Considerations

Grounding systems are normally an integral part of the specific signal or telecommunications cabling system that they protect. In addition to helping protect personnel and equipment from hazardous voltages, a proper grounding system may reduce EMI to and from the telecommunications cabling system. Improper grounding can produce induced voltages and those voltages can disrupt other telecommunications circuits.

Grounding shall meet the requirements and practices of applicable authorities or codes. In addition, telecommunications grounding/bonding shall conform with ANSI/TIA/EIA-607 requirements.

5 BACKBONE CABLING

5.1 General

The function of the backbone cabling is to provide interconnections between telecommunications closets, equipment rooms, and entrance facilities in the telecommunications cabling system structure (figure 1-1). Backbone cabling consists of the backbone cables, intermediate and main cross-connects, mechanical terminations, and patch cords or jumpers used for backbone-to-backbone cross-connection. Backbone cabling also includes cabling between buildings.

It is typically not possible or economically justifiable to preinstall backbone cabling for the entire life of a telecommunications cabling system. The useful life is therefore expected to consist of one or several planning periods, each period spanning three to ten years. During each planning period, growth and changes in service requirements are intended to be accommodated without installation of additional cabling. The length of the planning period should be based upon the stability and growth of the user organization.

Prior to the beginning of each planning period, the maximum amount of backbone cabling required during the period should be projected. For each telecommunications closet, equipment room and entrance facility, the maximum number of connections over the planning period should be estimated. Sufficient backbone cabling for both copper and fiber media should then be installed to accommodate the maximum number of connections either directly or using auxiliary electronic devices.

In planning the routing and support structure for the backbone copper cabling, care shall be taken to avoid areas where sources of high levels of EMI, such as motors and transformers, may exist. ANSI/TIA/EIA-569 specifies separation of the backbone cabling pathways from typical sources of EMI.

5.2 Topology

5.2.1 Star Topology

The backbone cabling shall use the conventional hierarchical star topology as illustrated by figure 5-1 wherein each horizontal cross-connect in a telecommunications closet is cabled to a main cross-connect or an intermediate cross-connect then to a main cross-connect, except as noted in 5.2.3. There shall be no more than two hierarchical levels of cross-connects in the backbone cabling. From the horizontal cross-connect, no more than one cross-connect shall be passed through to reach the main cross-connect. Therefore, interconnections between any two horizontal cross-connects shall pass through three or fewer cross-connects. Only a single cross-connect shall be passed through to reach the main cross-connect. This also is illustrated in figure 5-1.

A single backbone cabling cross-connect (the main cross-connect) may meet cross-connect needs. Backbone cabling cross-connects may be located in telecommunications closets, equipment rooms, or at entrance facilities. Bridged taps shall not be used as part of the backbone cabling.

NOTES:

1 The topology required by this standard has been selected because of its acceptance and flexibility in meeting a variety of application requirements. The limitation to two levels of cross-connects is imposed to limit signal degradation for passive systems and to simplify moves, adds and changes. This limitation may not be suitable for facilities which have a large number of buildings or those that cover a large geographical area, such as universities, industrial parks and military bases. In these cases it may be acceptable to divide the entire facility into smaller areas within the scope of this document and then connect these areas together.

2 The star topology is applicable to the individual units of the transmission medium, such as individual fibers or twisted pairs. Depending on the physical characteristics of a site and the facility architecture, cable sub-units that are terminated at different locations may be part of the same cable over a portion of the distance or may use individual cables over the entire distance.

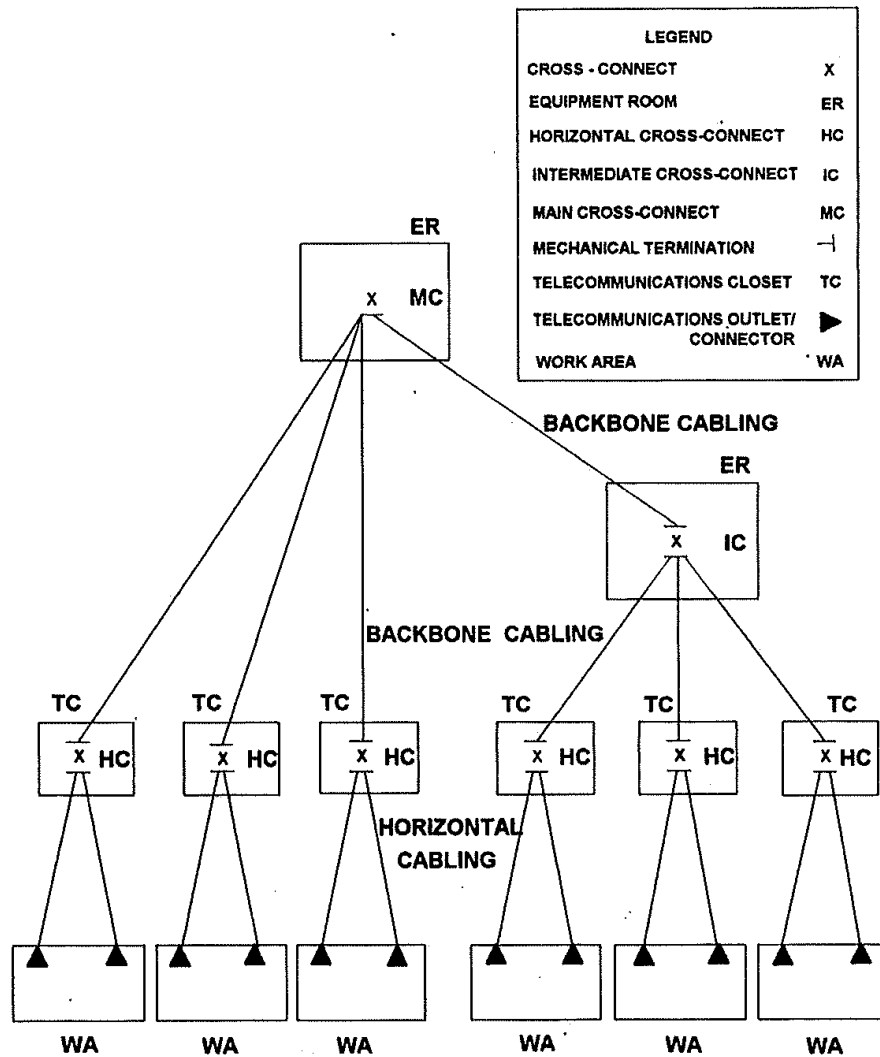


Figure 5-1 Backbone Hierarchical Star Topology

5.2.2 Accommodation of Non-Star Configurations

Systems that are designed for non-star configurations such as ring, bus, or tree, can often be accommodated by the topology in figure 5-1 through the use of appropriate interconnections, electronics, or adapters in the telecommunications closets.

5.2.3 Cabling Directly Between Telecommunications Closets

If requirements for "bus" or "ring" configurations are anticipated, cabling directly between telecommunications closets is allowed. Such cabling is in addition to the connections for the basic star topology in 5.2.1. See ANSI/EIA/TIA-569 for pathway considerations.

5.3 Recognized Cables

Due to the wide range of services and site sizes within which the backbone cabling will be used, more than one transmission medium is recognized. This standard specifies transmission media, which shall be used individually or in combination in the backbone cabling. The recognized media are:

- a) 100 Ω UTP cable (10.2 or 10.3);
- b) 150 Ω STP-A cable (11.3);
- c) 62.5/125 μm optical fiber cable (12.3.3);
- d) single-mode optical fiber cable (12.3.4).

At this time, 50 Ω coaxial cable is a recognized media type (see informative Annex G). It is not, however, recommended for new cabling installations and is expected to be removed from the next revision of this standard.

The specific performance characteristics for the recognized cables, associated connecting hardware, cross-connect jumpers and patch cords are described in sections 10, 11, 12 and informative Annex G.

NOTES:

- 1 The use of a generic name does not guarantee that the requirements of this standard are met.
- 2 Crosstalk between individual, unshielded twisted-pairs may affect the transmission performance of multipair cables. Informative Annex D provides some shared sheath guidelines on multipair cables.
- 3 Informative Annex G gives a brief description of a number of other backbone cables that have been used in telecommunications. These cables, as well as others, may be effective for specific applications, and are not part of the requirements of this standard, but may be used in addition to the minimum requirements of this standard.

5.4 Choosing Media

Backbone cabling specified by this standard is applicable to a wide range of different user requirements. Depending upon the characteristics of the individual application, choices with respect to transmission media have to be made. In making this choice, factors to be considered include:

- a) flexibility with respect to supported services;
- b) required useful life of backbone cabling;
- c) site size and user population.

Commercial building occupants' needs for telecommunications services vary over time and from occupant to occupant. Plans for the future use of the backbone cabling may range from highly predictable to very uncertain. Whenever possible, the different service requirements should first be determined. It is often convenient to group similar services together in a few categories such as voice, display terminal, Local Area Networks (LAN) and other digital connections. Within each group, individual types should be identified and required quantities projected.

When uncertain, use "worst case" scenarios when evaluating different backbone cabling alternatives. The higher the uncertainty, the more flexible the backbone cabling system needs to be.

Each recognized cable has individual characteristics that make it useful in a variety of situations. A single cable type may not satisfy all the user requirements at a site. It is then necessary to use more than one medium in the backbone cabling. In those instances the different media shall use the same facility architecture with the same location for cross-connects, mechanical terminations, interbuilding entrance facilities, etc.

5.5 Backbone Cabling Distances

5.5.1 Intra and Inter-Building Distances

The maximum distances are application dependent. The maximum distances specified in figure 5-2 are based on voice transmission for UTP and data transmission for fiber. The following distance limitations are listed for other applications.

To minimize cabling distances, it is often advantageous to locate the main cross-connect near the center of a site. Installations that exceed these distance limits may be divided into areas, each of which can be supported by backbone cabling within the scope of this standard. Interconnections between the individual areas, which are outside the scope of this standard, may be accomplished by employing equipment and technologies normally used for wide area applications.

The use of category 3 multipair UTP backbone cabling, for applications whose spectral bandwidth is in the range of 5 MHz to 16 MHz, should be limited to a total of 90 m (295 ft).

The use of category 4 multipair UTP backbone cabling, for applications whose spectral bandwidth is in the range of 10 MHz to 20 MHz, should be limited to a total of 90 m (295 ft).

The use of category 5 multipair UTP backbone cabling for applications whose spectral bandwidth is in the range of 20 MHz to 100 MHz, should be limited to a total distance of 90 m (295 ft).

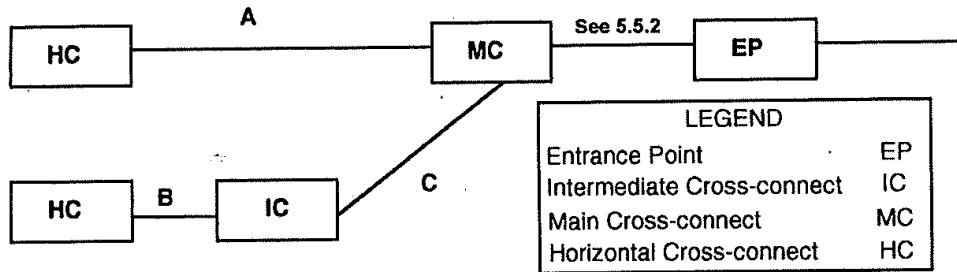
The use of 150 Ω STP-A backbone cabling for applications whose spectral bandwidth is in the range of 20 MHz to 300 MHz, should be limited to a total distance of 90 m (295 ft).

The 90 m (295 ft) distance assumes that 5 m (16 ft) are needed at each end for equipment cables (cords) connecting to the backbone.

NOTES:

1 The 90 m (295 ft) distance limitation assumes uninterrupted cabling runs between cross-connects that serve equipment (i.e., no intermediate cross-connect).

2 Users of this document are advised to consult other standards associated with the planned service or equipment in order to determine distance limitations for frequencies not listed herein. The user should also consult with systems suppliers, equipment manufacturers and systems integrators to determine the suitability of the cabling described herein for specific applications.



Media Type	A	B	C
UTP	800 m (2624 ft) maximum See 5.5.1	500 m (1640 ft) maximum See 5.5.1	300 m (984 ft) See 5.5.1
STP-A	See 5.5.1	See 5.5.1	See 5.5.1
62.5 μ m optical fiber	2000 m (6560 ft) maximum	500 m (1640 ft) maximum	1500 m (4920 ft)
Single-mode optical fiber	3000 m (9840 ft) maximum	500 m (1640 ft) maximum	2500 m (8200 ft)

NOTES:

1 While it is recognized that the capabilities of single-mode fiber may allow for backbone link distances of up to 60 km (37 miles), this distance is generally considered to extend outside the scope of this standard.

2 Specific applications may exist, or become available in the future, that do not operate properly over the maximum distances specified. For example, to support local exchange carrier and other provider services, it may be necessary to insert repeaters or regenerators (outside the scope of this standard) along the backbone cabling.

Figure 5-2 Backbone Distances

When the HC to IC distance is less than maximum, the IC to MC distance for optical fiber can be increased accordingly but the total distance from the HC to the MC shall not exceed the maximum of 2000 m (6560 ft) for 62.5 μ m optical fiber cable or 3000 m (9840 ft) for single-mode optical fiber cable.

When the HC to IC distance is less than maximum, the IC to MC distance for UTP cabling can be increased accordingly but the total distance from the HC to the MC shall not exceed the maximum of 800 m (2624 ft).

5.5.2 Main Cross-connect to Entrance Point

The distance between the entrance point and the main cross-connect shall be included in the total distance calculations when regulatory policies within the jurisdiction, which relate to the location of the demarcation point, deem it appropriate (see 9.3). The length and type of media (including gauge size for copper), shall be recorded and should be made available to the service provider upon request.

5.5.3 Cross-connections

In the main cross-connect, jumper and patch cord lengths should not exceed 20 m (66 ft). In the intermediate cross-connect, jumper and patch cord lengths shall not exceed 20 m (66 ft).

5.5.4 Cabling to Telecommunications Equipment

Telecommunications equipment that connects directly to main or intermediate cross-connections should do so via cables of 30 m (98 ft) or less.

5.5.5 Link Performance of Backbone Cabling

This subject is under study.

5.6 Cabling Installation Practices

Proper practices should be observed for backbone cabling to ensure initial and continuing performance of the cable facility over its life cycle. This is especially true for higher performance cables, including both copper and optical fiber cabling. Additional information regarding cabling installation practices can be found in sections 10, 11, and 12.

5.7 Grounding Considerations

Grounding systems are normally an integral part of the specific signal or telecommunications cabling system that they protect. In addition to helping protect personnel and equipment from hazardous voltages, a proper grounding system may reduce EMI to and from the telecommunications cabling system. Improper grounding can produce induced voltages and those voltages can disrupt other telecommunications circuits.

Grounding shall meet the appropriate requirements and practices of applicable authorities or codes. Additionally, grounding/bonding shall conform with ANSI/TIA/EIA-607 requirements.

6 WORK AREA

The work area components extend from the telecommunications outlet/connector end of the horizontal cabling system to the station equipment and are outside the scope of this standard. The station equipment can be any of a number of devices including but not limited to telephones, data terminals and computers. Work area cabling is critical to a well-managed distribution system; however, it is generally non-permanent and designed so that it is relatively easy to change. A separate specification of the work area cabling therefore is not included in this standard.

The maximum horizontal cable length has been specified in 4.3 with the assumption that a maximum length of 3 m (9.8 ft) of patch cord has been used in the work area. It is recommended that cables and connectors used in the work area meet or exceed patch cord performance requirements in sections 10, 11, and 12.

Work area cabling may vary in form depending on the application. A cord with identical connectors on both ends is commonly used. When application specific adaptations are needed at the work area, they shall be external to the telecommunications outlet/connector (see 4.2). Some of the most commonly encountered adaptations at the work area are:

- a) A special cable or adapter is required when the equipment connector is different from the telecommunications outlet/connector.
- b) A "Y" adapter is required when two services run on a single cable.
- c) Passive adapters may be needed when the cable type (media) in the horizontal cabling is different from the cable type (media) required by the equipment.
- d) Active adapters may be needed when connecting devices which use different signaling schemes.
- e) In some cases, pair transposition may be necessary for compatibility.
- f) Some telecommunications equipment (e.g., ISDN terminals) requires termination resistors in the work area (see 4.2).

NOTE - When used, cabling adapters in the work area may have detrimental effects on the transmission performance of the telecommunications cabling system. Therefore, it is important that their compatibility with premises cabling and equipment be considered before they are connected to the telecommunications network.

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7 TELECOMMUNICATIONS CLOSETS

7.1 General

Telecommunications closets provide many different functions for the cabling system and are often treated as a distinct sub-system within the hierarchical cabling system described in sections 4 and 5. This section describes the various functions provided by the telecommunications closet from a cabling perspective. This section also lists various cabling practices and includes guidelines showing the trade-offs between cross-connections and direct inter-connections.

7.2 Design

Telecommunications closets shall be designed and provisioned according to the requirements in ANSI/EIA/TIA-569.

7.3 Functions

The primary function of a telecommunications closet is for the termination of horizontal cable distribution. Horizontal cables of all recognized types are terminated in the telecommunications closet on compatible connecting hardware. Similarly, recognized types of backbone cable are also terminated in the telecommunications closet on compatible connecting hardware. The cross-connection of horizontal and backbone cable terminations using jumpers or patch cords allows flexible connectivity when extending various services to telecommunications outlet/connectors. Connecting hardware, jumpers, and patch cords used for this purpose are collectively referred to as "horizontal cross-connect".

A telecommunications closet may also contain the intermediate cross-connect or the main cross-connect for different portions of the backbone cabling system. Sometimes backbone-to-backbone cross-connections in the telecommunications closet are used to tie different telecommunications closets together in a ring, bus, or tree configuration as described in 5.2.

A telecommunications closet also provides a controlled environment to house telecommunications equipment, connecting hardware and splice closures serving a portion of the building. In some cases, the demarcation point and associated protection apparatus may be located in the telecommunications closet.

7.4 Cabling Practices

Cable management precautions should be observed, including the elimination of cable stress caused by cable tension. Cables should not be routed in tightly cinched bundles. Appropriate cable routing and dressing fixtures should be used for effective organization and management of the different types of cables in telecommunications closets. Additional information regarding cabling installation practices can be found in sections 10, 11, and 12.

7.4.1 Cross-connections and Interconnections

Horizontal and backbone building cables shall be terminated on connecting hardware that meets the requirements of this standard. These cable terminations shall not be used to administer cabling system moves, adds, and changes. All connections between horizontal and backbone cables shall be made through a horizontal cross-connect.

Equipment cables that consolidate several ports on a single connector shall be terminated on dedicated connecting hardware. Equipment cables that extend a single port appearance may either be permanently terminated or interconnected directly to horizontal or backbone terminations. Direct interconnections reduce the number of connections in a link but may reduce flexibility. See figure 7-1.

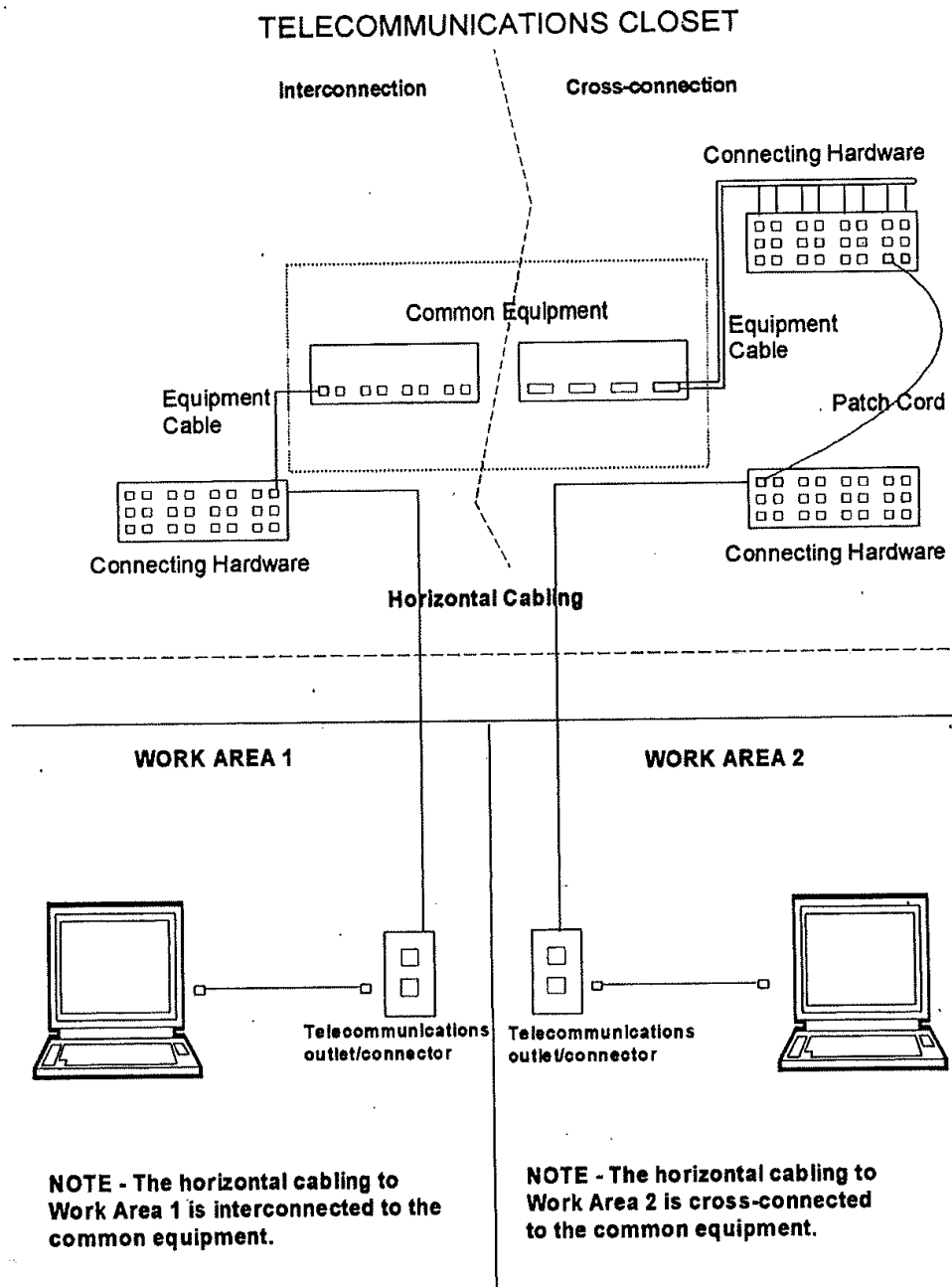


Figure 7-1 Illustration of InterConnection and Cross-Connection Schemes

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8 EQUIPMENT ROOMS

8.1 General

Equipment rooms are considered to be distinct from telecommunications closets because of the nature or complexity of the equipment they contain. Any or all of the functions of a telecommunications closet may be alternately provided by an equipment room.

8.2 Design

Equipment rooms shall be designed and provisioned according to the requirements in ANSI/TIA/EIA-569.

8.3 Functions

An equipment room provides a controlled environment to house telecommunications equipment, connecting hardware, splice closures, grounding and bonding facilities and protection apparatus where applicable.

From a cabling perspective, an equipment room contains either the main cross-connect or the intermediate cross-connect used in the backbone cabling hierarchy.

An equipment room may also house equipment terminations (and may contain horizontal terminations for a portion of the building). In many cases, the equipment room contains network trunk terminations and auxiliary terminations that are under the control of the premises cabling administrator.

8.4 Cabling Practices

Cabling practices described in 7.4 for telecommunications closets are also applicable to equipment rooms.

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9 ENTRANCE FACILITIES

9.1 General

The entrance facility consists of the cables, connecting hardware, protection devices, and other equipment needed to connect the outside plant facilities to the premises cabling. These components may be used for public network services, private network customer premises services, or both. The demarcation point between the regulated carriers/services providers and the customer premises cabling may be part of the entrance facility.

9.2 Design

The entrance facility pathway(s) and space(s) shall be designed and installed in accordance with the requirements of ANSI/EIA/TIA-569.

9.3 Functions

9.3.1 Network Demarcation Point

The demarcation point between the service providers and the customer premises cabling may be part of the entrance facilities. The location of this point for regulated carriers (Local Telephone Companies) is determined by federal/state regulations. The carrier should be contacted to determine the location policies in effect in the area.

9.3.2 Electrical Protection

Electrical protection is governed by the applicable electrical codes. Interbuilding backbone cables and antennas may require protection devices. Service providers should be contacted to determine the needs and policies.

9.3.3 Bonding and Grounding

The bonding and grounding requirements of ANSI/TIA/EIA-607 shall be followed.

9.3.4 Entrance Facility Connections

The entrance facilities include connections between cabling used in the outside environment and cabling authorized for in-building distribution. This connection may be accomplished via a splice or other means.

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10 100 Ω UNSHIELDED TWISTED-PAIR (UTP) CABLING SYSTEMS

10.1 General

This section covers requirements of cable and connecting hardware for the horizontal and backbone cabling systems. When the specifications for 100 Ω UTP cables and connecting hardware were first published in ANSI/EIA/TIA-568 in 1991, they were adequate for the range of frequencies found in office environments. Subsequently, TSB 36, TSB 40, and TSB 40A provided interim specifications for three categories of UTP cables and connecting hardware for high-frequency, high-bandwidth applications. Additional analysis refined both the cable and connecting hardware specifications and test methods. These changes are incorporated herein.

As transmission rates increase and users migrate to higher performance UTP cabling, it is important that the mechanical properties and transmission categories of components used in the same cabling system be properly matched to assure a consistently high level of dependability and transmission performance. This section specifies essential physical and transmission characteristics for the media and connecting hardware.

NOTE - For specific applications, users of this document are advised to consult other standards associated with the planned service or equipment in order to determine any system limitations. The user should also consult with systems suppliers, equipment manufacturers and systems integrators to determine the suitability of the cabling described herein.

The recognized categories of UTP cabling are:

- a) Category 3: This designation applies to 100 Ω UTP cables and associated connecting hardware whose transmission characteristics are specified up to 16 MHz.

NOTE - UTP specifications provided in the prior edition of this standard are consistent with the Category 3 specifications for horizontal cables and connecting hardware used with 100 Ω UTP cables.

- b) Category 4: This designation applies to 100 Ω UTP cables and associated connecting hardware whose transmission characteristics are specified up to 20 MHz.
- c) Category 5: This designation applies to 100 Ω UTP cables and associated connecting hardware whose transmission characteristics are specified up to 100 MHz.

Categories 1 and 2 cables and connecting hardware are not recognized as part of this standard and therefore their transmission characteristics are not specified.

All cable and connecting hardware shall meet the requirements of the applicable codes in that jurisdiction.

NOTE - Transmission parameters other than those specified in this section such as longitudinal conversion loss and longitudinal transfer conversion loss are under study.

The total number of measurement points within the specified frequency range shall be a minimum of 100 times the number of decades covered by the specified frequency range using linear or logarithmic frequency spacing.

10.2 Horizontal UTP Cable

10.2.1 General

Covered herein are the requirements for UTP cable for use in the horizontal cabling system. The cable consists of 24 AWG thermoplastic insulated solid conductors formed into four individually twisted pairs and enclosed by a thermoplastic jacket. The cable shall meet all requirements of ANSI/ICEA S-80-576 that are applicable to four-pair inside wiring cable for plenum or general cabling within a building.

NOTE - Cables enclosing the four unshielded twisted-pairs with an overall shield, (100 Ω screened twisted-pair cables) that meet the transmission requirements of 10.2 may be used. The mechanical and physical specifications of screened twisted-pair cables are under study. Refer to informative Annex G for information regarding the use of 100 Ω screened twisted-pair cables.

10.2.2 Applicability

The transmission characteristics presented herein apply to cables consisting of four unshielded twisted pairs of 24 AWG thermoplastic insulated solid conductors and enclosed by a thermoplastic jacket. Four-pair, 22 AWG cables that meet or exceed these requirements may also be used.

10.2.3 Mechanical

In addition to the applicable requirements of ANSI/ICEA S-80-576, the physical design of the cable shall meet 10.2.3.1 to 10.2.3.6 inclusive.

10.2.3.1 Insulated Conductor

The diameter of the insulated conductor shall be 1.22 mm (0.048 in) maximum.

10.2.3.2 Pair Assembly

The cable shall be restricted to four-pair size to support a broad range of applications. The pair twist lengths shall be selected by the manufacturer to ensure compliance with the crosstalk requirements of this standard.

10.2.3.3 Color Codes

The color code shall be as shown in table 10-1.

Table 10-1 Color Codes for Horizontal 100 Ω UTP Cable		
Conductor Identification	Color Code	Abbreviation
Pair 1	White-Blue (NOTE 1) Blue (NOTE 2)	(W-BL) (BL)
Pair 2	White-Orange (NOTE 1) Orange (NOTE 2)	(W-O) (O)
Pair 3	White-Green (NOTE 1) Green (NOTE 2)	(W-G) (G)
Pair 4	White-Brown (NOTE 1) Brown (NOTE 2)	(W-BR) (BR)
NOTES:		
1 The wire insulation is white, and a colored marking is added for identification. For cables with tightly twisted pairs [all less than 38.1 mm (1.5 in) per twist] the mate conductor may serve as the marking for the white conductor.		
2 A white marking is optional.		

10.2.3.4 Cable Diameter

The diameter of the completed cable shall be less than 6.35 mm (0.25 in).

10.2.3.5 Breaking Strength

The ultimate breaking strength of the completed cable, measured in accordance with ASTM D 4565, shall be 400 N (90 lbf) minimum.

10.2.3.6 Bending Radius

The cable tested in accordance with ASTM D 4565, Wire and Cable Bending Test shall withstand a bend radius of 25.4 mm (1 in) at a temperature of $-20\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ without jacket or insulation cracking. For certain applications (e.g., precabling buildings in cold climate) a cable with a lower temperature bending performance of $-30\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ may be required.

10.2.4 Transmission**10.2.4.1 DC Resistance**

The resistance of any conductor, measured in accordance with ASTM D 4566, shall not exceed 9.38 Ω per 100 m (328 ft) at or corrected to a temperature of $20\text{ }^{\circ}\text{C}$.

10.2.4.2 DC Resistance Unbalance

The resistance unbalance between the two conductors of any pair shall not exceed 5% when measured at or corrected to a temperature of 20 °C in accordance with ASTM D 4566.

10.2.4.3 Mutual Capacitance

The mutual capacitance of any pair at 1 kHz and measured at or corrected to a temperature of 20 °C, should not exceed 6.6 nF per 100 m (328 ft) for category 3 cable and should not exceed 5.6 nF per 100 m (328 ft) for category 4 and category 5 cables. The measurements are performed in accordance with ASTM D 4566. Mutual capacitance value is provided for engineering design purposes only and is not a requirement for conformance testing.

10.2.4.4 Capacitance Unbalance: Pair to Ground

The capacitance unbalance to ground at 1 kHz of any pair, measured in accordance with ASTM D 4566 and 10.2.4.9, shall not exceed 330 pF per 100 m (328 ft) at or corrected to a temperature of 20 °C.

10.2.4.5 Characteristic Impedance and Structural Return Loss (SRL)

The different categories of horizontal UTP cable specified in this document shall all have a characteristic impedance of $100 \Omega \pm 15\%$ in the frequency range from 1 MHz up to the highest referenced frequency when measured in accordance with ASTM D 4566 Method 3. Characteristic impedance has a specific meaning for an ideal transmission line (i.e., a cable whose geometry is fixed and does not vary along the length of cable).

NOTE - The characteristic impedance is commonly derived from swept frequency input impedance measurements using a network analyzer with an s-parameter test set. As a result of structural non-uniformities, the measured input impedance for an electrically long length of cable (greater than $1/8$ th wavelength) will fluctuate as a function of frequency. These random fluctuations are superimposed on the curve for characteristic impedance which asymptotically approaches a fixed value at frequencies above 1 MHz. The characteristic impedance can be obtained from these measurements by using a smoothing function over the bandwidth of interest.

The fluctuation in input impedance is related to the SRL for a cable that is terminated in its own characteristic impedance. The values of SRL are dependent on frequency and cable construction.

The SRL, measured in accordance with ASTM D 4566 Method 3, shall be greater than or equal to the values given in table 10-2 for all frequencies from 1 MHz to the highest referenced frequency for a length of 100 m (328 ft) or longer.

Table 10-2 Horizontal UTP Cable SRL (Worst Pair)			
Frequency (f)	Category 3 (dB)	Category 4 (dB)	Category 5 (dB)
1 - 10 MHz	12	21	23
10 - 16 MHz	$12 - 10 \log (f/10)$	$21 - 10 \log (f/10)$	23
16 - 20 MHz	--	$21 - 10 \log (f/10)$	23
20 - 100 MHz	--	--	$23 - 10 \log (f/20)$

Where f = frequency in MHz

10.2.4.6 Attenuation

The attenuation is commonly derived from swept frequency signal level measurements at the output of cable lengths greater than or equal to 100 m (328 ft) of cable. The maximum attenuation of any pair, in dB per 100 m, measured at or corrected to a temperature of 20 °C in accordance with ASTM D 4566 and 10.2.4.9 shall be less than or equal to the value determined using the formula :

$$\text{Attenuation } (f) \leq k1 \sqrt{f} + k2 f + k3/\sqrt{f}$$

for all frequencies (f) in MHz from 0.772 MHz to the highest referenced frequency. The value of the constants shown in table 10-3 shall be used with the formula above to compute attenuation values.

Table 10-3 Constants for Attenuation Formula			
	k1	k2	k3
Category 3	2.320	0.238	0.000
Category 4	2.050	0.043	0.057
Category 5	1.967	0.023	0.050

NOTE - The above formula is applicable only from 0.772 MHz to the highest referenced frequency for each category and is not valid outside of this range.

Table 10-4 gives values of attenuation at specific frequencies in the band of interest. These values are provided for engineering information and are derived from the above formula rounded to the nearest decimal place. Attenuation values below 0.772 MHz are not derived from the

formula, but are typical and included for engineering information only and are not required for conformance testing.

The cable attenuation shall be verified at a temperature of 40 °C and 60 °C and shall meet the requirements of the formula above after adjusting for temperature. The maximum attenuation determined using the above formula shall be adjusted at elevated temperatures using a factor of 0.4 % increase per °C for category 4 and 5 cables.

Table 10-4
Horizontal UTP Cable Attenuation
(per 100 m (328 ft) @ 20 °C)

Frequency (MHz)	Category 3 (dB)	Category 4 (dB)	Category 5 (dB)
0.064	0.9	0.8	0.8
0.256	1.3	1.1	1.1
0.512	1.8	1.5	1.5
0.772	2.2	1.9	1.8
1.0	2.6	2.2	2.0
4.0	5.6	4.3	4.1
8.0	8.5	6.2	5.8
10.0	9.7	6.9	6.5
16.0	13.1	8.9	8.2
20.0	—	10.0	9.3
25.0	—	—	10.4
31.25	—	—	11.7
62.5	—	—	17.0
100.0	—	—	22.0

NOTE - The attenuation of some category 3 UTP cables, such as those with PVC insulation, exhibits a significant temperature dependence. A temperature coefficient of attenuation of 1.5 % per °C is not uncommon for such cables. In particular installations where the cable will be subjected to higher temperatures, a less-temperature dependent cable may be required.

10.2.4.7 Near End Crosstalk (NEXT) Loss

NEXT loss is commonly derived from swept frequency measurements using a network analyzer or an s-parameter test set. A balanced input signal is applied on a disturbing pair while the crosstalk signal is measured in accordance with ASTM D 4566 at the output port on a disturbed pair at the near end of the cable.

NEXT loss decreases as the frequency increases. The minimum NEXT loss for any pair combination at room temperature shall be greater than the value determined using the formula:

$$\text{NEXT}(f) \geq \text{NEXT}(0.772) - 15 \log\left(\frac{f}{0.772}\right)$$

for all frequencies (f) in MHz in the range from 0.772 MHz to the highest referenced frequency for a length of 100 m (328 ft) or longer.

The NEXT value at 0.772 MHz shall be 43 dB for category 3 cable, 58 dB for category 4 cable and 64 dB for category 5 cable.

Table 10-5 gives values of worst pair NEXT loss at specific frequencies in the band of interest. These values are provided for engineering information and are derived from the above formula truncated to the nearest dB.

Frequency (MHz)	Category 3 (dB)	Category 4 (dB)	Category 5 (dB)
0.150	53	68	74
0.772	43	58	64
1.0	41	56	62
4.0	32	47	53
8.0	27	42	48
10.0	26	41	47
16.0	23	38	44
20.0	--	36	42
25.0	--	--	41
31.25	--	--	39
62.5	--	--	35
100.0	--	--	32

NOTE - 0.150 MHz is for reference purposes only.

10.2.4.8 Propagation Delay

The propagation delay of any pair at 10 MHz should not exceed 5.7ns/m.

10.2.4.9 Measurement Precaution

The transmission measurements of mutual capacitance, capacitance unbalance, characteristic impedance, SRL, attenuation, and NEXT shall be performed on cable samples of 100 m (328 ft) or greater removed from the reel or packages. The test sample shall be laid out along a non-conducting surface, loosely coiled, or supported in aerial spans. On-reel or packaged cable measurements that satisfy the performance requirements of 10.2 are acceptable. In case of conflict, the first method (off-reel or unpackaged) shall provide conformance to the minimum requirements of this standard.

It may be desirable to perform measurements on lengths of cable greater than 100 m (328 ft) to improve measurement accuracy at frequencies of 1 MHz or below.

NOTE - Attenuation shall be measured using the method outlined in ASTM D 4566. The sample length shall exhibit no less than 3 dB at the lowest frequency tested. More than one length may be required to test a full range of frequencies.

Cable tested for attenuation at elevated temperatures shall be placed inside an air-circulating oven until the cable has stabilized at the referenced temperatures. No more than 3 m (9 ft) of each cable end should exit the oven for connection to the measurement equipment.

10.2.5 Performance Marking

Horizontal UTP cable should be marked to designate transmission performance at the discretion of the manufacturer or the approval agency. If provided, these markings should be clearly visible on or through the outer jacket.

NOTE - Performance markings are in addition to, and do not replace, other markings required by listing agencies or those needed to satisfy electrical code or local building code requirements.

10.3 Backbone UTP Cabling

10.3.1 General

Covered herein are the requirements for multipair backbone cables in pair sizes greater than 4 pairs for use in the backbone cabling system. Multipair backbone cables consist of 24 AWG thermoplastic insulated copper conductors that are formed into one or more units of unshielded twisted pairs. The units are assembled into binder groups of 25 pairs or part thereof following the standard industry color code (ANSI/ICEA S-80-576). The groups are identified by distinctly colored binders and assembled to form the core. The core is covered by a protective sheath. The sheath consists of an overall thermoplastic jacket and may contain an underlying metallic shield and one or more layers of dielectric material applied over the core.

10.3.2 Applicability

The cable shall meet the requirements of ANSI/ICEA S-80-576 applicable to multipair cable. The cable shall be listed and marked as required by the applicable national and local building code requirements.

NOTES:

- 1 Multipair, 22 AWG cables that meet the transmission requirements of 10.3 may also be used.
- 2 Multipair screened twisted-pair cables that meet the transmission requirements of 10.3 may also be used. The mechanical and physical specifications are under study.

10.3.3 Mechanical

In addition to the applicable requirements of ANSI/ICEA S-80-576, the physical design of the cable shall meet the following specifications.

10.3.3.1 Insulated Conductor

The diameter over the insulation shall be 1.22 mm (0.048 in) maximum.

10.3.3.2 Pair Assembly

The pair twist lengths shall be selected by the manufacturer to ensure compliance with the crosstalk requirements of this standard.

10.3.3.3 Color Code

The conductor identification shall be indicated by coloring the insulation used on each conductor of a twisted-pair. The color code shall follow the industry standard color code composed of 10 distinctive colors to identify 25 pairs (refer to ANSI/ICEA S-80-576 for appropriate colors). For backbone cables with fewer than 25 pairs, colors shall be consistent with the industry standard color code starting from pair 1 up to the number of pairs in the cable. Marking of each conductor of a pair using its mate's color is optional.

10.3.3.4 Core Assembly

When cable sizes larger than 25 pairs are required, the core shall be assembled in units or subunits of up to 25 pairs. Each unit or subunit shall be identified by color-coded binders in accordance with ANSI/ICEA S-80-576 or the manufacturer's specifications. Binder color-code integrity shall be maintained whenever cables are spliced.

10.3.3.5 Core Wrap

The core may be covered with one or more layers of dielectric material of adequate thickness to ensure compliance with the dielectric strength requirements.

10.3.3.6 Core Shield

When an electrically continuous shield is applied over the core wrap, it shall comply with requirements in 10.3.4.9.

NOTE - Detailed information regarding shield criteria can be found in UL 444, ANSI/ICEA S-80-576 or ANSI/ICEA S-84-608.

10.3.3.7 Jacket

The core shall be enclosed by a uniform, continuous thermoplastic jacket.

10.3.4 Transmission**10.3.4.1 DC Resistance**

The resistance of any conductor, measured in accordance with ASTM D 4566, shall not exceed 9.38Ω per 100 m (328 ft) at or corrected to a temperature of 20 °C.

10.3.4.2 DC Resistance Unbalance

The resistance unbalance between the two conductors of any pair shall not exceed 5% measured at or corrected to a temperature of 20 °C in accordance with ASTM D 4566.

10.3.4.3 Mutual Capacitance

The mutual capacitance of any pair at 1 kHz, measured in accordance with ASTM D 4566 and 10.2.4.9, should not exceed 6.6 nF per 100 m (328 ft) for category 3 cables and 5.6 nF per

100 m (328 ft) for category 4 and category 5 cables at or corrected to a temperature of 20 °C. Mutual capacitance value is provided for engineering design purposes only and is not a requirement for conformance testing.

10.3.4.4 Capacitance Unbalance: Pair-to-Ground

The capacitance unbalance to ground at 1 kHz of any pair, measured at or corrected to a temperature of 20 °C in accordance with ASTM D 4566, shall not exceed 330 pF per 100 m (328 ft).

10.3.4.5 Characteristic Impedance and SRL

The backbone UTP cable shall have a characteristic impedance of $100 \Omega \pm 15\%$ in the frequency range from 1 MHz up to the highest measured frequency when measured in accordance with ASTM D 4566. Characteristic impedance has a specific meaning for an ideal transmission line (i.e., a cable whose geometry is fixed and does not vary along the length of cable).

NOTE - The characteristic impedance is commonly derived from swept frequency input impedance measurements using a network analyzer with an s-parameter test set. As a result of structural non-uniformities, the measured input impedance for an electrically long length of cable (greater than 1/8th wavelength) will fluctuate as a function of frequency. These random fluctuations are superimposed on the curve for characteristic impedance which asymptotically approaches a fixed value at frequencies above 1 MHz. The characteristic impedance can be obtained from these measurements by using a smoothing function over the bandwidth of interest.

The fluctuation in input impedance is related to the SRL for a cable that is terminated in its own characteristic impedance. The values of SRL are dependent on frequency and cable construction.

The SRL, when measured in accordance with ASTM D 4566 Method 3, shall be greater than or equal to the values given in table 10-6 for all frequencies from 1 MHz to the highest frequency for a length of 100 m (328 ft) or longer.

Table 10-6 Backbone UTP Cable SRL (Worst Pair)			
Frequency (f)	Category 3 (dB)	Category 4 (dB)	Category 5 (dB)
1 - 10 MHz	12	21	23
10 - 16 MHz	$12 - 10 \log (f/10)$	$21 - 10 \log (f/10)$	23
16 - 20 MHz	--	$21 - 10 \log (f/10)$	23
20 - 100 MHz	--	--	$23 - 10 \log (f/20)$

Where f = frequency in MHz

10.3.4.6 Attenuation

The attenuation of backbone cables shall meet the requirements for horizontal cables specified in 10.2.4.6.

The maximum attenuation given in table 10-4 shall be adjusted at elevated temperatures using a factor of 0.4% increase per °C for category 4 and category 5 cables. The cable attenuation shall be verified at a temperature of 40 °C and 60 °C and shall meet the requirements of 10.2.4.6 after adjusting for temperature.

For practical considerations involved with testing of large size cables, attenuation testing at elevated temperatures is not required for larger than 25-pair cables provided they consist of the same 25-pair binder groups and jacket material as the conforming cable.

10.3.4.7 NEXT Loss

NEXT loss is commonly derived from swept frequency measurements using a network analyzer or an s-parameter test set. A balanced input signal is applied on a disturbing pair while the crosstalk signal is measured in accordance with ASTM D 4566 at the output port on a disturbed pair at the near end of the cable.

NEXT loss decreases as the frequency increases. The minimum power sum NEXT loss within a 25-pair binder group, tested in accordance with ASTM D 4566, shall be greater than the value determined using the formula:

$$\text{NEXT}(f) \geq \text{NEXT}(0.772) - 15 \log\left(\frac{f}{0.772}\right)$$

for all frequencies (f) in MHz in the range from 0.772 MHz to the highest referenced frequency for a length of 100 m (328 ft) or longer.

The NEXT value at 0.772 MHz shall be 43 dB for category 3 cable, 58 dB for category 4 cable and 64 dB for category 5 cable.

Table 10-7 gives values of power sum NEXT loss at specific frequencies in the band of interest for all pairs. These values are provided for engineering information and are derived from the above formula truncated to the nearest dB.

Table 10-7
Backbone UTP Cable Power Sum NEXT Loss
[≥ 100 m (328 ft)]

Frequency (MHz)	Category 3 (dB)	Category 4 (dB)	Category 5 (dB)
0.150	53	68	74
0.772	43	58	64
1.0	41	56	62
4.0	32	47	53
8.0	27	42	48
10.0	26	41	47
16.0	23	38	44
20.0	--	36	42
25.0	--	--	41
31.25	--	--	39
62.5	--	--	35
100.0	--	--	32

NOTE - 0.150 MHz is for reference purposes only.

NOTE - In a multipair cable, a given pair receives crosstalk interference from other energized pairs sharing the same sheath. The total crosstalk energy that a pair receives is specified as the power sum crosstalk. The power sum crosstalk for uncorrelated disturbing pairs can be calculated from the individual pair-to-pair crosstalk measurements at a given frequency (ASTM D 4566). Generally, the power sum crosstalk energy is dominated by the couplings between pairs in close proximity and is relatively unaffected by pairs in separate binder groups. Therefore, it is desirable to separate services with different signal levels or services that are susceptible to impulse noise into separate binder groups. See informative Annex D.

10.3.4.8 Dielectric Strength

The insulation between each conductor and the core shield, when present, shall be capable of withstanding a minimum dc potential of 5 kV for 3 seconds in accordance with ASTM D 4566.

10.3.4.9 Core Shield Resistance

When a shield is present around the core, the dc resistance of the core shield shall not exceed the value given by the following equation:

$$R (\Omega/\text{km}) = 62.5/D (\text{mm})$$

or

$$R (\Omega/1000 \text{ ft}) = 0.75/D (\text{in})$$

where:
R = maximum core shield resistance
D = outside diameter of the shield

This requirement is applicable to outside plant cables or inside building cables having their shields bonded to the shields of outside plant cables at building entrances. The electrical and physical requirements of the shields of inside building cables contained within a building are under study.

10.3.4.10 Propagation Delay

The propagation delay of any pair at 10 MHz should not exceed 5.7ns/m.

10.3.4.11 Measurement Precautions

Certain measurement precautions apply to unshielded multipair backbone cable. See 10.2.4.9.

10.3.5 Performance Marking

Backbone UTP cable should be marked to designate transmission performance at the discretion of the manufacturer or the approval agency. If provided, these markings should be clearly visible on or through the outer jacket.

NOTE - Performance markings are in addition to, and do not replace, other markings required by listing agencies or those needed to satisfy electrical code or local building code requirements.

10.4 Connecting Hardware for UTP Cable**10.4.1 General**

Specified herein are mechanical and transmission performance requirements for UTP connecting hardware that are consistent with the UTP cables specified in 10.2 and 10.3. This sub-clause contains the minimum set of parameters and their associated limits necessary to assure that properly installed connectors will have minimal effects on cable performance. These requirements apply to only individual UTP connectors and connector assemblies which include, but are not limited to; telecommunications outlet/connectors, patch panels, transition connectors and cross-connect blocks.

It should be noted that requirements for connector categories 3, 4 and 5 are not sufficient in themselves to ensure required cabling system performance. Link performance also depends on cable characteristics (including cross-connect jumpers and patch cords), the total number of connections, and the care with which they are installed and maintained. For guidance and requirements on connector termination practices, cable management, the use of patch cords or cross-connect jumpers, and the effects of multiple connections, see 10.6.

It is desirable that hardware used to terminate UTP cables be of the insulation displacement contact (IDC) type.

Connecting hardware for the 100 Ω UTP cabling system is installed at the following;

- a) main cross-connect;
- b) intermediate cross-connect;
- c) horizontal cross-connect;
- d) horizontal cabling transition points;
- e) telecommunications outlet/connectors.

Typical cross-connect facilities consist of cross-connect jumpers or patch cords and terminal blocks or patch panels that are connected directly to horizontal or backbone cabling.

10.4.2 Applicability

The requirements specified herein are applicable to connecting hardware for use with 100 Ω UTP cables specified in 10.2 and 10.3. Product compliance with this specification does not imply compatibility with shielded cables or cables that are not in full compliance with 10.2 and 10.3. Unless otherwise specified, all products with plug and socket connections (e.g., modular jacks and plugs) shall be tested in a mated state.

NOTES:

- 1 This specification does not address requirements for equipment connectors, media adapters or other devices with passive or active electronic circuitry (i.e., impedance matching transformers, ISDN resistors, MAUs, filters, network interface devices, and protection devices) whose main purpose is to serve a specific application or provide safety compliance. Such cabling adapters and protection devices are treated as premises equipment that are not considered to be part of the cabling system.
- 2 Definition of a 50-pin standard backbone interface connector is under study.

10.4.3 Mechanical

10.4.3.1 Environmental Compatibility

The connecting hardware used for 100 Ω UTP cabling shall be fully functional for continuous use over the temperature range from -10 °C (14 °F) to 60 °C (140 °F). Connecting hardware shall be protected from physical damage and from direct exposure to moisture and other corrosive elements. This protection may be accomplished by installation indoors or in an appropriate enclosure for the environment.

10.4.3.2 Mounting

The connecting hardware used for 100 Ω UTP cabling should be designed to provide flexibility for mounting on walls, in racks or on other types of distribution frames and standard mounting hardware.

Telecommunications outlet/connectors shall be securely mounted at planned locations. Cables intended for future connections shall be covered with a face plate that identifies the outlet box for telecommunications use.

10.4.3.3 Mechanical Termination Density

The connecting hardware used for 100 Ω UTP cabling should have a high density to conserve space but also be of a size consistent with ease of cable management. To ensure that cross-connect fields may be properly administered as a means of field termination for jumpers, contact center spacing (front side only) should not be less than 3.1 mm (0.123 in). Other field terminated connecting hardware not classified as cross-connect devices, such as those providing direct means of terminating cable stubs with connectors, may have closer contact spacing as required by the interface constraints of the connector.

10.4.3.4 Design

The cross-connect hardware used for 100 Ω UTP cabling shall be designed to provide:

- a) means to cross-connect cables with cross-connect jumpers or patchcords;
- b) means to connect premises equipment to the 100 Ω UTP network;
- c) means to identify circuits for administration in accordance with ANSI/TIA/EIA-606;
- d) means to use standard colors as specified in ANSI/TIA/EIA-606 to functionally identify mechanical termination fields;
- e) means of handling wire and cable to permit orderly management;
- f) means of access to monitor or test cabling and premises equipment;
- g) means for protecting exposed terminals, an insulating barrier, such as a cover or a plastic shroud, for protecting terminals from accidental contact with foreign objects that may disturb electrical continuity.

Transition point and telecommunications outlet/connectors for 100 Ω UTP cable shall be designed to provide:

- a) appropriate mechanical termination means for horizontal cable runs;
- b) means of conductor identification to promote pin-pair practices consistent with 10.4.5.

10.4.3.5 Reliability

To assure reliable operation over the usable life of the cabling system, the connecting hardware used for 100 Ω UTP cabling shall meet all requirements of normative Annex A. This annex describes test procedures and performance requirements for contact resistance, insulation resistance, durability, environmental conditioning and other tests designed to assure consistently dependable and safe operation.

For connecting hardware with 8-position modular connectors, the modular connection shall comply with the Level A reliability requirements of IEC 603-7. Plug and socket connections that conform to IEC 603-7 are exempt from normative Annex A reliability testing.

10.4.4 Transmission

The connecting hardware used for 100 Ω UTP cabling shall meet the transmission requirements of 10.4.4.1 through 10.4.4.4, inclusive, when tested in accordance with the transmission test methods specified in normative Annex B. This annex describes set-up requirements and procedures necessary for accurate and repeatable transmission testing of connecting hardware used for 100 Ω UTP cabling.

10.4.4.1 Attenuation

Attenuation is a measure of signal power loss due to the connecting hardware and is derived from swept frequency voltage measurements on short lengths of 100 Ω twisted-pair test leads before and after inserting the connector under test.

Worst case attenuation of any pair within a connector shall not exceed the values listed in table 10-8 at each specified frequency for a given performance category.

Frequency (MHz)	Category 3 (dB)	Category 4 (dB)	Category 5 (dB)
1.0	0.4	0.1	0.1
4.0	0.4	0.1	0.1
8.0	0.4	0.1	0.1
10.0	0.4	0.1	0.1
16.0	0.4	0.2	0.2
20.0	--	0.2	0.2
25.0	--	--	0.2
31.25	--	--	0.2
62.5	--	--	0.3
100.0	--	--	0.4

10.4.4.2 NEXT Loss

NEXT loss is a measure of signal coupling from one circuit to another within a connector and is derived from swept frequency voltage measurements on short lengths of 100 Ω twisted-pair test leads terminated to the connector under test. A balanced input signal is applied to a disturbing pair of the connector while the induced signal on the disturbed pair is measured at the near-end of the test leads.

For all three performance categories, the worst case NEXT loss for any combination of disturbing and disturbed pairs shall be determined using the formula:

$$\text{NEXT}(f) \geq \text{NEXT}(16) - 20 \log \left(\frac{f}{16} \right)$$

Where NEXT(16) is the minimum NEXT loss at 16 MHz, f is frequency (in MHz) in the range from 1 MHz to the highest referenced frequency, and NEXT(f) is the performance at that frequency.

To determine NEXT loss requirements at a given frequency, the value for NEXT(16) shall be 34 dB for a category 3 connector, 46 dB for a category 4 connector and 56 dB for a category 5 connector. Calculations that result in NEXT loss values in excess of 65 dB shall revert to a requirement of 65 dB minimum. Table 10-9 gives values of worst-pair NEXT loss at specific frequencies in the band of interest. These values are provided for engineering information and are derived from the preceding formula rounded to the nearest decibel.

Frequency (MHz)	Category 3 (dB)	Category 4 (dB)	Category 5 (dB)
1.0	58	65	65
4.0	46	58	65
8.0	40	52	62
10.0	38	50	60
16.0	34	46	56
20.0	--	44	54
25.0	--	--	52
31.25	--	--	50
62.5	--	--	44
100.0	--	--	40

10.4.4.3 Return Loss

Connector return loss is a measure of the degree of impedance matching between the cable and connector and is derived from swept frequency voltage measurements on short lengths of 100 Ω twisted-pair test leads before and after inserting the connector under test. A balanced input signal is applied to a connector pair while signals that are reflected back due to impedance discontinuities are measured at the same port from which the signal is applied. The same set-up that is used for NEXT loss measurements is also used for return loss, except that only a single connection is made to the network analyzer.

Because the return loss characteristics of category 3 connecting hardware are not considered to have a significant effect on the link performance of category 3 UTP cabling, return loss requirements are not specified for category 3 connectors.

For category 4 and 5 connectors the minimum return loss shall be 23 dB or greater for all frequencies between 1 and 20 MHz. For all frequencies from 20 to 100 MHz, category 5 connectors shall exhibit a minimum return loss of 14 dB or greater. These return loss values are chosen to limit peak reflected voltage to 7% or less up to 20 MHz and to 20% or less from 20 to 100 MHz.

10.4.4.4 DC Resistance

The dc resistance between the input and output connections of the connecting hardware (not including the cable stub, if any) used for 100 Ω cabling shall not exceed 0.3 Ω when tested in accordance with ASTM D 4566.

NOTE - dc resistance is a separate measurement from the contact resistance measurements required in normative Annex A. Whereas dc resistance is measured to determine the connector's ability to transmit direct current and low frequency signals, contact resistance

measurements are used to determine the reliability and stability of individual electrical connections.

10.4.5 Telecommunications Outlet/Connector

Each four-pair cable shall be terminated in an eight-position modular jack at the work area. The 100 Ω UTP telecommunications outlet/connector shall meet the modular interface requirements specified in IEC 603-7: *Connectors for Frequencies Below 3 MHz for use with Printed Circuit Boards, Part 7: Detailed specification for connectors, 8-way, including fixed and free connectors with common mating features*. In addition, the telecommunications outlet/connector for 100 Ω UTP cable shall meet the requirements of 10.4.3 and 10.4.4 as well as the terminal marking and mounting requirements specified in EIA/TIA-570.

Pin/pair assignments shall be as shown in figure 10-1 or, optionally, per figure 10-2 if necessary to accommodate certain 8-pin cabling systems. The colors shown are associated with horizontal distribution cable (table 10-1). These illustrations depict the front view of the outlet/connector.

NOTES:

1 Although the title of IEC 603-7 appears to limit the bandwidth of 8-way modular connectors to 3 MHz or less, these types of connectors may be qualified for use at higher frequencies when tested and proven to be compliant with the performance requirements specified in 10.4.4.

2 U.S. Federal Government publication FIPS PUB 174 recognizes designation T568A only.

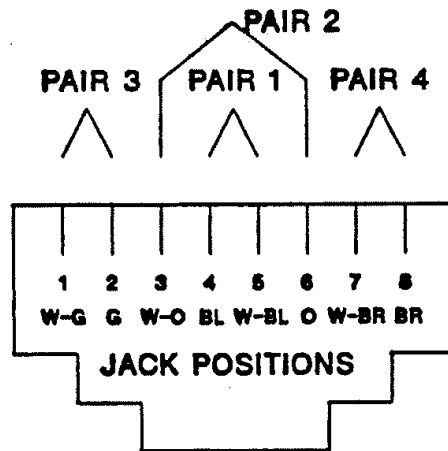


Figure 10-1 Eight-Position Jack Pin/Pair Assignments
(designation T568A)

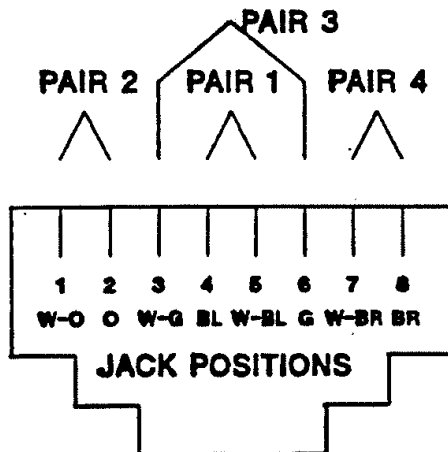


Figure 10-2 Optional Eight-Position Jack Pin/Pair Assignments
(designation T568B)

10.4.6 Performance Marking

Connecting hardware should be marked to designate transmission performance at the discretion of the manufacturer or the approval agency. The markings, if any, shall be visible during installation. It is suggested that such markings consist of:

"Cat 3" or "③" for category 3 components.

"Cat 4" or "④" for category 4 components.

"Cat 5" or "⑤" for category 5 components.

NOTES:

- 1 Performance markings are in addition to, and do not replace, other markings required by listing agencies or those needed to satisfy electrical code or local building code requirements.
- 2 Specific performance marking requirements for 100 Ω UTP cabling runs are specified in 10.6.5.

10.5 UTP Patch Cords and Cross-Connect Jumpers

10.5.1 General

Patch cords and cross-connect jumpers used for system moves, adds and changes are as critical to transmission performance as embedded horizontal cable runs. For this reason, all cross-connect jumpers and patch cords used in the 100 Ω UTP cabling system shall meet the requirements of 10.5.2 through 10.5.5 inclusive.

10.5.2 Applicability

These requirements apply only to wires and cables used for patch cords and cross-connect jumpers. Modular plugs and other connectors used for 100 Ω cable assemblies shall meet the requirements specified in 10.4.

10.5.3 Mechanical

To assure adequate flex-life, cables used for UTP patch cords shall have stranded conductors. In addition, cables used for patch cords shall meet the same mechanical performance requirements as those specified for 100 Ω horizontal UTP in 10.2, except as specified in 10.5.3.1 and 10.5.3.2. Also, stranded conductor lay lengths for 24 AWG conductors shall not exceed 15 mm (0.6 in).

10.5.3.1 Insulated Conductor

Cables intended for use in 100 Ω UTP patch cords terminated with modular plug connectors as specified in IEC 603-7 should have an insulated conductor diameter in the range of 0.8 mm (0.032 in) to 1 mm (0.039 in) and shall not exceed 1.2 mm (0.047 in).

NOTE - For cables with insulated conductor diameters in excess of 1 mm (0.039 in), a special modular plug connector may be required.

10.5.3.2 Color Codes

Color coding of cross-connect jumpers shall consist of one conductor with white insulation and another conductor with a visibly distinct color such as red or blue.

The color code of stranded cables used for patch cords shall conform to either "Color Code Option 1" or "Color Code Option 2" as shown in table 10-10.

Table 10-10 Color Codes for Stranded, 100 Ω UTP Patch Cord		
Conductor Identification	Color Code Option 1 (Abbreviation)	Color Code Option 2 (Abbreviation)
Pair 1	White-Blue (W-BL) Blue (BL) (NOTE 1)	Green (G) Red (R)
Pair 2	White-Orange (W-O) Orange (O) (NOTE 1)	Black (BK) Yellow (Y)
Pair 3	White-Green (W-G) Green (G) (NOTE 1)	Blue (BL) Orange (O)
Pair 4	White-Brown (W-BR) Brown (BR) (NOTE 1)	Brown (BR) Slate (S)
NOTES:		
1 A white marking is optional.		
2 Because of their identical pair groupings, patch cords terminated per either T568A or T568B pair assignments may be used interchangeably provided that both ends are terminated with the same pin/pair scheme.		

10.5.4 Transmission

Cross-connect jumpers and cables used for patch cords shall meet the same transmission performance requirements as those specified for 100 Ω horizontal UTP in 10.2.4, with the exceptions in 10.5.4.1.

10.5.4.1 Attenuation

For stranded wire cables, the attenuation of any pair shall be less than or equal to the value computed by multiplying the result of the attenuation equation in 10.2.4.6 by a factor of 1.2 for all frequencies (f) in MHz from 0.772 MHz to the highest referenced frequency. This is to allow a 20% increase in attenuation for stranded construction and design differences. Table 10-11 shows values of attenuation at specific frequencies in the band of interest. These values are provided for engineering information and are derived using the above computation rounded to the nearest decimal place. Testing at elevated temperatures is optional.

Table 10-11
Attenuation of Cable Used for Patch Cords
[dB per 100 m (328 ft) @ 20 °C]

Frequency (MHz)	Category 3 (dB)	Category 4 (dB)	Category 5 (dB)
0.064	1.1	1.0	1.0
0.256	1.6	1.3	1.3
0.512	2.2	1.8	1.8
0.772	2.7	2.3	2.2
1.0	3.1	2.6	2.4
4.0	6.7	5.2	4.9
8.0	10.2	7.4	6.9
10.0	11.7	8.3	7.8
16.0	15.7	10.7	9.9
20.0	—	12.0	11.1
25.0	—	—	12.5
31.25	—	—	14.1
62.5	—	—	20.4
100.0	—	—	26.4

10.5.5 Performance Marking

Cables and wires used for patch cords and cross-connect jumpers should be marked to designate transmission performance at the discretion of the manufacturer or the approval agency. If provided, these markings should be clearly visible on the outer jacket.

Performance markings are in addition to, and do not replace, other markings required by listing agencies or those needed to satisfy electrical code or local building code requirements. Performance markings that may appear on cables used for patch cord assemblies only indicate performance of the cable.

10.6 UTP Installation Practices

10.6.1 General

Cables should be terminated with connecting hardware of the same category or higher. The transmission characteristics of the cable and connector categories have been specified such that the impact of connectors, patch cords and cross-connect jumpers on link performance are minimized. Also, cross-connect jumpers and cables used for patch cords should be of the same performance category or higher as the horizontal cables to which they connect.

Connector and cable components that meet these requirements are not sufficient in themselves to ensure adequate installed cabling system performance. As with all cabling media, additional considerations that may degrade transmission performance of installed cabling systems include

cabling practices that relate to connector terminations, cable management, the use of cross-connect jumpers or patch cords and the effects of multiple connections in close proximity.

Installed transmission performance of components that meet requirements of different performance categories (i.e., cables, connectors and patch cords that are not rated for the same transmission capability) shall be classified by the least performing component in the link.

10.6.2 Applicability

The parameters used to characterize connector transmission performance are attenuation, NEXT, return loss, and dc resistance. While all of these parameters are sensitive to transmission discontinuities caused by connector terminations, NEXT performance is particularly susceptible to conductor untwisting and other poor installation practices that disturb pair balance and cause impedance variations. Besides signal degradation, improper termination practices may also create loop antenna effects resulting in levels of signal radiation that may exceed regulatory emissions requirements.

10.6.3 Mechanical

10.6.3.1 Connector Termination Practices

The connecting hardware used for 100 Ω UTP cabling shall be installed to provide minimal signal impairment by preserving wire pair twists as closely as possible to the point of mechanical termination. The amount of untwisting in a pair as a result of termination to connecting hardware shall be no greater than 13 mm (0.5 in) for category 5 cables, and shall be no greater than 25 mm (1.0 in) for category 4 cables.

This requirement is imposed to minimize untwisting of wire pairs and the separation of conductors within a pair. It is not a constraint on twist length for cable or jumper construction.

For termination fields that require frequent access, such as cross-connects used for network moves and changes, one way to control termination consistency is through the use of connectorized patch cables and patch panels that, in combination, meet appropriate category requirements. The use of patch cords for moves and changes can reduce performance variations that may be attributable to poor or inconsistent field cabling practices. If, however, jumpers are preferred, care is required in order to control the amount of untwisting as prescribed herein.

10.6.3.2 Cabling Practices

Performance specifications for cable and connecting hardware are based on the use of proper installation and cable management techniques. The connecting hardware used for 100 Ω UTP cabling shall be installed to provide well organized installation with cable management and mechanical termination practices, in accordance with manufacturer's guidelines. As with all transmission media, if recommended cabling precautions and installation methods are not observed, specified transmission capabilities of cabling components may not be achieved.

The maximum pulling tensions for 4-pair 24 AWG horizontal UTP cables should not exceed 110 N (25 lbf) to avoid stretching the conductors during installation.

Cable management precautions that should be observed include the elimination of cable stress as caused by tension in suspended cable runs and tightly cinched cable bundles. An additional cable management practice that should be observed to reduce untwisting of pairs, is to strip back

only as much cable jacket as is required to terminate on connecting hardware. Also, in spaces with UTP terminations, cable bend radii shall not be less than four-times the cable diameter for horizontal cable and shall not be less than ten-times the cable diameter for multipair cable. Care should be exercised to minimize twisting of cable during installation.

10.6.3.3 Multiple Connections

For cross-connect blocks and patch panels, the combined effects on channel and link performance of multiple connections in close proximity can be significant. These effects are addressed in informative Annex E.

10.6.4 Transmission

Information on worst case channel performance of horizontal UTP cabling is provided in informative Annex E. It should be noted that this information is provided for reference purposes only, and that UTP cabling systems may not be classified as category 3, 4 or 5 compliant unless all of the cabling system components are installed to satisfy the requirements of 10.6.

NOTES:

- 1 Field testing of UTP cabling runs at frequencies up to 100 MHz poses numerous technical difficulties, the values listed in informative Annex E are not intended to be used for installation verification. Test methods and apparatus for transmission testing of installed UTP cabling are under study.
- 2 When installed on a ground plane, metallic conduit or other conducting surface, the cable transmission parameters of mutual capacitance, characteristic impedance, return loss, and attenuation typically vary 2-3% from cables not installed on conducting surfaces.

Guidelines on shared sheath multipair backbone cables are covered in informative Annex D.

For information on cabling bandwidth considerations see informative Annex J.

10.6.5 Marking of UTP Cabling Runs

The 100 Ω UTP cabling system shall be installed to provide color coding, labeling and documentation consistent with the provisions of ANSI/TIA/EIA-606. In addition, the performance category of UTP cabling runs between the telecommunications closet and the work area, as well as the connecting hardware to which the installed cable is terminated, should be identified at both ends. When used, such markings should be located such that they are clearly visible after installation.

NOTES:

- 1 Requirements and guidelines on the combinations of UTP components that constitute UTP cabling of a given performance category are provided in 10.6.1.
- 2 When provided, performance markings of UTP cabling runs should be distinguishable from performance markings that appear on individual components such as telecommunications outlet/connectors and cables.

11 150 Ω SHIELDED TWISTED-PAIR CABLING SYSTEMS

11.1 General

This section specifies 150 Ω STP-A cable and associated telecommunications connectors.

When the specifications for 150 Ω shielded twisted-pair (STP) cabling were published in the EIA Interim Standard Omnibus Specification, NQ-EIA/IS-43 and detailed specifications NQ-EIA/IS-43AA, AB, AC, AD, AE, AF, and AG, the transmission characteristics supported signals up to 20 MHz. These specifications were adequate in the past for the range of frequencies found in office environments. However, as LAN speeds and their operating frequencies increased, the original STP specifications needed to be modified and extended to provide stable performance criteria in these higher frequency applications. An improved cable specification and a new connector, intermateable with the original connector, has been introduced to meet these additional specifications.

NOTE - For specific applications, users of this document are advised to consult other standards associated with the planned service or equipment in order to determine any system limitations. The user should also consult with systems suppliers, equipment manufacturers and systems integrators to determine the suitability of the cabling described herein.

All cable and connecting hardware shall meet the requirements of the applicable codes in that jurisdiction.

The total number of measurement points within the specified frequency range shall be a minimum of 100 times the number of decades covered by the specified frequency range using linear or logarithmic frequency spacing.

NOTE - Transmission parameters other than those specified in this section such as longitudinal conversion loss and longitudinal transfer conversion loss are under study.

11.2 Horizontal 150 Ω STP-A Cable

11.2.1 General

Covered herein are the requirements for 150 Ω STP-A inside cable for use in the horizontal cabling system.

11.2.2 Applicability

The transmission characteristics presented herein apply to cables consisting of two individually twisted pairs of 22 AWG thermoplastic insulated solid conductors enclosed by a shield and an overall thermoplastic jacket.

The cable shall be listed and marked as required under the applicable electrical and local building code requirements.

11.2.3 Mechanical Requirements

In addition to the requirements of ANSI/CEA S-80-576, the physical design of the cable shall meet the specifications in 11.2.3.1 to 11.2.3.12.8 inclusive.

11.2.3.1 Insulated Conductor

The diameter of the insulated conductor shall not exceed 2.6 mm (0.102 in) maximum.

11.2.3.2 Pair Assembly

The cable shall be restricted to two-pair size. The pair twist lengths shall be selected by the manufacturer to ensure compliance with the crosstalk requirements of this standard.

11.2.3.3 Color Codes

The color code shall be as shown in table 11-1.

Table 11-1 Color Codes Horizontal 150 Ω STP-A Cable	
Conductor Identification	Color Code
Pair 1	Red Green
Pair 2	Orange Black
NOTE - Color coding may be accomplished by use of helical striping, band marking, solid color skin, or pigment in the insulation itself. Helical striping shall complete a 360° rotation at least every 2.5 cm (1 in). Band spacing shall be ≤ 1.25 cm (0.492 in). Bands and stripes shall adhere to the insulation during cable preparation and termination.	

11.2.3.4 Core Wrap

The core may be covered with one or more layers of dielectric material of adequate thickness to ensure compliance with the dielectric strength requirements.

11.2.3.5 Core Shield

An electrically continuous shield shall be applied over the core wrap.

The shield shall consist of a plastic and aluminum laminated tape with the aluminum side facing out and a braid of tin-coated copper wires with a minimum of 65% coverage in contact with the aluminum. The tape may be applied in such a manner as to isolate the two pairs within the cable core.

11.2.3.6 Braided Shielded Core Sizing

The braided shielded core assembly shall be capable of being formed without the use of tools to fit through the gauge block pictured in figure 11-1. In addition, the angle of the braided shield

shall be such that it can be pushed back over the gauge block. The diameter of the braided shielded core shall not exceed 8.6 mm (0.34 in) when measured with a diameter tape.

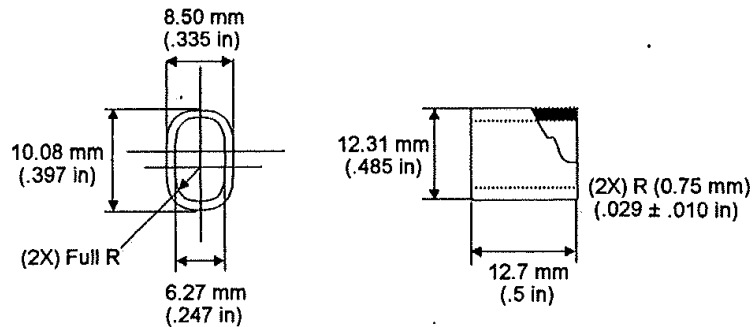


Figure 11-1 Gauge Block

11.2.3.7 Jacket Slitting Cord

A jacket slitting cord shall be laid longitudinally beneath the outer jacket.

11.2.3.8 Jacket

The core shield shall be enclosed by a uniform, continuous thermoplastic jacket.

11.2.3.9 Cable Diameter

The overall diameter of the completed non-plenum cable shall be less than 11 mm (0.433 in). The overall diameter of the completed plenum cable shall be less than 10 mm (0.394 in) when measured with a diameter tape.

11.2.3.10 Breaking Strength

The ultimate breaking strength of the completed cable, measured in accordance with ASTM D 4565, shall be 780 N (175 lbf) minimum.

11.2.3.11 Low Temperature Bending Radius

The cable shall be tested in accordance with ASTM D 4565, Wire and Cable Bending Test. The cable shall withstand a bend radius of 7.5 cm (3 in) for non-plenum, 15 cm (6 in) for plenum, at a temperature of $-20\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ without jacket or insulation cracking.

NOTE - For certain applications (e.g., precabling buildings in cold climate) a cable with a lower temperature bending performance of $-30\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ may be required.

11.2.3.12 Additional Mechanical Durability Requirements**11.2.3.12.1 General**

The cable shall be of suitable construction to withstand the mechanical durability requirements in 11.2.3.12.1 to 11.2.3.12.8 inclusive. Unless specified otherwise, the transmission requirements shall be met up to 20 MHz, after the low temperature bending radius and the tests in 11.2.3.12.1 to 11.2.3.12.8 inclusive have been completed at room temperature. Unless specified otherwise, tests shall be performed on a minimum cable length of 305 m (1000 ft). See 11.2.4.4 for other required test lengths.

11.2.3.12.2 Tensile Strength

The cable shall withstand a tensile load of 244 N (55 lbf) when tested as follows. Apply the load at a maximum rate of 45 N/s (10 lbf/s) to the first 100 m (328 ft) of the cable sample. Transmission measurements shall be made from the pulled end of the sample.

11.2.3.12.3 Minimum Bend Radius

The non-plenum cable shall withstand bending over a 7.5 cm (3 in) mandrel, [15 cm (6 in) for plenum cables] under a tensile force of 244 N (55 lbf) when tested as follows. The cable is alternately pulled and released 5 times at a 0.1 m/s (4 in/s) maximum rate a distance of 1 m (3 ft) minimum across the mandrel at 90°.

11.2.3.12.4 Compression Strength

The cable tested in accordance with EIA-455-41 shall withstand a compressive load of 444 N (100 lbf) for a period of 1 minute.

11.2.3.12.5 Impact Force

The cable tested in accordance with EIA-455-25A shall withstand a series of 10 impacts of 4.5 J. The first impact shall be applied at a point 1 m (3 ft) from the end of the cable and each successive impact shall be applied 1 cm (0.394 in) further from the end.

11.2.3.12.6 Number of Flexes

The cable shall be tested in accordance with EIA-455-104. The non-plenum cable shall withstand 20 flex cycles over a 7.5 cm (3 in) mandrel. For plenum cable, a 15 cm (6 in) mandrel shall be used.

11.2.3.12.7 One-Time Bend Radius

The braided shielded core assembly shall withstand 1 flex cycle over a 20 mm (0.79 in) mandrel when tested in accordance with EIA-455-104.

11.2.3.12.8 Humidity Cycling

The cable shall undergo 5 cycles of: +60 °C, 90 - 98% RH, 6 hours; +10 °C, uncontrolled RH, 6 hours; with 2 to 3 hours transition time and humidity reduced prior to temperature change. Humidity shall be controlled to prevent condensation on the cable jacket during temperature transition. Following the cycling, the cable shall be allowed to stabilize at room temperature for 24 hours prior to performing transmission measurements.

11.2.3.12.9 Temperature

The cable shall undergo 5 cycles of: +80 °C, 12 hours; -40 °C, 12 hours. The transmission measurements shall be made during the fifth cycle and again after allowing the cable to stabilize at room temperature for 24 hours. Attenuation and dc resistance measurements made during the fifth cycle shall be adjusted for temperature effects at -40 °C and +80 °C. Input impedance at -40 °C and +80 °C for frequencies equal to or less than 10 kHz shall not vary more than 15% of the values measured at room temperature.

11.2.4 Transmission Requirements**11.2.4.1 DC Resistance**

The resistance of any conductor measured in accordance with ASTM D 4566 and corrected to a temperature of 25 °C shall not exceed 5.71 Ω /100 m (328 ft).

11.2.4.2 DC Resistance Unbalance

The resistance unbalance between the two conductors of any pair, at or corrected to a temperature of 25 $\pm$ 3 °C and measured in accordance with ASTM D 4566, shall not exceed 4%.

11.2.4.3 Capacitance Unbalance: Pair to Ground

The capacitance unbalance to ground at 1 kHz of any pair, at a temperature of 25 $\pm$ 3 °C and measured in accordance with ASTM D 4566, shall not exceed 100 pF/100 m (328 ft).

11.2.4.4 Balanced Mode Attenuation

The balanced mode attenuation of any pair, at or corrected to a temperature of 25 $\pm$ 3 °C and measured in accordance with ASTM D 4566, shall not exceed:

0.30 dB/100 m (328 ft) (at 9.6 kHz, 22 to 28 °C and 270 Ω terminations)

0.50 dB/100 m (328 ft) (at 38.4 kHz, 22 to 28 °C and 185 Ω terminations)

$2.2\sqrt{f/4}$ dB/100 m (328 ft), for all frequencies from 4.0 MHz to 20.0 MHz, 22 to 28 °C and 150 Ω terminations

$9.75\sqrt{f/62.5}$ dB/100 m (328 ft), for all frequencies from 20 MHz to 300 MHz, 22 to 28 °C and 150 Ω terminations

where f = frequency in MHz.

The attenuation measurements from 9.6 kHz to 20 MHz shall be performed on cable lengths of 305 m (1000 ft) or greater.

The attenuation measurements from 20 MHz to 300 MHz shall be performed on cable lengths of 100 m (328 ft) to 305 m (1000 ft) using a balun meeting the specification in normative Annex C.

The values in table 11-2 are given for reference purposes only.

Table 11-2 Cable Balanced Mode Attenuation Horizontal STP-A Cable	
Frequency (MHz)	Maximum Attenuation [dB/100 m (328 ft)]
0.0096	0.30
0.0384	0.50
4.0	2.2
8.0	3.1
10	3.6
16	4.4
20	4.9
25	6.2
31.25	6.9
62.5	9.8
100	12.3
300	21.4

11.2.4.5 Common Mode Attenuation

The common mode attenuation of any pair, at or corrected to a temperature of 25 ± 3 °C and measured in accordance with ASTM D 4566, shall not exceed:

$$95.0 \sqrt{f/50} \text{ dB/km, for all frequencies from 50 MHz to 600 MHz,}$$

where f = frequency in MHz.

The attenuation measurements from 50 MHz to 600 MHz shall be performed on cable lengths of 100 m (328 ft) to 305 m (1000 ft).

NOTES:

- 1 For common mode attenuation measurements, tie both nearside conductors together and drive them with respect to the shield with a 50 Ω source; tie both far-side conductors together and terminate into 50 Ω between the pairs to the shield.
- 2 Common mode measurements are valid when the pairs are individually shielded or wrapped using the S-shield.

11.2.4.6 Characteristic Impedance and SRL

The characteristic impedance shall meet the requirements of table 11-3 when measured in accordance with ASTM D 4566.

NOTE - The characteristic impedance is commonly derived from swept frequency input impedance measurements using a network analyzer with an s-parameter test set. As a result of structural non-uniformities, the measured input impedance for an electrically long length of cable (greater than 1/8th wavelength) will fluctuate as a function of frequency. These random fluctuations are superimposed on the curve for characteristic impedance

which asymptotically approaches a fixed value at frequencies above 1 MHz. The characteristic impedance can be obtained from these measurements by using a smoothing function over the bandwidth of interest.

Table 11-3 Characteristic Impedance Horizontal STP-A Cable	
Frequency (MHz)	Characteristic Impedance (Ω)
0.0096	270 $\pm$ 10%
0.0384	185 $\pm$ 10%
3.0 - 20*	150 $\pm$ 10%
20 - 300*	Under study
* The specification shall be met over the entire frequency range specified.	

The characteristic impedance, measured and normalized in accordance with ASTM D 4566 and performed on cable lengths of 100 m (328 ft) to 305 m (1000 ft) using a balun meeting the specification in normative Annex C, for the entire frequency range from 3 MHz to 300 MHz, shall be bounded by the values given in table 11-3.

The structural return loss, measured and normalized to the characteristic impedance value in accordance with ASTM D 4566 and performed on cable lengths of 100 m (328 ft) to 305 m (1000 ft) using a balun meeting the specification in normative Annex C, for the entire frequency range from 3 MHz to 300 MHz, shall exceed 24 dB up to 20 MHz and $24 - 10 \log(f/20)$ dB above 20 MHz, where f = frequency in MHz.

11.2.4.7 NEXT Loss

The NEXT loss between the two pairs within a cable, measured in accordance with ASTM D 4566, shall exceed:

- +58.0 dB, at 9.6 kHz terminated into 270 Ω ,
 - +58.0 dB at 38.4 kHz terminated into 185 Ω ,
 - +58.0 dB for all frequencies from 0.1 MHz to 5 MHz terminated into 150 Ω , and
 - +58.0-15 $\log(f/5)$ dB, for all frequencies from 5 MHz to 300 MHz terminated into 150 Ω ;
- where f = frequency in MHz.

The NEXT loss measurements from 9.6 kHz to 20 MHz shall be performed on cable lengths of 305 m (1000 ft) or greater. The NEXT loss measurements from 20 MHz to 300 MHz shall be performed on cable lengths of 100 m (328 ft) to 305 m (1000 ft) using a balun meeting the specification in normative Annex C.

The values in table 11-4 are given for reference purposes only.

Table 11-4 Horizontal STP-A Cable NEXT	
Frequency (MHz)	NEXT Loss Worst Pair (dB)
0.0096	58.0
0.0384	58.0
4.0	58.0
8.0	54.9
10	53.5
16	50.4
20	49.0
25	47.5
31.25	46.1
62.5	41.5
100	38.5
300	31.3

11.2.4.8 Dielectric Strength

The insulation between each conductor and the core shield shall be capable of withstanding a minimum dc potential of 5 kV for 3 seconds when tested in accordance with ASTM D 4566.

11.2.4.9 Propagation Delay

The propagation delay of any pair at 10 MHz should not exceed 5.7 ns/m.

11.2.5 Marking

The cable shall be listed and marked as required under the applicable electrical and local building code requirements. The cable should be marked with 150 Ω STP-A.

11.3 Backbone STP-A Cable

The requirements for the backbone 150 Ω STP-A cable shall be the same as the requirements given in 11.2 for horizontal 150 Ω STP-A cable.

An optional backbone 150 Ω STP-A cable, suitable for outdoor applications shall have the following characteristics:

- A conductor insulation diameter of less than 2.9 mm (0.114 in),
- A single aluminum tape shield (core separator tape) with an insulation coating on both sides, longitudinally applied, wrapped around and separating each pair,
- A filled core,

- d) A flooded, corrugated aluminum tape armor over the shield,
- e) A black polyethylene jacket,
- f) A completed cable diameter less than 15 mm (0.591 in), and
- g) Conformance to the remaining requirements in 11.2 and ANSI/ICEA-S-84-608,

11.4 Connecting Hardware for STP-A Cable

11.4.1 General

The telecommunications connector transmission characteristics specified by this standard extend beyond those specified in ANSI/IEEE Std 802.5.

11.4.2 Applicability

Connectors meeting these specifications shall be used in terminating 150 Ω shielded twisted-pair cable as specified in 11.2, 11.3, and 11.5.

11.4.3 Transmission Characteristics for Connectors Used With 150 Ω STP-A cable

The extended transmission specifications for connectors used with 150 Ω STP-A cable ensure that the overall transmission characteristics of the link will be maintained.

11.4.3.1 Attenuation

Attenuation is a measure of signal power loss due to the connecting hardware and is derived from swept frequency voltage measurements on short lengths of 150 Ω twisted-pair test leads before and after splicing-in the connector under test.

The attenuation of either pair within a connector shall lie at or below the piece-wise linear curve drawn using the values in table 11-5 when measured using the method described in normative Annex C.

Table 11-5 Maximum Attenuation For Connectors Used With 150 Ω STP-A Cable (Applies To Prime And Self-Shorting Paths)	
Frequency (MHz)	dB
0.1	0.05
1	0.05
4	0.05
8	0.10
10	0.10
16	0.15
20	0.15
25	0.15
31.25	0.15
62.50	0.20
100	0.25
300	0.45

11.4.3.2 NEXT Loss

NEXT loss is a measure of signal coupling from one circuit to another within a connector and is derived from swept frequency voltage measurements on short lengths of 150 Ω STP-A test leads terminated to the connector under test. A balanced input signal is applied to a disturbing pair of the connector while the induced signal on the disturbed pair is measured at the near end of the test leads.

The NEXT loss between pairs, when measured using the method described in normative Annex C, shall not be less than the values determined by the formula:

$$\text{NEXT}(f) \geq \text{NEXT}(16) - 20 \log \left(\frac{f}{16} \right)$$

(f) = frequency in MHz

Table 11-6 gives values of NEXT loss at specific frequencies in the band of interest. These values are provided for engineering information and are derived from the preceding formula.

Table 11-6 NEXT Loss for Connectors Used With 150 Ω STP-A Cable	
Frequency (MHz)	dB
0.1	65
1	65
4	65
8	65
10	65
16	62.4
20	60.5
25	58.5
31.25	56.6
62.5	50.6
100	46.5
300	36.9

11.4.3.3 Shielding Effectiveness

Shield effectiveness is a measure of the ratio of the source voltage of a cable or a cable assembly to the shield current of the wires inside the cable. This ratio can be used to determine the amount of current that can radiate from the connector or the cable assembly from a known voltage source.

NOTE - Shield effectiveness is under study.

The shield effectiveness of a single connector shall be below the limits in table 11-7 for all frequencies from 30 MHz to 1000 MHz using the test procedure described in normative Annex C. The shield effectiveness in dB for all frequencies up to 400 MHz is expressed in the following formula:

$$L = (25 \log f) - 87$$

where L = the limit using an absorbing clamp and f = the frequency in MHz.

For all frequencies above 400 MHz, the limit is -22 dB.

Table 11-7
Shield Effectiveness For Connectors Used With
150 Ω STP-A Cable

Frequency (MHz)	dB
30	-50
40	-47
50	-44
60	-42
80	-39
100	-36
200	-30
300	-24
400	-22
500	-22
700	-22
1000	-22

These measurements shall be made using the method described in normative Annex C.

11.4.3.4 Connector Return Loss

Connector return loss is a measure of impedance matching between the cable and the connector and is derived from swept frequency voltage measurements on short lengths of 150 Ω STP-A test leads after inserting the connector under test. A balanced input signal is applied to a connector pair while signals that are reflected back due to impedance discontinuities are measured at the same port from which the signal is applied.

The return loss through the primary path of the connector used with 150 Ω STP-A cable shall be 36 dB or greater for all frequencies between 0.1 MHz and 16 MHz using the test procedure described in normative Annex C. For all frequencies between 16 MHz and 300 MHz, the return loss in dB shall be equal to or greater than the following formula:

$$RL \geq 36 - 20 \log \left(\frac{f}{16} \right)$$

where f = the frequency of the input signal in MHz.

11.4.3.5 Marking

The connecting hardware shall be listed and marked as required under the applicable electrical code and local building code requirements. Connecting hardware should be marked to designate transmission performance at the discretion of the manufacturer or the approval agency. The markings, if any, shall be visible during installation. It is suggested that such markings consist of:



11.4.4 Mechanical**11.4.4.1 Telecommunications Outlet/Connector Used With 150 Ω STP-A Cable**

Each 150 Ω STP-A cable shall be terminated in a shielded, 4-position hermaphroditic connector at the work area. The connector used with 150 Ω STP-A cable shall meet the interface requirements specified in IEC 807-8. In addition, the connector used with 150 Ω STP-A cable shall meet the requirements of 11.4.3 and 11.4.4.2.

Pin/pair assignments shall be as specified in ISO 8802-5.

NOTE - Although the title of IEC 807-8 appears to limit the bandwidth of this connector to 3 MHz or less, this type of connector may be qualified for use at higher frequencies when tested and proven to be compliant with the performance requirements specified in 11.4.3.

The telecommunications outlet/connector interface for 150 Ω STP-A cable is currently unspecified.

11.4.4.2 Reliability

For connecting hardware with 4-position hermaphroditic connectors, the modular connection shall comply with the reliability requirements of IEC 807-8. Hermaphroditic connections that conform to IEC 807-8, are specifically exempt from normative Annex A reliability testing.

To assure reliable operation over the usable life of the cabling system, the connecting hardware used with 150 Ω STP-A cabling shall meet all requirements of normative Annex A. This annex describes test procedures and performance requirements for contact resistance, insulation resistance, durability, environmental conditioning and other tests designed to assure consistently dependable and safe operation.

11.5 150 Ω STP-A Patch Cable**11.5.1 General**

Cables used to administer moves, adds, and changes are as critical to transmission performance as imbedded horizontal cabling. For this reason, this clause describes the mechanical and electrical specifications of cable used for patch cords that shall be used with installations of 150 Ω STP-A cabling.

11.5.2 Applicability

The requirements in this clause apply only to cables used for patch cords. Connectors are subject to separate requirements as specified in 10.4.

11.5.3 Mechanical Requirements

The cable used for patch cords and cross-connect jumpers shall meet the same mechanical performance requirements as those specified for horizontal 150 Ω STP-A in 11.2.3 with the exceptions in 11.5.3.1 to 11.5.3.4.2 inclusive.

11.5.3.1 Insulated Conductor

The conductor shall be 26 AWG stranded tin coated copper. The overall insulated diameter shall be 1.9 mm (0.075 in) maximum.

11.5.3.2 Jacket Slitting Cord

A jacket slitting cord may be laid longitudinally beneath the outer jacket.

11.5.3.3 Cable Diameter

The diameter of the completed cable shall be less than 9.5 mm (0.374 in).

11.5.3.4 Additional Mechanical Durability Requirements**11.5.3.4.1 Tensile Strength**

The cable tested as follows shall withstand a tensile load of 124 N (28 lbf). Apply the load at a maximum rate of 45 N/s (1- lbf/s) to the first 100 m (328 ft) of the cable sample. Transmission measurements shall be made from the pulled end of the sample. A length correction factor shall be applied to the measurements.

11.5.3.4.2 Number of Flexes

The cable shall withstand 1000 flex cycles over a 7.5 cm (3 in) mandrel.

11.5.4 Transmission Requirements

The cable used for patch cords and cross-connect jumpers shall meet the same transmission performance requirements as those specified for horizontal 150 Ω STP-A in 11.2.4 with the exceptions in 11.5.4.1 to 11.5.4.4 inclusive.

11.5.4.1 DC Resistance

The resistance of any conductor shall not exceed 14.5 Ω /100 m (328 ft) corrected to a temperature of 25 °C.

11.5.4.2 Balanced Mode Attenuation

The balanced mode attenuation of any pair, at or corrected to a temperature of 25 $\pm$ 3 °C, shall not exceed:

0.60 dB/100 m (328 ft) at 9.6 kHz
0.74 dB/100 m (328 ft) at 38.4 kHz

$3.3\sqrt{f/4}$ dB/100 m (328 ft), for all frequencies from 4.0 MHz to 20.0 MHz, and

$$14.75 \sqrt{f/62.5} \text{ dB/100 m (328 ft), for all frequencies from 20 MHz to 300 MHz;}$$

where f = frequency in MHz.

11.5.4.3 Characteristic Impedance

The characteristic impedance shall be per the requirements of table 11-8 when measured in accordance with ASTM D 4566.

Table 11-8 Characteristic Impedance Horizontal STP-A Patch Cord	
Frequency (MHz)	Characteristic Impedance (Ω)
0.0096	390 $\pm$ 15%
0.0384	235 $\pm$ 15%
3 - 20*	150 $\pm$ 10%
20 - 300*	Under Study
* The specification shall be met over the entire frequency range specified	

The characteristic impedance, measured and normalized in accordance with ASTM D 4566 and performed on cable lengths of 100 m (328 ft) to 305 m (1000 ft) using a balun meeting the specification in normative Annex C for the entire frequency range from 3 MHz to 300 MHz, shall be 150 $\Omega \pm 10\%$.

The structural return loss, measured and normalized to the characteristic impedance value in accordance with ASTM D 4566 and performed on cable lengths of 100 m (328 ft) to 305 m (1000 ft) using a balun meeting the specification in normative Annex C for the entire frequency range from 3 MHz to 300 MHz, shall exceed 24 dB up to 20 MHz and $24 - 10 \log(f/20)$ dB above 20 MHz, where f = frequency in MHz.

11.5.4.4 NEXT Loss

The NEXT loss between the two pairs within a cable, shall be greater than or equal to:

52.0 dB, for all frequencies from 9.6 kHz to 5 MHz, and
 $52.0 - 15 \log(f/5)$ dB, for all frequencies from 5 MHz to 300 MHz;
 where f = frequency in MHz.

The values in table 11-9 are given for reference purposes only.

Table 11-9 150 Ω STP-A Patch Cord NEXT Loss	
Frequency (MHz)	NEXT Loss Worst Pair (dB)
0.0096	52.0
0.0384	52.0
4.0	52.0
8.0	48.9
10	47.5
16	44.4
20	43.0
25	41.5
31.25	40.1
62.5	35.5
100	32.5
300	25.3

11.6 Cabling Practices

The cable's braided shield shall be grounded at the telecommunications closet to the telecommunications grounding busbar. At the workstation end, the voltage measured between the braided shield and the green wire ground in the electrical outlet used to supply power to the workstation shall not exceed 1 V rms. The cause of any higher voltage should be rectified before using the cable. The resistance should then be measured between the green wire ground at the electrical outlet and the braided shield. The resistance should not exceed 3.5 Ω . The cause of any higher resistance should be rectified before using the cable.

For attenuation measurements at temperatures other than 23 °C, the attenuation may change 0.6 dB/km (3280 ft) for each 10 °C change at 4 MHz and 1.2 dB/km (3280 ft) for each 10 °C change at 16 MHz. Generally, the attenuation change (in dB) for STP-A cable at a frequency (f in MHz) at a given temperature (T in Celsius) is:

$$0.03(T-23)\sqrt{f}$$

For some high frequency applications whose configurations approach the transmission limits of the cable, allowance may be necessary for operation in high temperature environments.

For cabling between buildings with different ground potentials, placement of optical fiber cable should be considered.

The subject of STP-A link performance is under study.

12 OPTICAL FIBER CABLING SYSTEMS

12.1 General

This section specifies the component requirements for an optical fiber cabling system (cable, connectors, etc.) for both horizontal and backbone cabling. 62.5/125 μm optical fiber cable is a recognized horizontal cable and both 62.5/125 μm and single-mode optical fiber cables are recognized backbone cables.

Electrical codes do not normally include any transmission requirements. This section specifies essential media transmission characteristics.

NOTE - For specific applications, users of this document are advised to consult other standards associated with the planned service or equipment in order to determine any system limitations. The user should also consult with systems suppliers, equipment manufacturers and systems integrators to determine the suitability of the cabling described herein.

All cable and connecting hardware shall meet the requirements of the applicable codes in that jurisdiction.

12.2 Horizontal 62.5/125 μm Optical Fiber Cable

12.2.1 General

Covered herein are the detailed specifications of the optical fiber cable for use in horizontal cabling.

The optical fiber cable shall consist of a minimum of two 62.5/125 μm optical fibers enclosed by a protective sheath. This cable has bandwidth capacity in the order of 1 GHz for the 90 m (295 ft) distance specified for horizontal cabling.

12.2.2 Applicability

The transmission characteristics presented herein apply to optical fiber cables with a minimum of two 62.5/125 μm fibers enclosed in jackets for horizontal cabling.

12.2.3 Optical Fiber Specifications

The fiber shall be multimode, graded-index optical fiber waveguide with nominal 62.5/125 μm core/cladding diameter. The fiber shall comply with ANSI/EIA/TIA-492AAAA.

12.2.4 Cable Transmission Performance Specifications

Each cabled fiber shall meet the graded performance specifications of table 12-1. Attenuation shall be measured in accordance with ANSI/EIA/TIA-455-46, -53, or -61. Information

transmission capacity shall be measured in accordance with ANSI/EIA/TIA-455-51 or -30. The cable shall be measured at $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$.

Table 12-1 Horizontal 62.5/125 μm Optical Fiber Cable Transmission Performance Parameters		
Wavelength (nm)	Maximum Attenuation (dB/km)	Minimum Information Transmission Capacity (MHz-km)
850	3.75	160
1300	1.5	500
NOTE - The information transmission capacity of the fiber, as measured by the fiber manufacturer, can be used by the cable manufacturer to demonstrate compliance with this requirement.		

12.2.5 Physical Cable Specifications

The mechanical and environmental specifications for plenum all-dielectric indoor optical fiber cable shall be in accordance with ANSI/TIA/EIA-472CAAA and for other constructed indoor optical fiber cable shall be in accordance with ANSI/ICEA S-83-596.

12.2.6 Marking

The cable shall be listed and marked as required under the applicable electrical code and local building code requirements.

12.3 Backbone Optical Fiber Cable

12.3.1 General

Covered herein are the detailed specifications of the optical fiber cable for use in backbone cabling.

The optical fiber cable construction shall consist of 62.5/125 μm optical fibers or single-mode optical fibers, or both, typically formed into groups of 6 or 12 fibers each. These groups and individual fibers shall be identifiable in accordance with ANSI/EIA/TIA-598. These groups are assembled to form a single compact core and the core is covered by a protective sheath. The sheath consists of an overall jacket and may contain an underlying metallic shield and one or more layers of dielectric material applied over the core.

12.3.2 Applicability

Customer premises optical fiber backbone cabling has been and continues to be primarily 62.5/125 μm multimode fiber based because this fiber can use LED transmitters. With rapidly growing bandwidth requirements, consideration should be given to installing single-mode optical

fiber in addition to multimode optical fiber. Single-mode optical fiber systems inherently have higher bandwidth and longer distance capabilities than 62.5/125 μm optical fiber.

System bandwidth is not only a function of the fiber but also distance and transmitter characteristics, specifically center wavelength, spectral width, and optical rise time. Therefore, only typical system bandwidth values can be given. Figure 12-1 depicts typical system bandwidth relative to distance for a 62.5/125 μm system utilizing ANSI/EIA/TIA-568-A specified fiber with a typical LED transmitter operating at 1300 nm wavelength. Figure 12-2 depicts typical system bandwidth relative to distance for a single-mode system utilizing the specified fiber with a typical laser transmitter operating at 1310 nm wavelength.

While it is recognized that the capabilities of single-mode optical fiber may allow for backbone link distances of up to 60 km (37 miles), this distance is generally considered to extend outside the scope of this standard.

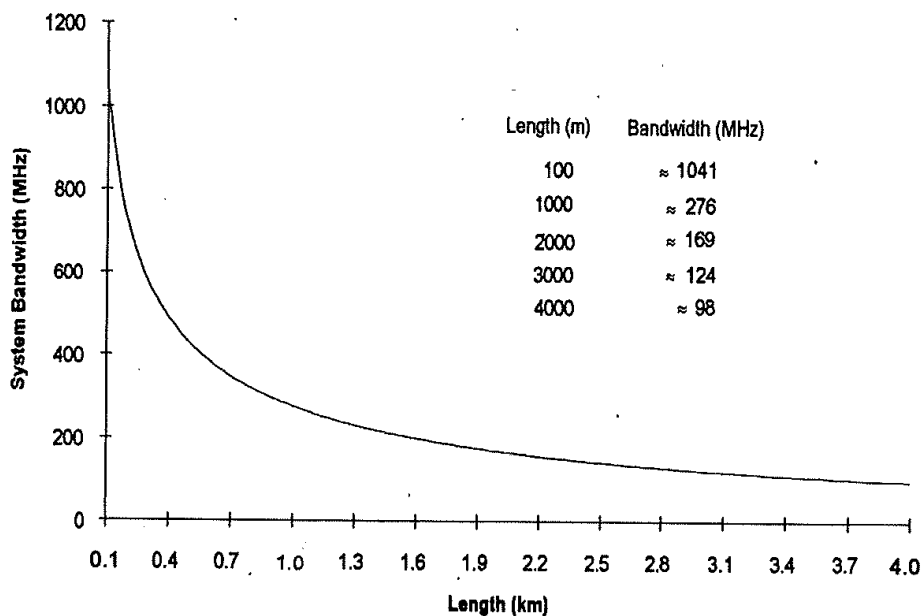


Figure 12-1 Typical System Bandwidth Utilizing ANSI/TIA/EIA-568A 62.5/125 μm Optical Fiber Cable and a 1300 nm LED

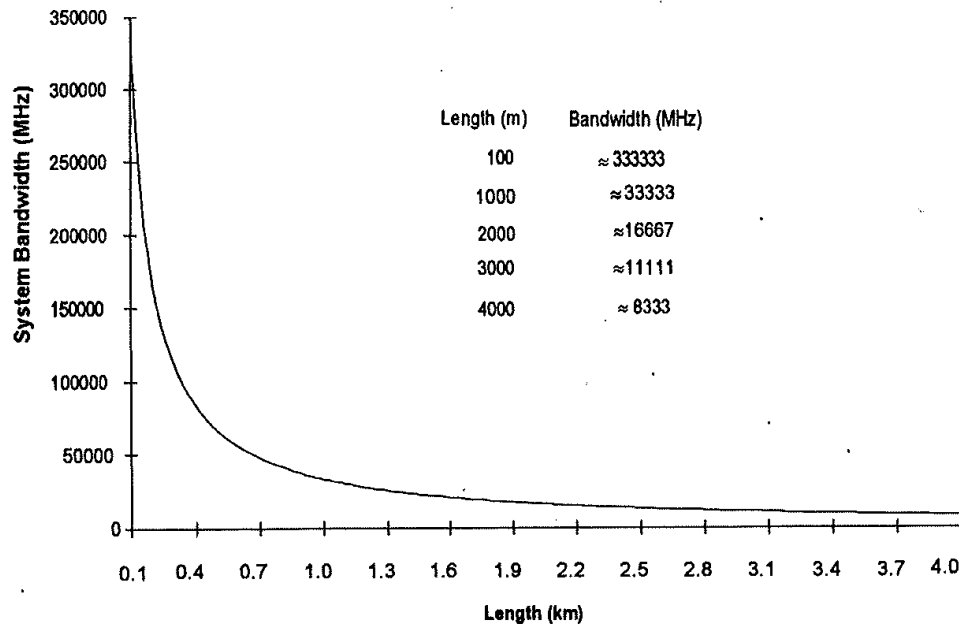


Figure 12-2 Typical System Bandwidth Utilizing ANSI/TIA/EIA-568A Single-mode Optical Fiber Cable and a 1310 nm Laser

12.3.3 Backbone 62.5/125 μm Optical Fiber Cable

12.3.3.1 Optical Fiber Specifications

The optical fiber shall be multimode, graded-index optical fiber waveguide with nominal 62.5/125 μm core/cladding diameter. The optical fiber shall comply with ANSI/EIA/TIA-492AAAA.

12.3.3.2 Cable Transmission Performance Specifications

Each cabled optical fiber shall meet the graded performance specifications of table 12-2. Attenuation shall be measured in accordance with ANSI/EIA/TIA-455-46, -53, or -61. Information transmission capacity shall be measured in accordance with ANSI/EIA/TIA-455-51 or -30. The cable shall be measured at $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$.

Table 12-2
Backbone 62.5/125 μm Optical Fiber Cable Transmission Performance Parameters

Wavelength (nm)	Maximum Attenuation (dB/km)	Minimum Information Transmission Capacity (MHz-km)
850	3.75	160
1300	1.5	500

NOTE - The information transmission capacity of the fiber, as measured by the fiber manufacturer, can be used by the cable manufacturer to demonstrate compliance with this requirement.

12.3.3.3 Physical Cable Specifications

The mechanical and environmental specifications for plenum all-dielectric indoor optical fiber cable shall be in accordance with ANSI/TIA/EIA-472CAAA and for all-dielectric outside optical fiber cable shall be in accordance with ANSI/TIA/EIA-472DAAA. The specifications for other constructed indoor optical fiber cable shall be in accordance with ANSI/ICEA S-83-596 and for other constructed outdoor optical fiber cable shall be in accordance with ANSI/ICEA S-83-640.

12.3.4 Backbone Single-mode Optical Fiber Cable

12.3.4.1 Optical Fiber Specifications

Single-mode optical fibers shall be Class IVa Dispersion-Unshifted Single-mode Optical Fibers and shall comply with ANSI/EIA/TIA-492BAAA.

12.3.4.1.1 Chromatic Dispersion

The zero-dispersion wavelength, λ_0 , shall be between 1300 nm and 1324 nm, and the maximum value of the dispersion slope at λ_0 shall be no greater than 0.093 ps/km-nm². Dispersion measurements shall be made in accordance with ANSI/EIA/TIA-455-168, *Spectral Group Delay*, ANSI/EIA/TIA-455-169, *Phase-Shift*, or ANSI/EIA/TIA-455-175, *Differential Phase-Shift*.

12.3.4.1.2 Mode Field Diameter

The nominal mode field diameter shall be 8.7 μm to 10.0 μm with a tolerance of $\pm 0.5 \mu\text{m}$ at 1300 nm when measured in accordance with ANSI/EIA/TIA-455-164, *Far-Field Scanning* or ANSI/EIA/TIA-455-167, *Variable Aperture Method in the Far Field*.

12.3.4.2 Cable Transmission Performance Specifications**12.3.4.2.1 Attenuation**

Each cabled optical fiber shall meet the following attenuation performance specifications of table 12-3. Attenuation shall be measured in accordance with ANSI/EIA/TIA-455-78A or -61. The cable shall be measured at $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$.

Table 12-3 Backbone Single-Mode Optical Fiber Cable Transmission Performance Parameters		
Wavelength (nm)	Maximum Attenuation of Outside Optical Fiber Cable (dB/km)	Maximum Attenuation of Inside Optical Fiber Cable (dB/km)
1310	0.5	1.0
1550	0.5	1.0

12.3.4.2.2 Cut-Off Wavelength

The cutoff wavelength of cabled single-mode optical cable shall be < 1270 nm when measured in accordance with ANSI/EIA/TIA-455-170.

12.3.4.3 Physical Cable Specifications

The mechanical and environmental specifications for indoor optical fiber cable shall be in accordance with ANSI/ICEA S-83-596. The mechanical and environmental specifications for outdoor optical fiber cable shall be in accordance with ANSI/ICEA S-83-640.

12.3.5 Marking

The cable shall be listed and marked as required under the applicable electrical code and local building code requirements.

12.4 Connecting Hardware for Optical Fiber Cable**12.4.1 General**

Covered herein are the minimum specifications and recommendations for the optical fiber connector, adapter and connecting hardware for 62.5/125 μm and single-mode optical fiber cables. These requirements apply to both backbone and horizontal cabling and the connecting hardware at the main cross-connect, intermediate cross-connect, horizontal cross-connect, and telecommunications outlet/connector. The recommended adapter and connector specified by this document is referred to as 568SC.

NOTE - The term adapter, when used in reference with optical fiber, should not be confused with its' definition when used in reference with other media types, such as UTP and STP. The term adapter has been adopted by the optical fiber industry and standards organizations to define a mechanical termination device designed to align and join two like optical

connectors. The term hybrid adapter has been adopted to define a mechanical termination device designed to align and join two unlike optical connectors.

While the intent of this sub-clause is to provide minimum specifications and guidelines for optical fiber connections, it should be noted that the connectors and adapters are relatively new in the configuration recommended and other standards committees are working to create additional specifications and performance criteria to ensure intermatability and proper performance. Users of this sub-clause are advised to consult with equipment manufacturers and system integrators to determine the suitability of these requirements for specific networking applications. Additionally, users are advised to consult ANSI Z136.2 when using lasers which exceed hazard level 1 in their systems.

12.4.2 Applicability

As LAN transmission rates increase and users employ more optical fiber cables it becomes increasingly important to specify the minimum optical fiber interconnection premises cabling requirements. Careful selection of optical fiber connecting hardware and cabling guidelines will help to assure users that they have a functional and manageable optical fiber system. Outlined here are the minimum requirements for optical fiber connectors (on backbone cables, horizontal cables and patch cord cables), the optical fiber adapter, guidelines for optical fiber cabling and system testing.

A 568SC connection is recommended because of the ability to establish and maintain the correct polarization of transmit and receive optical fibers in two optical fiber transmission systems, while still allowing transmission systems using other optical fiber counts. While the connector on the cabling side of the patch panel or telecommunications outlet/connector shall use either two simplex SCs or the 568SC, the optical fiber patch cord shall use the 568SC for two fiber applications.

12.4.3 Mechanical

12.4.3.1 Physical Design

The connection (connector and adapter) shall be capable of simplex or duplex optical fiber connection. The 568SC connection shall be a duplex SCFOC/2.5 with a 12.7 mm (0.5 in) center spacing between connector ferrules.

The 568SC adapter shall be either two simplex SC adapters or a duplex SC adapter of a one piece construction. It shall maintain the nominal 12.7 mm (0.5 in) center spacing when mounted in an optical fiber patch panel or telecommunications outlet/connector. The 568SC connector and adapter shall have the keys and keyways oriented as shown in figure 12-3.

Other versions of the duplex SC connector may be specified by specific applications. The duplex SC adapter and connector specified by this document shall be referred to as 568SC. The dimensions of the components of the 568SC, connectors and adapters, to include the key and keyways, shall meet ANSI/EIA/TIA-604-3.

NOTE - Users having an installed base of BFOC/2.5 connectors and adapters (commonly referred to as ST) may remain with the BFOC connector and adapter for both existing and future additions to their optical fiber network. Informative Annex F describes a migration path for users of such networks.

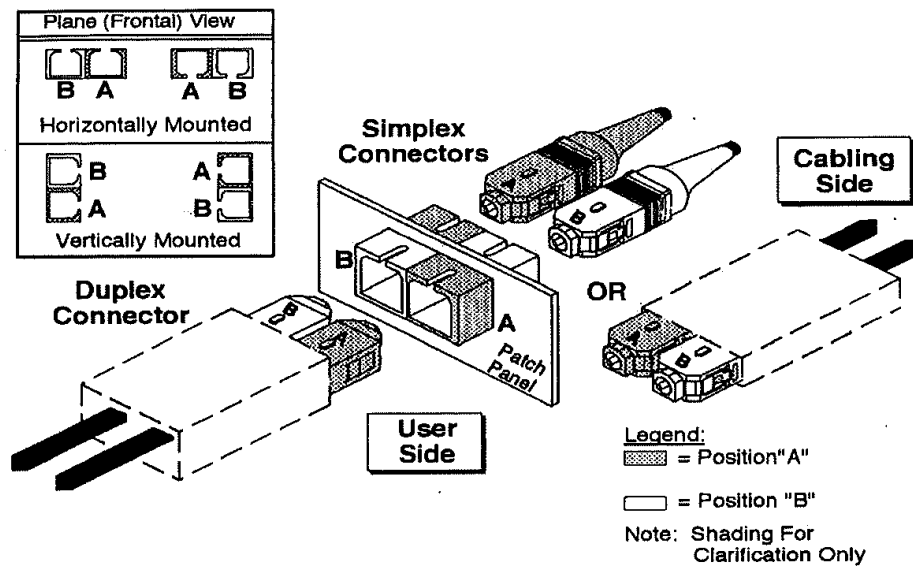


Figure 12-3 Position A and B Configuration on a 568SC Connector and Adapter

12.4.3.2 62.5/125 μ m and Single-Mode Identification

Both the 62.5 μ m and single-mode 568SC connector and adapter shall be of the same dimensions and shall not prevent intermatability between the two optical fiber types. However, the 62.5 μ m connector and adapter shall be beige in color and the single-mode connector and adapter shall be blue in color to distinguish between the two optical fiber types.

12.4.3.3 Keying and Labeling

The two connectors in a 568SC connector and the corresponding 568SC adapter shall be referred to as Position A and Position B. Figure 12-3 shows the location of Position A and B in the 568SC connector and adapter with respect to the keys and keyways. As the figure indicates, the 568SC adapter shall perform a pair-wise crossover between connectors. Additionally, figure 12-3 shows Position A and Position B in the two possible horizontal and two possible vertical orientations. The shading used in figure 12-3 is for clarification only and is not a specified identification scheme. The two positions of the 568SC adapter shall be identified as Position A and Position B by using the letter designator A and B respectively. Labeling may be field or factory installed.

12.4.3.4 Pull Strength

The connector shall have an optical axial pull strength of 2.2 N (0.5 lbf) at a 0° angle and an optical off axial pull strength of 2.2 N (0.5 lbf) at a 90° angle, with a maximum 0.5 dB increase in attenuation for both tests when tested in accordance with ANSI/EIA/TIA-455-6B.

NOTE - These requirements are different from those of the connector on optical fiber patch cords because the connection on the cabling side of the patch panel will experience limited or no reconfiguration. Also, the connector will experience limited pull stresses if the cable is properly secured either to the patch panel or prior to entry into the patch panel. See 12.5 for connector requirements on optical fiber patch cords.

12.4.4 Transmission**12.4.4.1 Attenuation**

The maximum optical attenuation per each mated field-installed 568SC connector pair shall not exceed 0.75 dB per ANSI/EIA/TIA-455-34 Method A, factory testing or ANSI/EIA/TIA-455-59, field testing. The maximum optical attenuation per each mated connector pair shall not exceed 0.75 dB on cable assemblies per ANSI/EIA/TIA-455-171. The total optical attenuation through the cross-connect from any terminated optical fiber to any other terminated optical fiber shall not exceed 1.5 dB. These measurements shall be performed at $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$.

12.4.4.2 Return Loss

The 568SC connector shall have a return loss ≥ 20 dB on 62.5/125 μm optical fiber and a return loss ≥ 26 dB on single-mode optical fiber when tested in accordance with ANSI/EIA/TIA-455-107, factory testing or ANSI/EIA/TIA-455-8, field testing. These measurements shall be performed at $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$.

12.4.4.3 Durability

The 568SC connectors shall sustain a minimum of 500 mating cycles per ANSI/EIA/TIA-455-21, without violating specifications. These measurements shall be performed at $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$.

12.4.5 Optical Fiber Telecommunications Outlet/Connector

Telecommunications outlet/connector boxes shall be securely mounted at planned locations. As a minimum, the telecommunications outlet/connector box shall be capable of terminating two optical fibers into a 568SC adapter. The outlet/connector and adapter shall meet the requirements of 12.4.3 and 12.4.4 and the adapter shall be in the A-B orientation. The outlet/connector box shall have the ability to secure the optical fiber cable and provide for a minimum of 30 mm (1.18 in) bend radius. A minimum of 1 m (3.28 ft) of two-fiber optical cable or two buffered optical fibers shall be accessible for termination purposes. Typically, the telecommunications outlet/connector box consists of a 100 mm x 100 mm (4 in by 4 in) electrical box with an additional surface mounted box (which mounts to the electrical box) both providing the bend radius, slack storage, and adapter interface (see figure 12-4). This additional box is used in lieu of a typical face plate. Optical fiber runs intended for future connections shall be housed in a telecommunications outlet/connector box.

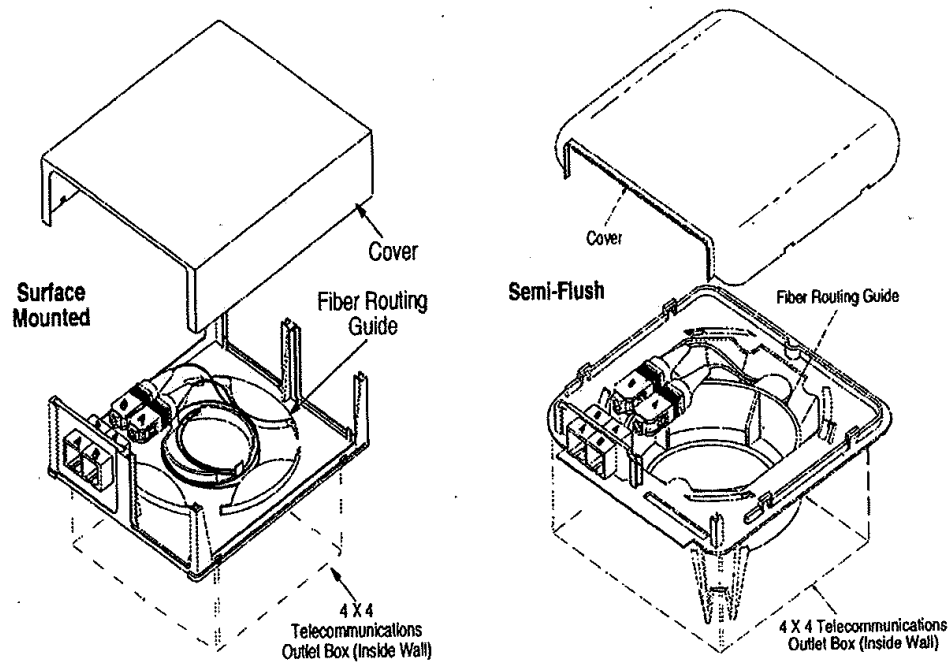


Figure 12-4 Examples of Optical Fiber Telecommunications Outlet/connectors

12.4.6 Patch Panel

12.4.6.1 General

Connecting hardware for the optical fiber cable is installed at the following:

- a) the main cross-connect;
- b) intermediate cross-connect;
- c) horizontal cross-connect;
- d) horizontal cabling transition points;
- e) telecommunications outlet/connectors.

Typical cross-connect facilities consist of cross-connect jumpers or patch cords and patch panels that are connected directly to horizontal or backbone optical fiber cabling.

12.4.6.2 Environmental Compatibility

Optical fiber cable connecting hardware shall be protected from physical damage and from direct exposure to moisture and other corrosive elements. This protection may be accomplished by installation indoors or in an appropriate enclosure for the environment.

12.4.6.3 Mounting

Optical fiber cable connecting hardware should be designed to provide flexibility for mounting on walls, in racks, or on other types of distribution frames and standard mounting hardware.

12.4.6.4 Mechanical Termination Density

Optical fiber cable connecting hardware should have a high density to conserve space but also be of a size consistent with ease of optical fiber cable management.

Wall-mountable optical fiber cross-connects with capacity to terminate no more than 144 optical fibers should be contained within a wall area 610 mm x 610 mm (24 in x 24 in).

Rack-mountable optical fiber cross-connects with capacity to terminate no more than 144 optical fibers should occupy a maximum of 622.3 mm (24.5 in) or 14 rack mount spaces of linear rack space.

Rack-mountable optical fiber cross-connects with capacity to terminate more than 144 optical fibers should provide mechanical terminations for 12 or more optical fibers per 44.45 mm (1.75 in or 1 rack mount space) of linear rack space.

12.4.6.5 Design

The optical fiber cross-connect hardware shall be designed to provide:

- a) means to cross-connect cabling runs with patch cords;
- b) means to interconnect premises equipment to the optical fiber network;
- c) means to identify circuits for administration in accordance with ANSI/TIA/EIA-606;
- d) means to use standard colors to functionally identify termination groups per ANSI/TIA/EIA-606;
- e) means of handling optical fiber cable and patch cords and to permit orderly patch cord management;
- f) means of access to monitor or test optical fiber cabling and premises equipment;
- g) an insulating barrier, such as a cover or a door, for protecting connectors and adapters on the cabling side from accidental contact with foreign objects that may disturb optical continuity.

12.4.6.6 Installation

The optical fiber connecting hardware shall meet 12.4.3, 12.4.4, and 12.7.1 and be installed to provide:

- a) neat, well organized installation with optical fiber management and sound optical termination practices in accordance with manufacturer's guidelines;
- b) color coding, labeling and documentation consistent with ANSI/TIA/EIA-606.

12.5 Optical Fiber Patch Cords

12.5.1 General

The optical fiber patch cord shall be a two fiber cable, of the same fiber type as the optical fiber cabling, of an indoor construction, and shall meet the requirements of 12.3.

12.5.2 Optical Fiber Connector

The functional requirements for the connector on an optical fiber patch cord are different from those for the connector installed on the premises cabling. The connector on an optical fiber patch cord shall allow for easy connection and reconnection, ensure polarity is maintained, and offer high pull-proof capabilities. Therefore, the connector used on patch cords shall be in the 568SC form and shall have an optical axial pull strength of 33 N (7.5 lbf) at a 0° angle and an optical off axial pull strength of 22 N (5 lbf) at a 90° angle, with a maximum 0.5 dB increase in attenuation for both tests when tested in accordance with ANSI/EIA/TIA-455-6B.

12.5.3 Configuration

568SC optical fiber patch cords, whether they be used for cross-connections or interconnecting to equipment, shall be of a cross-over orientation such that Position A goes to Position B on one fiber and Position B to Position A on the other fiber, of the fiber pair (figure 12-5). Each end of the 568SC optical fiber patch cord shall be identified to indicate Position A and Position B, if the connector can be separated into its simplex components.

Optical fiber patch cords with a 568SC connector on one end shall be used when the application electronics interface is different from the 568SC. When the electronics interface is two simplex connectors, one connector shall be labeled A and the other B. When the electronics interface is a duplex connector other than the 568SC, the connector that plugs into the receiver shall be considered Position A and the connector that plugs into the transmitter shall be considered Position B. The optical fiber patch cord shall be assembled in a cross-over orientation such that Position A goes to Position B on one fiber and Position B to Position A on the other fiber of the fiber pair.

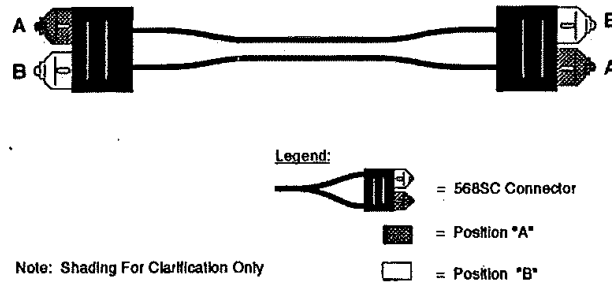


Figure 12-5 568SC Optical Fiber Patch Cord

12.6 Optical Fiber Splices

Optical fiber splices, fusion or mechanical, shall not exceed a maximum optical attenuation of 0.3 dB when measured in accordance with ANSI/EIA/TIA-455-34, Method A (factory testing) or ANSI/EIA/TIA-455-59 (field testing).

12.7 Cabling Practices

12.7.1 Polarization

To ensure a 568SC connection will maintain the correct polarization throughout the cabling system, the correct adapter orientation and optical fiber cabling shall be followed. Once the system is installed and correct polarization is verified, the optical fiber cabling system will maintain the correct polarization of transmit and receive fibers and will not be a concern for the end user.

The backbone and horizontal premises cabling shall be installed so as to pair an odd numbered fiber with the next consecutive even numbered fiber (i.e., fiber 1 with 2, 3 with 4, and so forth) to form two-fiber transmission paths. Each premises cabling segment shall be installed in a pair-wise cross-over orientation such that odd numbered fibers are Position A at one end and Position B at the other end while the even numbered fibers are Position B at one end and Position A at the other end.

The cross-over shall be achieved by using consecutive fiber numbering (i.e., 1,2,3,4...) on both ends of an optical fiber link, but the 568SC adapters shall be installed in opposite manners on each end (i.e., A-B, A-B... on one end and B-A, B-A... on the other). This approach is illustrated in figure 12-6.

Figure 12-7 provides the rules for the proper orientation of the 568SC adapter at the MC, IC, HC and telecommunications outlet/connector to ensure proper polarization of an optical fiber system from the main cross-connect to the telecommunications outlet/connector. Optical fiber links not shown in figure 12-7 shall simply ensure that on one end the 568SC adapter be installed in the A-B orientation and the other end in the B-A orientation.

By ensuring that all optical fiber patch cords and premises cabling is oriented in a cross-over orientation, i.e., A to B and B to A the user is assured that the correct polarization of transmit and receive fibers are maintained and need not be a concern of the user of the network.

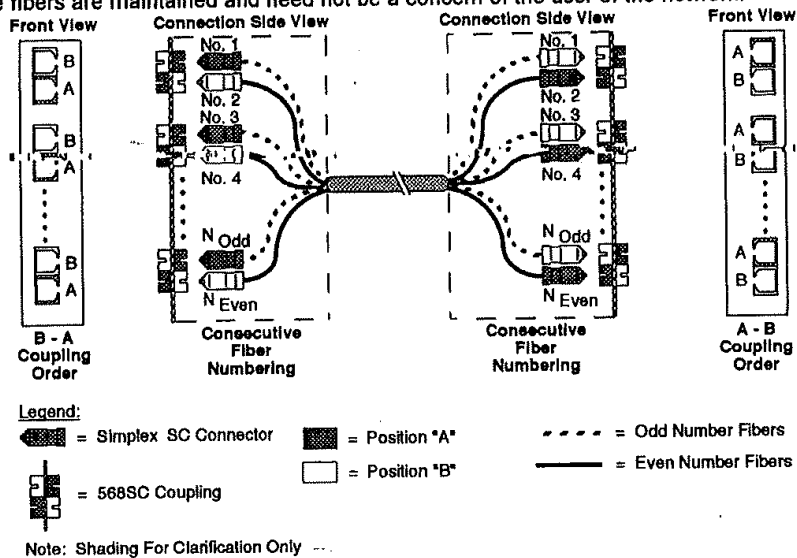


Figure 12-6 Specified Optical Fiber Cabling for Proper Polarization

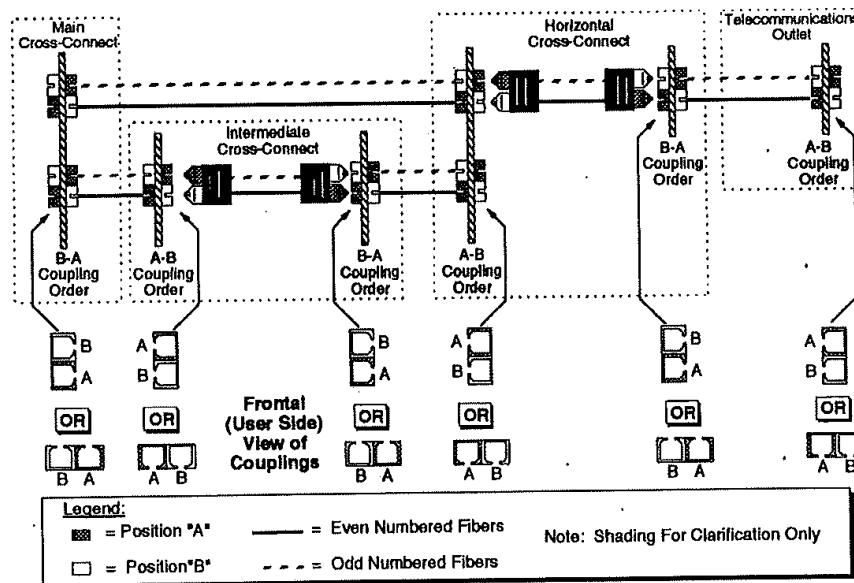


Figure 12-7 Optical Fiber Cabling Plan for Premises Cabling

12.7.2 Passive System Testing

It is recommended that each installed 62.5/125 μm and single-mode optical fiber link be tested in accordance with informative Annex H. Additionally, it is recommended that the correct polarization, i.e., Position A to Position B and Position B to Position A, be ensured for each optical fiber cabling segment.

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13 HYBRID AND UNDERCARPET CABLES

13.1 Hybrid Cables

Hybrid cables may be used for horizontal cabling provided that each recognized cable type (see 4.4) meets the transmission and color-code specifications for that cable type given in sections 10, 11, and 12. Additionally, crosstalk between any non-fiber recognized cable type shall be $[6+10\log(n)]$ dB better than the specified crosstalk of each recognized cable type at all of the specified frequencies (or ranges). In this instance, "n" refers to the number of recognized cables within the hybrid cable.

NOTES:

- 1 Hybrid UTP cables (color coded per 10.2) can be distinguished from multipair UTP backbone cables (color coded per 10.3) and by the transmission performance.
- 2 Hybrid cables consisting of optical fiber and copper conductors are sometimes referred to as composite cables.

13.2 Undercarpet Cables

13.2.1 Applications

Undercarpet cabling may be used as a segment of the horizontal cabling, extending from a transition point in a wall, column, or floor duct to a work area floor telecommunications outlet/connector.

Undercarpet cabling is typically used for limited areas that are bounded by four building columns. When used, the undercarpet cable shall meet the requirements set forth in 10.2.3.2, 10.2.3.3, 10.2.4, 10.2.5, and ANSI/IPC-FC-211.

13.2.2 Installation Considerations

Undercarpet cabling may be installed on any level, continuous, and relatively smooth floor surface of concrete, ceramic, composition, or wood. Undercarpet cabling should not be used in wet locations or where the cabling may be subjected to solvent spills.

In the area where installed, undercarpet cabling shall be installed after construction of the building is completed, just prior to the installation of the carpet. The cabling should be installed as a system using accessories, mechanical terminations, and fixtures designed to be used with the cabling and following the instructions provided by the manufacturer. Components from different systems should not be mixed unless the user has determined that they are compatible.

Undercarpet installations typically include undercarpet power circuits as well as the telecommunications cabling. Telecommunications cabling may cross power cables but otherwise should be separated from power cables by at least 152 mm (6 in). Undercarpet power cables shall not cross over telecommunications cabling. The preferred layout of cable runs is to feed power circuits and telecommunications circuits from opposite sides of a floor area to minimize crossings.

The use of carpet squares is recommended for accessibility to the undercarpet cabling.

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Annex A (normative) Reliability Testing of Connecting Hardware Used For 100 Ω UTP Cabling

This annex is normative and is considered part of the standard.

A.1 General

Connecting hardware reliability is vital to the cabling system. Changes in contact resistance because of operational and environmental stress can negatively affect the transmission characteristics of the building cabling system. Product life testing is accomplished by subjecting the product to a number of mechanical and environmental conditions and measuring any resistance deviation that may occur during and after completion of the test cycle. In addition, the product shall not show evidence of degradation with respect to ease of mechanical termination, safety or other functional attributes at any time during or after testing.

NOTE - Where connecting hardware consists of assemblies of modular connectors and cable terminations, the modular connectors and cable terminations may be tested separately, as components.

To ensure that all connecting hardware used for 100 Ω UTP cabling will perform reliably under field installation conditions, it shall be capable of passing the test sequence, illustrated in figure A-1, when mounted and connected in accordance with manufacturer's guidelines. Unless otherwise specified, the measuring atmosphere should be room climate in accordance with IEC 68-1, subclause 5.3.1. For connecting hardware with 8-position modular connectors, the modular connection shall comply with the Level A reliability requirements of IEC 603-7. Where connecting hardware consists of assemblies of modular connectors and cable terminations, the modular connectors and cable terminations may be tested separately as components.

For each of the four test sequences shown in figure A-1, a minimum of 100 test contacts shall be tested without failure. Unless otherwise specified, all products shall be tested in a mated or terminated state.

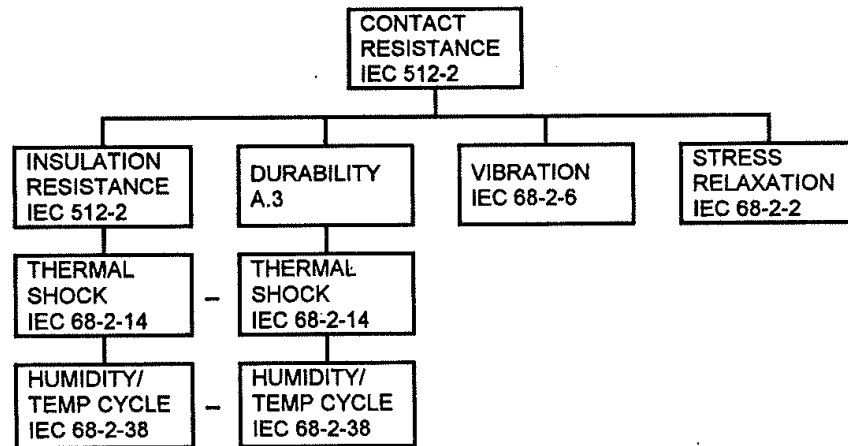


Figure A-1 Reliability Test Program

A.2 Contact Resistance Measurement

Contact resistance shall be measured in accordance with IEC 512-2, Test Method 2A, Millivolt Level Method and shall conform with the following requirements:

- a) If voltage probes cannot be placed within 1.3 mm (0.051 in) from the connection point, bulk resistance should be measured and subtracted out to determine contact resistance.
- b) Initial interface resistance (the electrical connection, not including bulk resistance) between elements of connecting hardware and between connecting hardware and cabling shall not exceed 1 m Ω . Also, elements of a connecting system that are subject to more than a single connecting operation throughout normal use shall not exhibit an initial interface resistance in excess of 1 m Ω when newly terminated, at any time during or after environmental conditioning.
- c) Whenever contact resistance measurements are required on the following tests, interface resistance shall not change by more than 5 m Ω from the initial value.

As stated in sections 10 and 11, 2-piece connector interfaces that comply with IEC 603-7 or IEC 807-8 are exempt from this annex.

A.3 Insulation Resistance

Insulation resistance shall be measured in accordance with IEC 512-2, Test 3a, Method C, Test Voltage 500 Vdc. Insulation resistance between any two conductors shall be at least 100 M Ω .

These specimens shall be used as Sample Group A.

A.4 Durability

Elements of the connecting system that are subject to more than a single connecting operation throughout normal use shall withstand at least 200 insertion and withdrawal cycles without failing. 100 cycles are done before thermal shock and humidity/temperature cycling tests, and an additional 100 cycles are performed during and after these environmental tests.

Evaluation:

Inspect and measure contact resistance after 100 cycles. These specimens shall be used as Sample Group B.

A.5 Vibration

Vibration tests shall be performed in accordance with IEC 68-2-6, Test Method Fc and Guidance.

a) Test Conditions:

- | | |
|----------------------------|-------------------|
| 1) Frequency Range: | 10-55 Hz |
| 2) Displacement Amplitude: | 0.75 mm (0.03 in) |
| 3) Sweep Cycles: | 20 |
| (each of 3 linear axes) | |
| 4) Elapsed Time: | 1 hour 45 minutes |
| (each axis) | |

b) Evaluation:

Inspect and measure contact resistance after vibration cycling of each axis.

A.6 Stress Relaxation

Stress relaxation tests shall be performed in accordance with IEC 68-2-2, Test Method Ba.

a) Test Conditions:

- | | |
|----------------------|--------------|
| 1) Test Temperature: | 70 °C ± 2 °C |
| 2) Test Period: | 500 hours |

b) Evaluation:

Inspect and measure contact resistance at 168 ± 10 hour intervals.

A.7 Thermal Shock

Thermal shock tests shall be performed in accordance with IEC 68-2-14. Test Method Nb. One-half of the Sample Group A terminals shall be tested in a mated (terminated) state. The remaining Sample Group A terminals shall be tested in an unmated (unterminated) state. Sample Group B terminals shall be tested in mated (terminated) state only.

a) Test Conditions:

- | | |
|---|---------------|
| 1) Low Temperature: | -40 °C ± 2 °C |
| 2) High Temperature: | 70 °C ± 2 °C |
| 3) Minimum Average Transition Rate: | 3 °C/min. |
| 4) Exposure Time: | 30 min. |
| (each temperature) | |
| 5) Number of cycles: | 100 |
| 6) Sample Group B shall be subjected to 33 insertion and withdrawal cycles after 50 temperature cycles. | |

b) Evaluation:

Inspect and measure contact resistance after 50 ± 5 cycles and at the completion of test cycling. These specimens shall be used for humidity/temperature cycle testing.

A.8 Humidity/Temperature Cycle

Humidity/Temperature cycle testing shall be performed in accordance with IEC 68-2-38, Test Method Z/AD with cold subcycle. One-half of the Sample Group A terminals shall be tested in a mated (terminated) state. The remaining Sample Group A terminals shall be tested in an unmated (unterminated) state. Sample Group B terminals shall be tested in mated (terminated) state only.

a) Test Conditions:

This test is performed only on product that has passed thermal shock testing.

- 1) Low Temperature: $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$
- 2) High Temperature: $65^{\circ}\text{C} \pm 2^{\circ}\text{C}$
- 3) Cold Subcycle: $-10^{\circ}\text{C} \pm 2^{\circ}\text{C}$
- 4) Relative Humidity: $93 \pm 3\%$
(at high and low temperatures)
- 5) Cycle Time: 24 hours
- 6) Number of cycles: 21
- 7) Sample Group B shall be subjected to 33 insertion and withdrawal cycles after 7 days and an additional 34 cycles after 21 days.

b) Evaluation:

Inspect and measure contact resistance (for Groups A and B) and insulation resistance (for Group A only) immediately upon removal from the test chamber at seven-day intervals and after final drying. Recovery of insulation resistance from a humid state to least $100\text{ M}\Omega$ shall occur within 1 hour.

A.9 Other Testing

Connecting hardware that is used for the $100\ \Omega$ UTP network shall also comply with the safety and performance requirements of UL 1863.

Annex B (normative) Transmission Testing of Connecting Hardware Used for 100 Ω UTP Cabling

This annex is normative and is considered part of the standard.

B.1 General

The transmission tests described in this annex typically require the use of a network analyzer or equivalent, coaxial cables, baluns, UTP test leads, and impedance matching terminations. Each set-up component shall be qualified to a measurement bandwidth of at least 1 MHz to 100 MHz. Calibration procedures for attenuation, NEXT loss, and return loss measurements are specified by the manufacturer of the test equipment.

The test methods and set-up requirements described herein apply to two (2) or more pairs of unshielded twisted-pair wires. The nature of these tests is such that, when conducted properly, worst case transmission performance may be determined for a specific connector, regardless of the number of pairs that it is capable of terminating. For example, it may be necessary to sample groupings of adjacent pairs on cross-connect blocks designed for use in 10-pair or 25-pair increments to determine worst case crosstalk performance variations.

The test results on connecting hardware shall be based upon products terminated per manufacturer's guidelines and recommended installation methods. For connecting hardware with modular interface components (i.e., plug and jack connectors) transmission tests shall be performed with both connectors in a mated state. For qualification testing, both plug and jack components shall be identified. Product compliance shall be determined using worst case measured values based upon a minimum of ten (10) randomly selected samples.

For connecting hardware having multiple ports on the same assembly (e.g., a patch panel), the ten samples shall be tested from a minimum of two separate finished assemblies. Compliance testing shall be performed on one of each port per circuit board. Based on this testing, the worst case port designs shall be identified for each measurement parameter (i.e., Attenuation, NEXT Loss, Return Loss and DC Resistance). The worst case port configuration(s) for each measurement parameter shall be fully tested with a minimum of 10 samples.

For mateable connectors where one component is intended to be fixed (rigidly mounted, such as modular sockets) and the other is free (such as modular plugs), product compliance shall be determined using worst case measured values based upon a minimum of ten (10) of each fixed component and a minimum of five (5) of each free component (i.e., 10 sockets and 5 plugs) tested in a minimum of ten (10) combinations total. There shall be no more than two socket samples tested with the same plug. All test specimens shall be randomly selected from production samples.

For IEC 603-7 connectors, additional test plug requirements are specified in B.5.

NOTE - Because the transmission performance of modular jack and plug connectors is determined in a mated state, and because cables used for modular patch cords are subject to the requirements of 10.5, the performance category of modular plug-ended patch cords is determined by the performance capability of the plugs and cables tested separately, and not by the performance of the finished cable assembly. Although this annex provides specifications on connections to test plugs for proper performance characterization of modular jack and plug connections; termination

practices and qualification guidelines for factory and field administered modular plug and cable terminations may use the procedure specified in B.5.1 and are under study.

B.2 Test Set-up and Apparatus

UTP test leads are used for connections to and from the test sample. Test leads shall be 24 AWG and shall be taken from cables that meet or exceed requirements for category 5 cable specified in 10.2. Test leads for modular test plugs may also be taken from category 5 patch cable specified in 10.5. UTP test leads shall be limited to a length of 65 mm (2.6 in) between each balun and the connector under test. If used, coaxial cable assemblies extending to and from test equipment should be as short as possible. It is recommended that they do not exceed 0.6 m (24 in) each. If a balun ground plane is used, a separation of at least 10 mm (0.4 in) shall exist between it and the UTP test leads at the point they are connected to the baluns. In addition, separation between the active conductors of the product under test and the balun ground plane (if present) shall be at least 50 mm (2 in).

Impedance matching terminations for the UTP test leads and the product under test shall be 100 Ω with a tolerance not to exceed $\pm 3\%$ ($\pm 1\%$ precision metal film resistors are recommended) throughout the frequency range from 1 MHz to 100 MHz.

Unless the network analyzer is equipped with 100 Ω balanced outputs, baluns are required to provide transmission continuity to the UTP test leads. Test baluns shall be RFI shielded and shall comply with the specifications listed in table B-1.

Table B-1
Test Balun Performance Characteristics
(1-100 MHz)

Parameter:	Value:
Impedance, Primary*	50 Ω unbalanced
Impedance, Secondary	100 Ω balanced
Attenuation	1.2 dB maximum
Return Loss, Bi-directional	20 dB minimum
Power Rating	0.1 watt minimum
Longitudinal Balance**	50 dB minimum

* Primary impedance may differ, if necessary to accommodate analyzer outputs other than 50 Ω .

** Measured per ITU-T (formerly CCITT) Recommendations G.117 and O.9.

For crosstalk measurements, near-end of the transmission test set-up corresponds to the end from which test signals are applied. Far-end is specified as the end of the product under test that is not directly connected to measurement equipment. For NEXT loss and return loss measurements, pairs at the far-end are terminated with 100 Ω impedance matching terminations. For pairs not under test, impedance matching terminations are not required on the near-end. Product orientation, with respect to near-end and far-end,

may affect measurement results. Due to these affects, the connector shall be tested in the orientation that best reflects installed field use.

Products that are intended to receive near-end signals from either orientation (e.g., those that may be used as telecommunications outlet/connector as well as in telecommunications closets for patching) shall be tested in both orientations for NEXT loss, attenuation, and return loss.

B.3 Test Method

Transmission performance of connecting hardware for UTP cabling (without cross-connect jumpers or patch cords) is determined by evaluating its impact upon measurements of attenuation, NEXT loss and return loss for pairs of 100 Ω balanced 24 AWG test leads. Calibration, reference data sweeps, or both are collected with UTP test leads in place to assure a minimum noise floor of 80 dB for attenuation and NEXT loss measurements. For return loss measurements, the set-up return loss shall be ≥ 50 dB when calibrated with the impedance matching terminations specified in B.2.

After calibration, reference sweeps, or both are performed, the test leads and impedance matching terminations are connected to the test sample and connector transmission performance data is collected for each parameter.

See B.6 for an example of a set-up implementation that has proven to yield accurate and repeatable NEXT performance data for modular jack connectors.

B.4 Measurement Precautions

To assure a high degree of reliability for connecting hardware transmission measurements, the following measurement precautions are required:

- a) That consistent and stable balun and resistor terminations are used for each pair throughout the test sequence. In order to reduce variability, it is recommended that terminating resistors be connected directly to the far-end of the connector under test. Balun terminations may be used, provided they are shown to yield equivalent results.
- b) That cable and test lead discontinuities, as introduced by physical flexing, sharp bends and restraints, be avoided before, during and after connector termination.
- c) That, throughout the test sequence, the relative spacing of the test leads be preserved to the greatest extent possible.
- d) That the test leads and connector under test be separated from metallic surfaces, such as ground planes (see B.2), and isolated from sources of EMI.
- e) That the balance of the 100 Ω test leads is maintained by consistent wire lengths and pair twisting to the point of termination.
- f) That coaxial and twisted-pair lead lengths be kept as short as possible such that resonance and parasitic effects are minimized. If resonance or deviations from

linear slope are observed during NEXT loss measurements, balun grounding or length reduction of coaxial leads may improve measurement accuracy.

- g) That connections between the connector under test and measurement baluns be made such that wire movement resulting from connection of different pairs to the network analyzer will produce minimal variability for repeated measurements on the same product (± 0.5 dB or less is acceptable). Where practical, a rigid test fixture is recommended.

The sensitivity to set-up variations for these measurements at high frequencies warrants thorough documentation of all measurement facilities and procedures. Data interpretation and application of the requirements in this annex are appropriate only if satisfactory measurement repeatability is achieved.

B.4.1 Set-up Validation

For two port measurements such as attenuation and NEXT loss, tests shall be performed to assure an acceptable level of accuracy and linearity throughout the frequency range of interest. The two tests include set-up attenuation of the baluns plus test leads and an attenuation measurement on the baluns and test leads using resistors. These requirements provide a general indication of the ability of the set-up to provide consistent and accurate measurements over the frequency range of 1 MHz to 100 MHz.

B.4.1.1 Balun and Test Lead Attenuation

The measured attenuation of the combined baluns and test leads shall not exceed 3 dB from 1 MHz to 100 MHz (figure B-1).

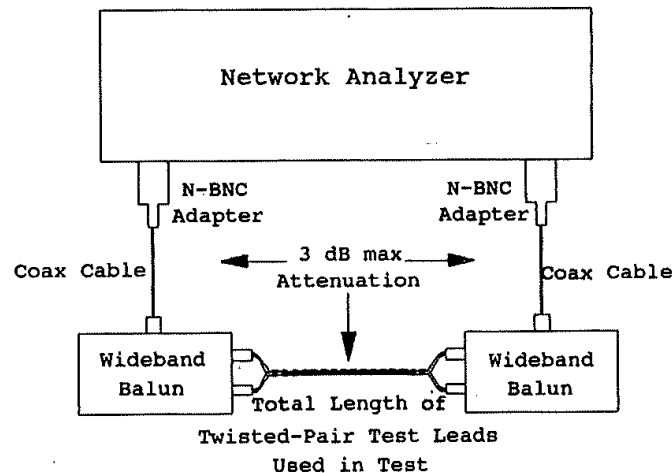


Figure B-1 Balun and Test Lead Attenuation Measurement

With the network analyzer calibrated to factor out the combined attenuation of the baluns and test leads, the addition of 100 Ω resistors connected across each of the two balanced outputs of the test baluns (one 100 Ω resistor connected in parallel with, and on each end of the UTP test leads) shall result in an attenuation of 6 ± 1.5 dB from 1 MHz to 100 MHz (figure B-2). In order to minimize inductive effects, the resistor leads should be kept as short as possible [5 mm (0.2 in) or less per side].

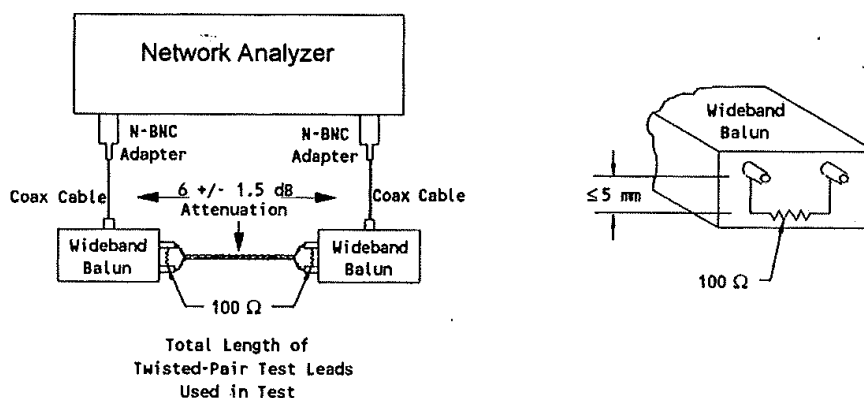


Figure B-2 Attenuation Measurement Using Resistors

B.5 Termination Procedure and Set-up Verification for Modular Jack and Plug Testing

Because of variations that are inherent to terminating UTP cables to modular plugs (and to a lesser extent, modular jacks), the following requirements and guidelines have been developed. When implemented properly, these guidelines assure that accurate and repeatable transmission test measurements will be performed with minimal variations between test facilities and personnel. It should be noted that the same plug qualification requirements apply to transmission testing in either direction (see B.5.2). These specifications are not intended to replace other requirements and guidelines in this annex.

B.5.1 Test Plug Termination

Connections between the UTP test leads and the modular test plug should be made using the following procedure. It should be noted that the following termination procedure will not always result in plugs that meet the requirements of B.5.2. Familiarity with these guidelines through repeated use has been observed to yield improved consistency between terminations.

- a) Strip or position the jacket such that the twisted conductors extend a distance of 20 mm (0.8 in) beyond it. The jacket itself should be at least 13 mm (0.5 in) long.
- b) Position the cable pairs such that they are sequenced 1&2, 3&6, 4&5, 7&8 respectively (figure B-3). To prevent physical invasion between pairs under the jacket when the plug is crimped, the side-by-side orientation of the test leads shall extend into the jacket a distance of at least 8 mm (0.3 in), creating a flat

portion. The flat, jacketed portion of the test leads will appear to be oblong in cross-section.

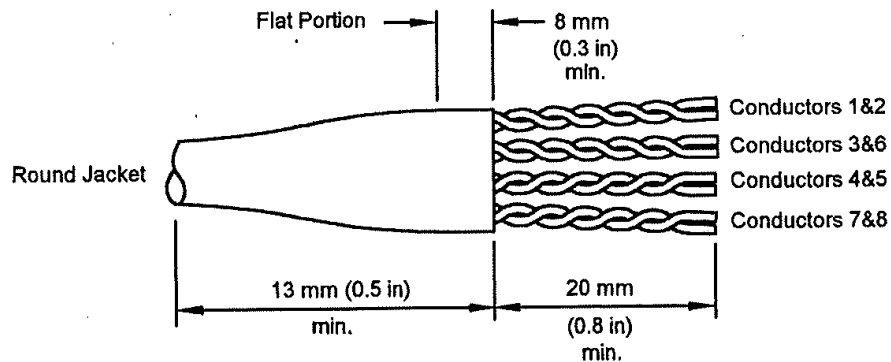


Figure B-3 UTP Test Leads and Jacket Prior to Untwisting

- c) Untwist the pairs and orient them in correct order for termination such that they are parallel and conductor 6 is made to cross over conductors 4 and 5. There shall be no untwisting of the paired conductors inside of the jacket.
- d) The trimmed length of conductors should be about 14 mm (0.55 in), measured from the jacket. There shall be no physical crossings between conductors for a length of at least 10 ± 1 mm (0.4 ± 0.04 in) from the wire tips (figure B-4). The distance from the jacket where conductor 4 crosses over conductors 5 and 6 shall not exceed 4 mm (0.16 in).

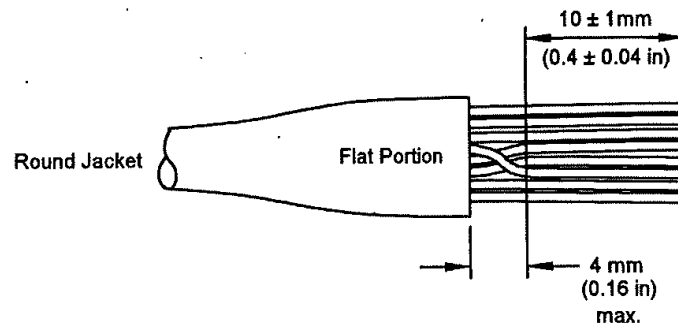


Figure B-4 UTP Test Leads Prior to Plug Termination

- e) Insert the plug over the prepared test leads. The conductors shall be "bottomed-out" in the front of the plug and the flattened portion of the jacketed test leads shall extend from the back of the plug to beyond the primary strain relief (figure B-5). The jacket shall protrude beyond the back of the plug by at least 6 mm (0.24 in).

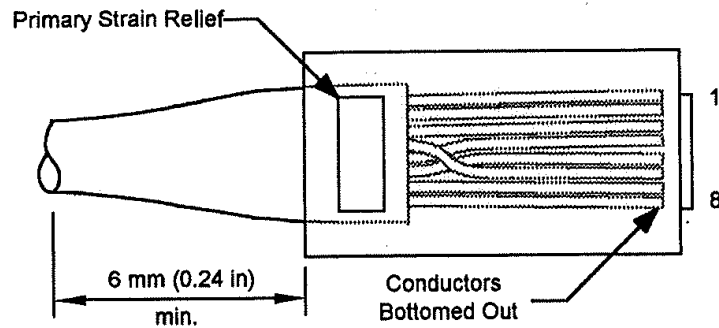


Figure B-5 Completed Test Plug

- f) Crimp the plug and measure the conductor and jacket dimensions again to assure that they conform to the required geometry.

B.5.2 Test Plug Qualification

Once the test plug is terminated in accordance with B.5.1, its characteristics shall be verified by measuring its crosstalk loss in an unmated state with 100 Ω resistors connected in parallel with 100 Ω test leads where they connect to the baluns.

For each of the six (6) test plug pair combinations, connect a 100 Ω resistor in parallel with the test leads (where they connect to the baluns) and measure NEXT (figure B-6). In order to minimize inductive effects, the resistor leads should be kept as short as possible [5 mm (0.2 in) or less per side]. For each of the six (6) pair combinations, the measured NEXT loss of the open circuit plug, with 100 Ω resistors connected in parallel with the UTP test leads, shall measure in the range shown in table B-2. This measurement is sometimes referred to as a "terminated open circuit" or TOC test. In addition, for pin combination 4&5 - 3&6, the difference between the NEXT loss measured at 100 MHz and the NEXT loss measured at 10 MHz for this set-up shall be 20 ± 0.5 dB.

Table B-2
Test Plug NEXT Loss Requirements

Pin Combination	Test Plug NEXT Loss at 100 MHz
4&5 - 3&6	≥ 40 dB
3&6 - 1&2	≥ 45 dB
3&6 - 7&8	≥ 45 dB
4&5 - 1&2	≥ 55 dB
4&5 - 7&8	≥ 55 dB
1&2 - 7&8	≥ 55 dB

If test plug complies with these requirements, the 100 Ω resistors shall be removed from the baluns before any mated plug/jack measurements are made.

For product qualification testing, a minimum of five (5) test plugs shall be used. TOC NEXT results may be rounded to the nearest 0.1 dB. Of the minimum five (5) test plugs

used, three (3) are subject to the following additional TOC requirements for pin combination 4&5 - 3&6.

- a) At least one of the five (5) test plugs used shall exhibit TOC NEXT loss in the range from ≥ 40.0 dB to < 40.5 dB at 100 MHz.
- b) At least one of the five (5) test plugs used shall exhibit TOC NEXT loss in the range from ≥ 40.5 dB to < 41.5 dB at 100 MHz.
- c) At least one of the five (5) test plugs used shall exhibit TOC NEXT loss of ≥ 41.5 dB at 100 MHz.

NOTE - The test plug should be periodically examined for physical wear and mechanical degradation.

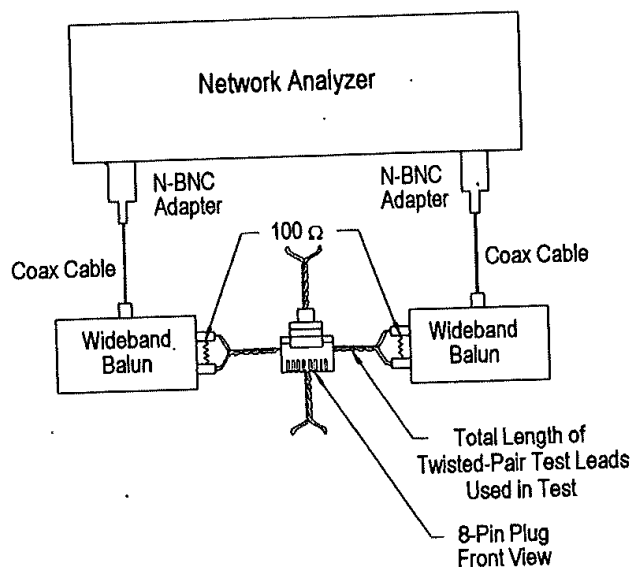


Figure B-6 Test Plug Qualification Measurement

B.6 Typical Work Area Outlet NEXT Measurement Procedure

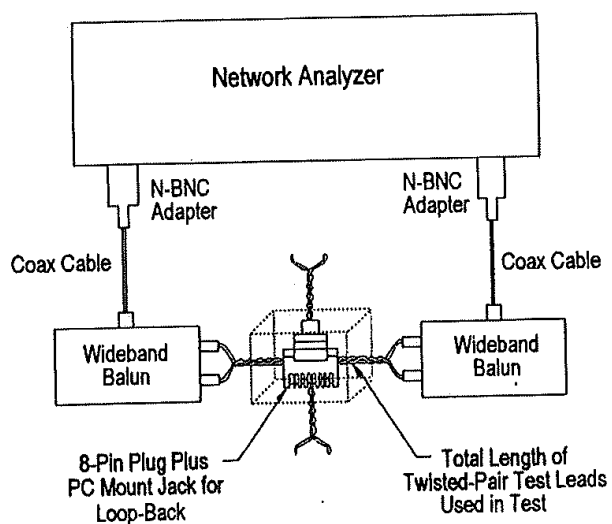
Described herein is a measurement method that may be used to categorize NEXT for various types of work area outlets. Although this method may not be directly applicable to other types of connecting hardware, it is shown to illustrate a set-up that is accurate, simple to implement and that will allow a large number of connectors to be characterized in a short period of time. Set-up variations that yield equivalent results are also acceptable.

Advantages of this procedure are the lack of any soldered connections, the reuse of one 8-pin modular plug with a short length of category 5 cable attached to it, and the fact that all test leads can be as short as 50 mm (2 in). The test set-up is shown in figure B-7, detail A. Test baluns may also be connected directly to the network analyzer. To make

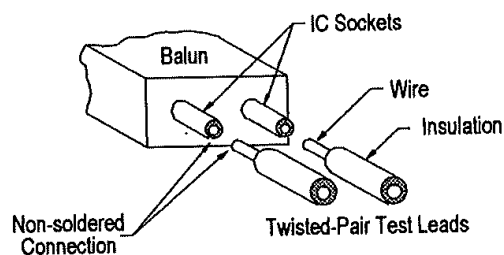
solderless connections to balun ports, the test leads are fitted with pins from an IC socket. These pins may be easily removed from a socket and attached to the terminals of the balun. Connections to the baluns are then made by inserting wires from the test leads into the hollow portion of the pin receptacles (figure B-7, detail B). This connection is comparable to inserting an IC into a socket. A pressure fit is provided and no soldering is required nor are any special tools required.

The 8-pin plug used in this set-up is constructed per B.5 with a short piece of category 5 cable that has the outer jacket removed approximately 6 mm (0.24 in) beyond the plug. Beyond the jacket, the 4 pairs are oriented 90° with respect to one another as shown in figure B-7, detail C. The tips of these wires are connected to measurement baluns by insertion into the balun-mounted IC sockets (figure B-7, detail B). The lengths of the pairs are adjusted to just reach the baluns with the two pairs being measured in exactly opposite directions coming out of the test plug (180° apart). In this way, various pair combinations may be measured without soldering.

To factor-out attenuation of the set-up, a series of through-calibration jacks are constructed from PC mountable jacks. There is one through-calibration jack for each of six possible pair combinations (based on four test pairs). Each through-calibration jack connects a specific transmit pair to a specific receive pair (figure B-7, detail D). For example, when measuring pins 4-5 and 3-6, the through-calibration jack for this combination connects pin 3 to pin 5 and pin 4 to pin 6 to allow a signal entering pins 4 and 5 to exit on pins 3 and 6. Once the jack is mated to the measurement plug, the analyzer is calibrated. Since the connector under test is considered to consist of a mated plug and outlet, it is important that the calibration procedure does not factor-out crosstalk noise that may be attributed to the modular plug and jack combination. To measure a telecommunications outlet/connector, the plug is then mated with the test jack and NEXT loss measurements are performed.



Detail A: Test Setup Without DUT



Detail B: Test Lead-to-Balun Connections

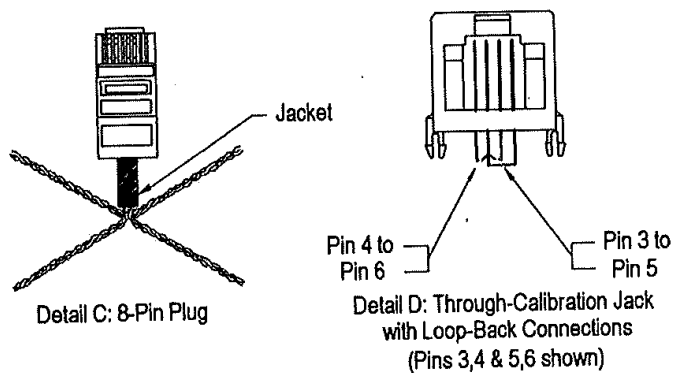


Figure B-7 Typical Work Area Outlet NEXT Measurement Setup

Annex C (normative) Transmission Testing of Connecting Hardware for 150 Ω STP-A Cables

This annex is normative and is considered part of the standard.

C.1 Test Methods

□

C.1.2 Test Balun Specifications

The balun required for testing in this bulletin shall meet the following electrical specifications.

Impedance	50 Ω unbalanced; Primary 150 Ω balanced; Secondary
Frequency Range	0.1 - 300 MHz
Attenuation	(1-300 MHz) 1 dB Maximum
DC Isolation	None
Return Loss	(into 50 Ω), 1-300 MHz - 20 dB Minimum
Power Rating	0.1 watt minimum
Common Mode Rejection	50 dB minimum at 1 MHz, decreasing at 15 dB per decade to a minimum value of 20 dB at 100 MHz and above. (Measured per CCITT recommendations G.117 and O.9.)

C.1.3 Near End Crosstalk (NEXT)

PURPOSE:	NEXT is a measure of signal coupling from one circuit to another within a connector and is derived from swept frequency voltage measurements on short lengths of 150 Ω STP-A cable test leads terminated to the connector under test. A balanced input signal is applied to a disturbing pair of the connector while the induced signal on the disturbed pair is measured at the near end of the test leads.
PARAMETERS:	Set the network analyzer to a 15 dBm level and measure the NEXT from 0.1 MHz to 300 MHz on a length of STP-A cable equal to the test leads, making sure both pairs are terminated on the far end with 75 Ω from each conductor to ground, then measure the NEXT on the mated connector pair. STP-A test leads shall be limited to a length of 64 mm (2.5 in) between each balun and the connector under test.
EQUIPMENT	Use a 50 Ω "s parameter" test set (or equivalent) network analyzer. Baluns shall be mounted and grounded to a suitable grounding fixture. The shields of both test leads shall be grounded to the fixture.

PASS/FAIL CRITERIA: The NEXT loss between pairs shall exceed the values determined by the formula in 11.4.3.2.

C.1.4 Attenuation

PURPOSE: Attenuation is a measure of signal power loss due to the connecting hardware and is derived from swept frequency voltage measurements on short lengths of 150 Ω twisted-pair cable test leads before and after splicing in the connector under test.

PARAMETERS: Set the network analyzer to a 15 dBm output level and measure the attenuation, from 0.1 MHz to 300 MHz for a length of STP-A cable equal to the test leads, then measure the attenuation of the mated connector pair, or of a single connector if measuring the self-shorting path. The attenuation of the pair or the self-shorting path is the difference in dB between the two readings. STP-A test leads shall be limited to a length of 64 mm (2.5 in) between each balun and the connector under test.

EQUIPMENT: Use a 50 Ω "s parameter" test set (or equivalent) network analyzer. Baluns shall be mounted and grounded to a suitable grounding fixture. The shields of both test leads shall be grounded to the fixture.

PASS/FAIL CRITERIA: The attenuation of any pair within a connector shall lie at or below the piece-wise curve drawn using the values in table 11-5.

C.1.5 Return Loss

PURPOSE: Return loss is a measure of impedance matching between the cable and the connector and is derived from swept frequency voltage measurements on short lengths of 150 Ω STP-A test leads after inserting the connector under test.

PARAMETERS: Set the network analyzer to a 15 dBm level and measure the return loss of a mated connector pair from 0.1 MHz to 300 MHz, making sure both pairs of cable are terminated on the far end with 75 Ω resistors from each conductor to ground. The terminating resistors should be the same resistors used in calibration.

EQUIPMENT: Use a 50 Ω "s parameter" test set (or equivalent) network analyzer. Baluns shall be mounted and grounded to a suitable grounding fixture. The shields of both test leads shall be grounded to the fixture.

PASS/FAIL CRITERIA: The return loss shall be equal to or greater than the values specified by the formula in 11.4.3.4.

C.1.6 Shielding Effectiveness

This section specifies the method of testing the electromagnetic compatibility performance of the connectors with 150 Ω STP-A cable. The performance criteria is found in 11.4.3.3. This section provides procedures for the sample preparation and associated hardware needed to perform the test.

The connector used with 150 Ω STP-A cable reduces unwanted electromagnetic energy from radiating from the cable system.

- a) The radio frequency leakage current on the shield of the cable is the dominant radiation source at the frequencies of interest (below 1 GHz).
- b) Direct aperture radiation from the connector can be neglected. The magnitude of the leakage current on the shield of the cable can be measured using a calibrated radio frequency current probe to determine the ratio of the leakage current to source voltage within the cable. This ratio will define the shield effectiveness of the connectorized cable assembly or connectorized cable assembly and panel mount connector.

C.1.6.1 Testing Assumptions

The shield effectiveness of a single connector shall be below the limits specified in figure C-1 from 30 MHz to 1000 MHz using the test procedure described in this annex on hardware assembled and connected per the manufacturer's guidelines.

The shield effectiveness criteria shown in figure C-1 can be expressed using the following equation below 400 MHz.

$$L = 25 \log f - 87 \text{ in dB for } f \text{ below 400 MHz}$$

where: L = limit using the absorbing clamp
 f = frequency in MHz

The criteria can be expressed using the following equation above 400 MHz.

$$L = -22 \text{ dB for } f \text{ greater than 400 MHz.}$$

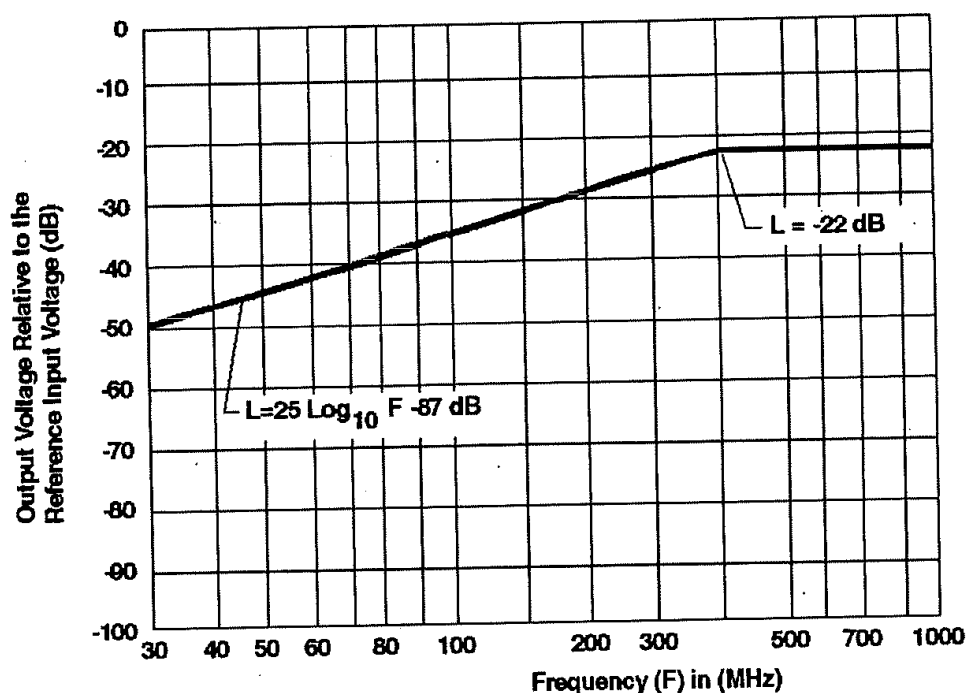


Figure C-1
Shield Effectiveness Limits

C.1.6.2 Cable Connector Configurations for Qualification

The connector shall be tested attached to the following types of cables and in the following connector configurations:

- | | |
|-----------------------------------|-----------|
| a) 150 Ω STP-A cable | rear exit |
| b) 150 Ω STP-A patch cable | rear exit |
| c) 150 Ω STP-A patch cable | 45° exit |

A minimum of 10 samples of each of the three configurations shall be tested and the data recorded. The mean of the envelopes of the highest measured levels using the sample of 30 total connectors should be 3 dB below the limit shown in figure C-1. No single connector shall exceed the limit shown in figure C-1 at any frequency.

C.1.6.3 Reference Cable Test

A shielded reference cable shall be used to establish the dynamic range of the test set-up. This reference should ensure that the test is capable of measuring the shield effectiveness of the test sample and is not susceptible to external sources of measurement error.

The shielded reference cable, 2.4 m (8 ft) in length, shall be placed inside the test chamber. The cable type shall be of the same type and construction as that to be used with the connectorized assemblies, the connections between the cable shield and the termination fixture shall be soldered or 360° compression type connections. See figure C-2 for construction details. The

reference cable measurement will establish that portion of the total leakage current due to the cable rather than the connector.

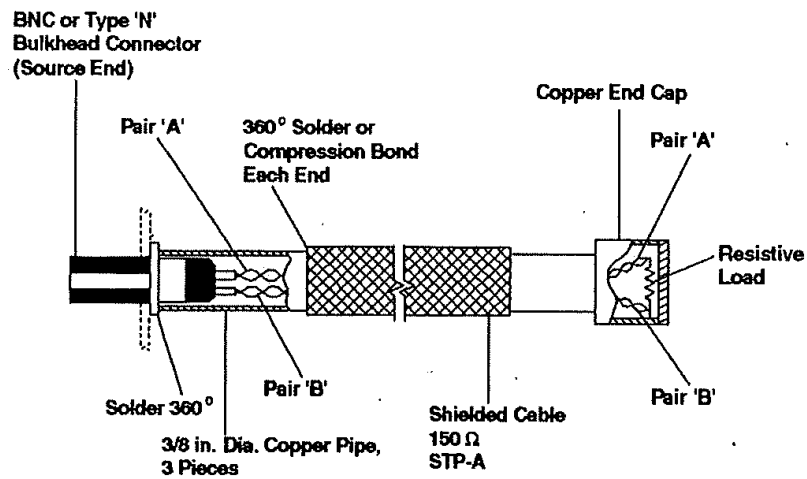


Figure C-2
Construction Details of the Shielded Reference Cable

C.1.6.4 Test Chamber

The dimensions of the test chamber shall be as shown in figure C-3.

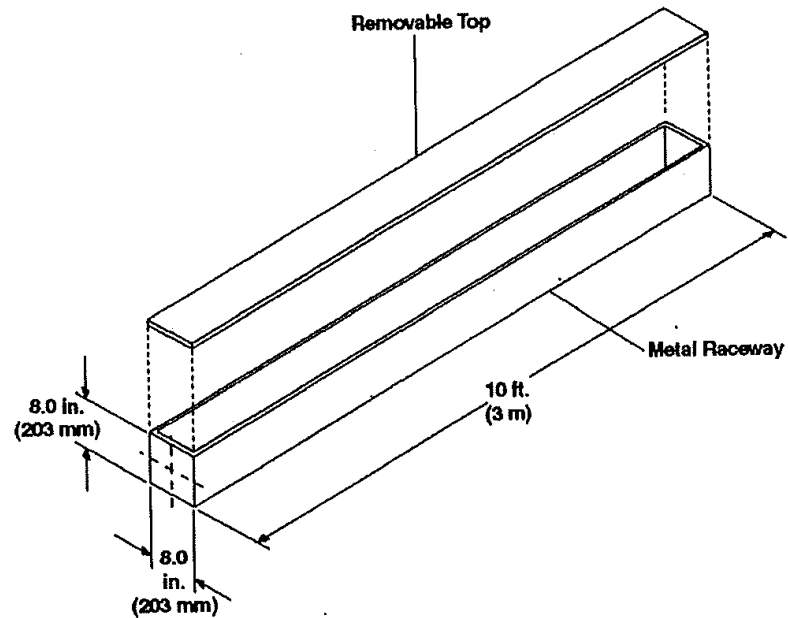


Figure C-3
Dimensions of the Shield Effectiveness Test Chamber

The test chamber shall provide sufficient shielding and isolation from the ambient to provide the dynamic range needed to measure the reference samples. All test samples shall be centered within the confines of the test chamber using non-metallic supports. The termination hardware at the chamber entry shall be constructed as shown in figures C-4 and C-5. A fully shielded connector with internal termination resistor may also be used as an alternate to the mechanical configuration shown in figure C-5.

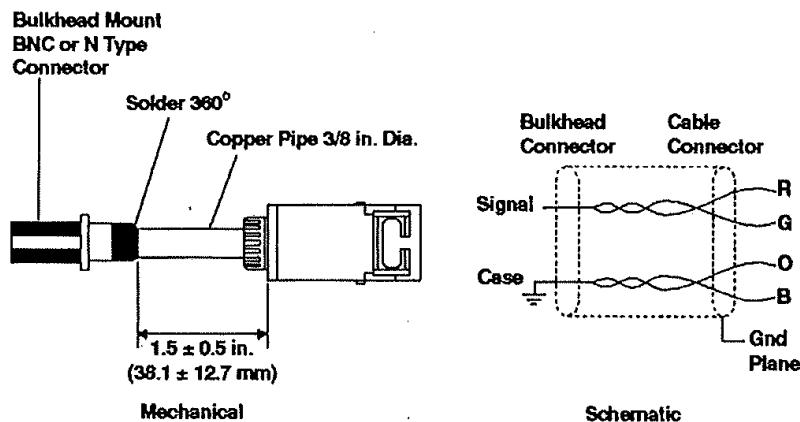


Figure C-4

Source Termination for Measuring Connectorized Cable Assemblies (Cable Attached Connector)

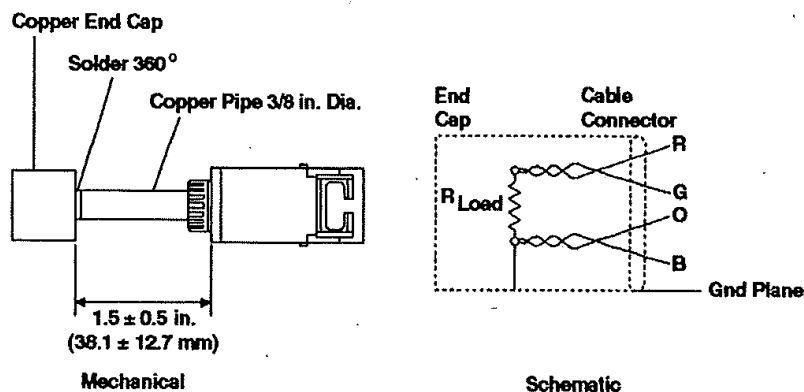


Figure C-5

End Termination for Measuring Connectorized Cable Assemblies (Cable Attached Connector)

The entry connector shall be mounted and centered on the end plate of the test chamber. The termination end containing the resistor should not contact the chamber wall and should be mounted in the center of the test chamber. Cable assemblies which use the 45° exit should be mounted with the cable exiting toward the bottom of the test chamber and not toward the top or sides.

C.1.6.5 Shield Effectiveness Measurement Fixture

A 50 Ω absorbing clamp, meeting the specifications in C.1.6.9.1 shall be used to measure the leakage current from the test assemblies as a function of frequency from 30 MHz to 1000 MHz. If the calibration curve supplied by the manufacturer meets the limits shown in figure C-6, then no further calibration is necessary, and the voltage response of the clamp can be used directly.

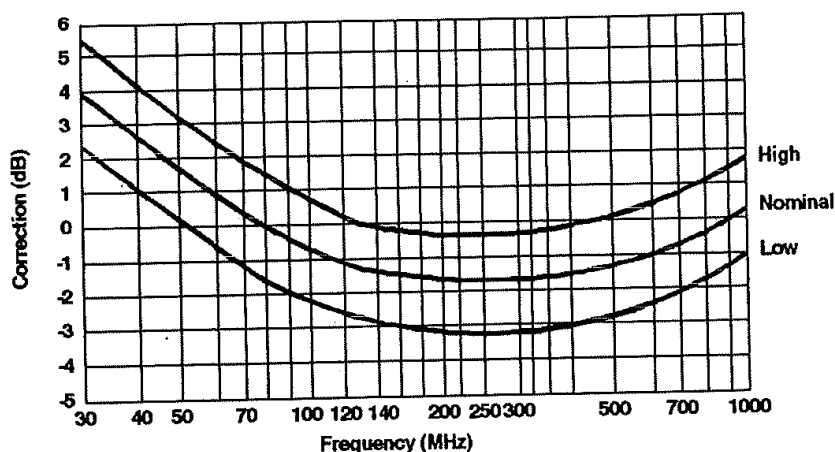


Figure C-6
Acceptable Ranges of Clamp Used Without Further Correlation

If the calibration curve supplied by the vendor does not meet the limit shown in figure C-6, then a correction factor should be applied to the manufacturer's correction curve that will establish equivalent results. The absorbing clamp shall remain at a fixed position throughout the measurement for consistency and repeatability. The receptor end of the clamp shall always be placed nearest the source end of the cable assembly.

The clamp should be placed no more than 10 cm (4 in) from the cable exit end of the connector assembly under test or the actual shield termination connection in the case of the reference cables without connectors.

Care should be taken so that the clamp does not apply torque to the mated connector pair causing separation of the ground planes within the connector under test.

C.1.6.6 Termination and Load Selection

The characteristic impedance of the test cable shall be determined by the time domain reflectometer (TDR). The measured impedance shall be used to terminate the sample cable. The load resistor shall be placed within the termination fixture as shown in figure C-2. The resistor shall be placed within the termination fixture as shown in figure C-2. The resistance value shall be the measured value of the characteristic impedance within 10%. The impedance shall be measured in the configuration described C.1.6.5. An impedance matching pad may be used for improved matching at the input of the test chamber. Pad loss correction shall be included in the plots of the test data.

C.1.6.6.1 Cable-Attached Connector

Termination shall be constructed as shown in figures C-4 and C-5, which will allow connectorized jumper assemblies to be measured within the test chamber. Similar terminations should be constructed without connectors for performing the reference cable measurement (See figure C-2). In the latter case, the shield shall be slipped over the copper pipe and soldered or compression bonded to the pipe to ensure proper shield termination.

C.1.6.7 Cable Wiring Configuration

The two twisted-pair cable shall be tested with a single pair driven relative to the shield. The unused pair shall be bonded to the shield at each termination fixture. The terminating resistor shall also be bonded to the shield.

C.1.6.8 Test Procedure

All equipment shall have an adequate warm-up period to ensure instrument stability (refer to the equipment reference manuals).

The measurements in C.1.6.8.1 shall be executed.

C.1.6.8.1 Reference Cable Measurement

The reference cable with termination hardware shall be placed within the shield effectiveness fixture. The signal source shall be connected to the BNC connector at the source termination as shown in figure C-2. The resistive end terminator shall be centered within the fixture and not allowed to contact the fixture walls.

The absorbing clamp shall be positioned on the cable with the pick-off end toward the BNC connector. The clamp shall be located no more than 10 cm (4 in) from the fixture bulkhead and centered in the fixture. The output voltage from the absorbing clamp shall be recorded from 300 to 1000 MHz using a spectrum analyzer, network analyzer, or equivalent.

The measured output voltage from the absorbing clamp shall be a minimum of 90 dB below the reference input voltage. The source voltage shall be a constant amplitude (± 1 dB) sinusoid, swept between 30 and 1000 MHz. The absorbing clamp output voltage will be recorded in decibels relative to the reference input voltage.

If the measured response is not less than or equal to the required level, the fixture and equipment should be examined for malfunction.

NOTE - At low levels such as encountered with the reference cable, the coax used for connecting the test instrumentation may need to be double shielded.

C.1.6.8.2 Test Cable Measurement

The connectorized cable assembly with termination hardware installed as shown in figure C-7 shall be placed in the shield effectiveness fixture.

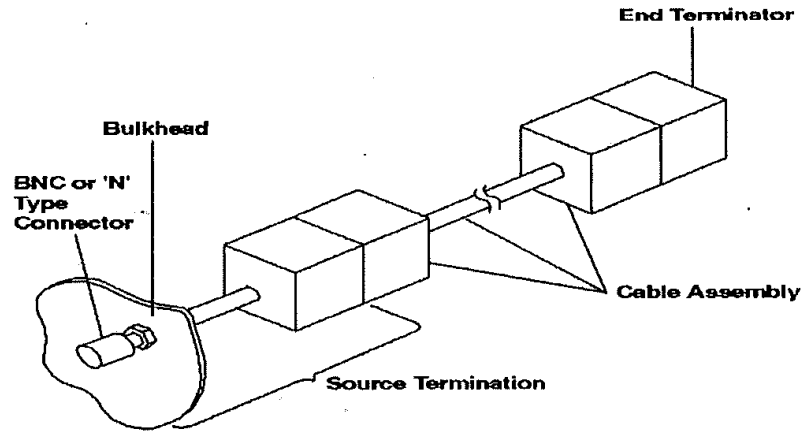


Figure C-7
Cable Attached Connector and Undercarpet Connector Test Assembly Configuration

The clamp shall be placed 5 cm (2 in) to 10 cm (4 in) from the cable entry point of the connector under test.

The source voltage shall be applied and the output voltage from the absorbing clamp shall be measured and recorded.

The position of the absorbing clamp shall be adjusted within its specified range so that the measured voltage is maximized.

Each end of the jumper assembly under test shall be measured by reversing the cable assembly in the fixture.

C.1.6.9 Typical Instrumentation and Measurement Set-Up

A typical measurement test set-up is shown in figure C-8. A network analyzer, a computer capable of controlling the instrumentation bus, and a plotter are shown in the typical set-up. A spectrum analyzer with a tracking generator or equivalent test equipment can be used in place of the network analyzer. The measurement system should be a 50 Ω system and capable of measuring from 30 to 1000 MHz.

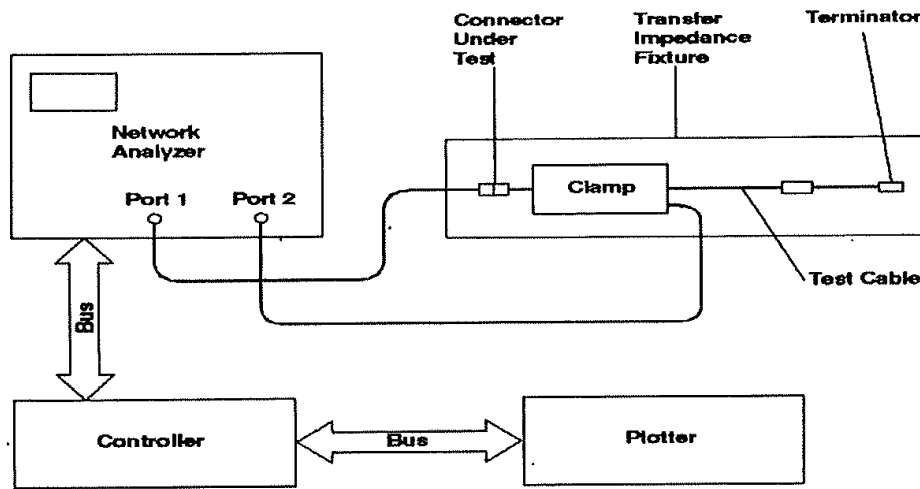


Figure C-8
Typical Equipment Set-Up for Performing Shield Effectiveness Measurements

C.1.6.9.1 Absorbing Clamp Specifications

The absorbing clamp shall be calibrated for a $50\ \Omega$ receiver impedance and accept a cable of up to 20 mm (0.8 in) in overall diameter. The range of operation shall be from 30 MHz to 1000 MHz.

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Annex D (informative) Shared Sheath Guidelines for Multipair UTP Cables

This annex is informative only and is not part of the standard.

D.1 General

Shared sheath and distance guidelines described in this annex are typical, and not intended to cover every combination of applications. It is recommended that the user consult with equipment manufacturers, applications standards, and system providers, for additional information. For additional guidelines regarding distance see 5.5.1.

D.2 Shared Sheath Guidelines

There are many issues to consider when deciding which applications and how many systems can share a common 25 pair binder group in a multipair UTP cable. Some of the most important considerations are:

- a) transmit amplitudes;
- b) signal;
- c) robustness of protocols; and
- d) receiver sensitivity.

In general, applications using totally different frequency ranges tend not to interfere with one another. If receiver bandwidths are appropriately restricted, there is little chance for crosstalk from one system to interfere with another. The main problem occurs when systems with a common bandwidth share a common binder group in a multipair cable. In this case, one has to know additional information such as the type of transmission (bursty, continuous, synchronized or random). This information should be taken into consideration before making a decision on whether or not to use the same binder group for such systems. Once this is known, appropriate guidelines regulating distances and the number of systems in a multipair binder group can be determined. The best example of this is the 10BASE-T standard which accounted for all of the effects listed herein and determined that 12 systems could share a common binder group for category 3 multipair UTP cabling. Some examples of shared sheath restrictions for specific applications using category 3 binder groups are:

- a) EIA232D and ISDN applications should be on separate binder groups.
- b) 3270 type signals converted to balanced UTP should not share the same binder group as 10BASE-T. (Many 3270 baluns have poor rejection capabilities at higher frequencies.)
- c) Signals from hosts with multiple controllers should not share the same binder group (signals from the same controller can share a binder group).
- d) Signals with significantly different power levels should not share the same binder group.

Shared sheath performance using category 4 and 5 cabling is considerably better than category 3 for applications with data rates up to 10 Mb/s. Shared sheath guidelines for applications with data rates beyond 10 Mb/s need to be developed in conjunction with the applications standard committees, and are under study.

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Annex E (informative) Unshielded Twisted-Pair (UTP) Channel Performance

This annex is informative only and is not part of the standard.

E.1 General

This annex describes the worst case performance characteristics of a UTP channel in the horizontal cabling of a telecommunications cabling system installed in accordance with the topology and components specified in section 10. The objective of this annex is to provide to users information on transmission characteristics of a UTP channel built with compliant sections of cable and connecting hardware. The UTP channel characterized in this annex includes the telecommunications outlet/connector in the work area, the horizontal section of UTP cabling from the telecommunications outlet/connector to the horizontal termination in the telecommunications closet and the patch cords and jumpers located in the telecommunications closet. Specifically excluded from this model (being outside the scope of this standard) are equipment connectors in the work area and the telecommunications closet. The model does however account for the performance of equipment and cross-connect cables installed in accordance with section 10 of this standard.

E.2 Channel

For purposes of this analysis, the worst case channel in the horizontal is illustrated in figure E-1. Figure E-1 illustrates the interfaces to the cabling where performance characteristics can be calculated based on worst case component specifications and cabling implementations allowed by this standard. The components that make up the channel are:

- a) a telecommunications outlet/connector;
- b) a transition point;
- c) balanced UTP cable of 90 m (295 ft) length;
- d) horizontal cross-connect consisting of two connecting blocks or patch panels, and
- e) a total of 10 m (33 ft) of equipment and patch cords.

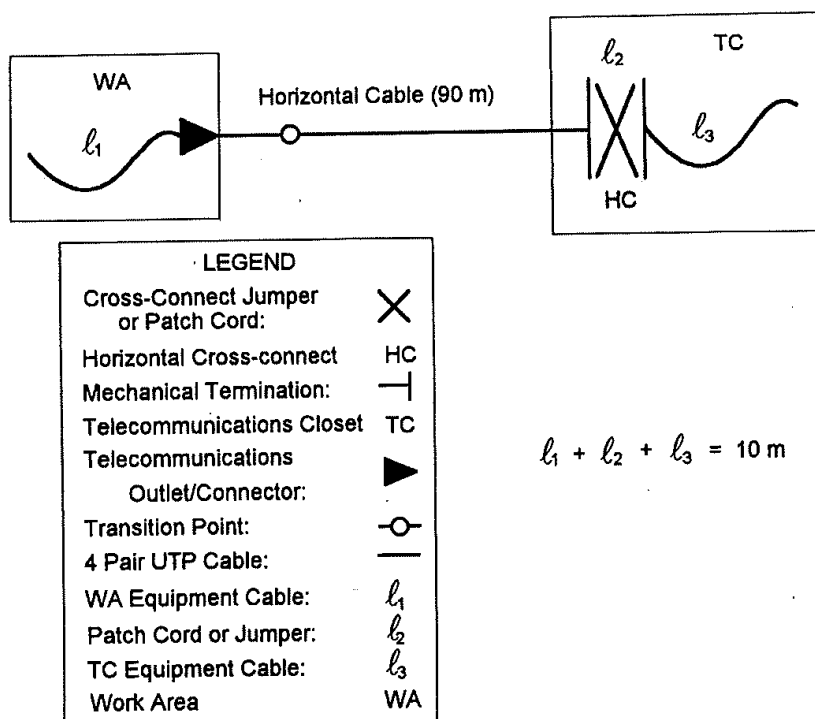


Figure E-1 Channel Model

E.2.1 Worst Case Model Assumptions

The worst case models developed in this section were based on the following assumptions.

- The components installed in the cabling system are minimally compliant with the appropriate UTP category specifications.
- A voltage summation model adequately represents the worst case Near End Crosstalk (NEXT).
- Noise voltages, due to NEXT, add in phase.
- Connecting blocks or patch panels in the telecommunications closet are cross-connected with short lengths of jumpers or patch cords.
- A transition point is installed a short distance away from the telecommunications outlet/connector.
- Temperature of the installation is at 20 °C.
- Cable is not in the proximity of metallic surfaces.
- Return losses are not included.

NOTE - The type and nature of the components and the installation practices, especially the length of equipment and cross-connect patch cords, can affect the actual NEXT values in a system.

E.3 Applicability

The intent of this annex is to characterize a cabling plant for specific networking applications based on established performance limits of the components used in the channel. The worst case channel performance is derived for a model with the previously stated assumptions. It is not intended for conformance testing of installed cabling plants because field test equipment and methods have not yet been standardized. The model and the calculations presented here are applicable only if the link is made up of components from the same category.

NOTE - When swept frequency testing is performed, the total number of measurement points should be consistent with 10.1. Field test methods and accuracy limits are under study.

E.4 Channel Performance Parameters

The performance parameters addressed in this annex are the following.

- a) Attenuation
- b) NEXT

Other parameters such as return loss, longitudinal balance, longitudinal impedance and attenuation variation, which may be of interest to specific networking applications, are under study.

E.4.1 Performance Limits

E.4.1.1 Attenuation

Channel attenuation is equal to the sum of the attenuation of the various components in the channel. The worst case model consists of 90 m (295 ft) of horizontal cable and up to a total of 10 m (33 ft) of equipment and patch cords combined. Generally, the patch cords and line cords are of flexible stranded conductor construction and therefore present higher losses per unit length. Allowance should be made for the extra losses in the cords. In the present analysis, the patch cord losses are assumed to be 20% higher than the losses corresponding to the horizontal cable of the same category, per 10.5.

NOTE - Connector losses for each category were taken from 10.4.4.1. Cable attenuation values were taken from 10.2.4.6 and are based on an ambient temperature of 20 °C. Refer to section 10 for temperature correction factors for cables.

Table E-1 Maximum Attenuation at 20 °C			
Frequency (MHz)	Category 3 (dB)	Category 4 (dB)	Category 5 (dB)
1.0	4.2	2.6	2.5
4.0	7.3	4.8	4.5
8.0	10.2	6.7	6.3
10.0	11.5	7.5	7.0
16.0	14.9	9.9	9.2
20.0	—	11.0	10.3
25.0	—	—	11.4
31.25	—	—	12.8
62.5	—	—	18.5
100.0	—	—	24.0

E.4.1.2 NEXT Loss

The NEXT loss in the channel is the vector sum of crosstalk induced in the cable, connectors and patch cords. For NEXT loss calculations, the effect of connectors and cables on the far end can be ignored. Therefore, for calculation of NEXT loss at the telecommunications outlet/connector, effects of the optional transition point are taken into account, but connecting hardware in the telecommunications closet can be ignored, since the model assumes 90 m (295 ft) of horizontal UTP cable (See figure E-1). Conversely, for measurements in the telecommunications closet, the effect of the transition point and the telecommunications outlet/connector can be ignored. The phase shift between the various crosstalk voltages can result in peaks or nulls in the channel crosstalk. For worst case conditions, considered here, the phase shift is assumed to be zero. The combined crosstalk model, under the worst case conditions, is given by:

$$\text{NEXT}(f) = -20 \log_{10} \sum_i 10^{-N_i/20}, i = 1, 2, \dots, n$$

where N_i = NEXT of component i at frequency f and

n = number of components in the channel at the near end.

The worst case channel NEXT loss, calculated from the respective component values for cables and connectors from section 10, are tabulated for each category in table E-2. These values are valid for both the telecommunications outlet/connector end and the telecommunications closet end of the channel.

NOTE - NEXT loss is dominated by components in the near zone (<20 m). To verify channel performance, it is recommended that NEXT loss should be measured from both the telecommunications closet and from the telecommunications outlet/connector.

Table E-2
Worst Case Channel NEXT Loss

Frequency (MHz)	Category 3 (dB)	Category 4 (dB)	Category 5 (dB)
1.0	39.1	53.3	60.3
4.0	29.3	43.3	50.6
8.0	24.3	38.2	45.6
10.0	22.7	36.6	44.0
16.0	19.3	33.1	40.6
20.0	--	31.4	39.0
25.0	--	--	37.4
31.25	--	--	35.7
62.5	--	--	30.6
100.0	--	--	27.1

For information on cabling bandwidth considerations, see informative Annex J.

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Annex F (informative) Migration Paths for Optical Fiber Connections

This annex is informative only and is not part of the standard.

F.1 General

This annex discusses migration paths which may be available for networks with an installed base of BFOC/2.5 connectors and adapters.

This paragraph contains the minimum requirements for such networks and applies to all of the listed migration paths. Networks with an installed base should implement the pair-wise cabling, polarity identification, and media identification as specified in 12.7 to assist in the management of the network. Networks should not continue the use of connectors which do not meet the minimum optical and mechanical transmission requirements as established by 12.4. Additionally, networks should not propagate the use of simplex connections (adapters and connectors) on the user side of the telecommunications outlet/connector.

The migration paths given herein may be used to retrofit existing networks or for additions to existing networks or both.

F.2 Migration Paths

F.2.1 Remain with Existing Connector

Networks with an installed base of BFOC/2.5 optical fiber connectors and adapters may remain with the same for both existing and future additions to the optical fiber network.

F.2.2 Duplex BFOC/2.5

Networks may use the BFOC/2.5 connector and adapter in a duplex form as specified in ANSI/EIA/TIA-604-2. These networks should use optical patch panels and telecommunications outlet/connectors which mount the adapters at the proper 12.7 mm (0.5 in) center-to-center spacing and in the proper orientation. The duplex option allows the network to reuse existing simplex threaded adapters and simplex connectors on the cabling side, while enabling the use of duplex connectors on the user side (figure F-1).

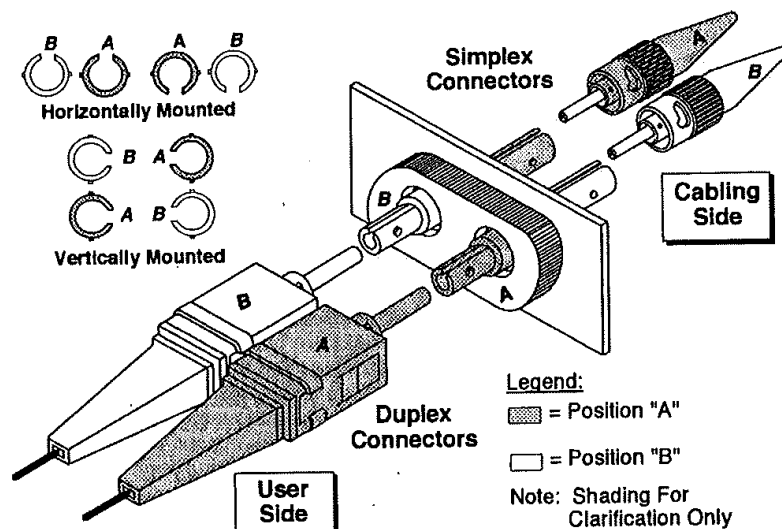


Figure F-1 Duplex BFOC/2.5 Convention

F.2.3 Hybrid Adapters

Networks may migrate to 568SC connections by the use of a duplex hybrid adapter solution. A hybrid adapter mates two different connector types together by providing different interfaces on each side. The hybrid adapter may allow the network to reuse and remain with the existing connector type on the cabling side of an optical fiber patch panel, however, it would provide a 568SC connection on the user side of the patch panel or telecommunications outlet/connector (figure F-2).

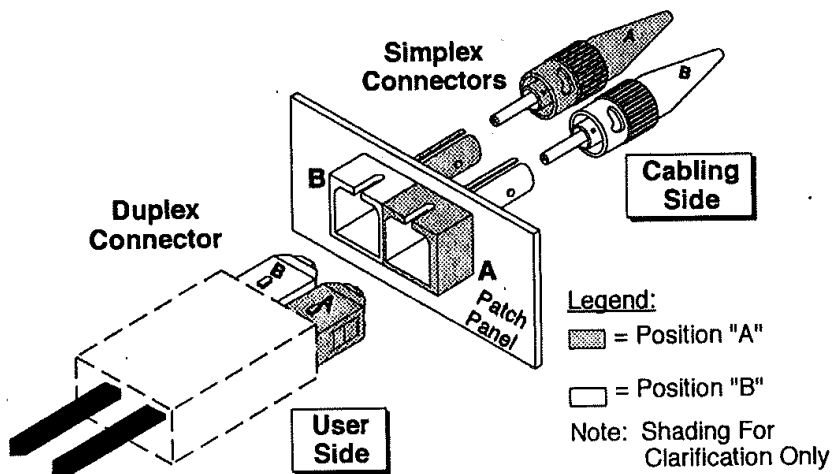


Figure F-2 568SC Hybrid Adapter

F.2.4 Switch to 568SC

Networks may switch to the 568SC connector and adapter for new additions to the installed base or to retrofit the existing network.

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Annex G (informative) Other Cable Specifications

This annex is informative only and is not part of the standard.

G.1 General

This annex discusses some additional cables which may be of interest. The descriptions given are brief and do not include full transmission specifications. In some cases, the reason for not including the cables in this standard is discussed.

These cables are included because they can be used effectively in some cases. Many have large installed bases. In addition, some of the cables, properly configured, can actually offer performance equivalent to the recognized cables. It is the user's responsibility to make certain that these cables provide adequate performance.

G.2 Horizontal Cabling

G.2.1 100 Ω Screened Twisted-Pair Cable

100 Ω screened twisted-pair cable may be used in certain installations where shielding effectiveness is required. Shielded media is generally available in the same pair counts and is designed to meet the same applicable electrical code requirements as unshielded media.

The shield or shields should be grounded. The equipment manufacturers' recommendations should be followed concerning specific installations. It is not desirable that the shield be terminated on connector pins. Shield continuity should be provided external to the connector housing.

NOTE - The practice for grounding of 100 Ω Screened Twisted Pair is under study.

G.2.2 Multipair UTP Cables

25-pair inside cabling has been traditionally used for voice services between the telecommunications closet and a remote distribution termination. A typical configuration is illustrated in figure G-1.

Although such an arrangement may provide installation efficiencies, it is not recommended for the general case. Some services will co-exist, but the variety and demands of modern voice and data networks make it difficult to characterize and guarantee performance. In commercial buildings where occupancy is by more than one tenant, there would be the possibility of one user's system interfering with another's. If interference occurred, finding the source and resolving the problem would be difficult and time consuming.

Transmission categories for multipair cables used in such configurations should be identical to those of multipair backbone cables as specified in 10.3.

Consequently, the use of 25-pair cables for horizontal distribution should be undertaken only as a special case considering system engineering guidelines.

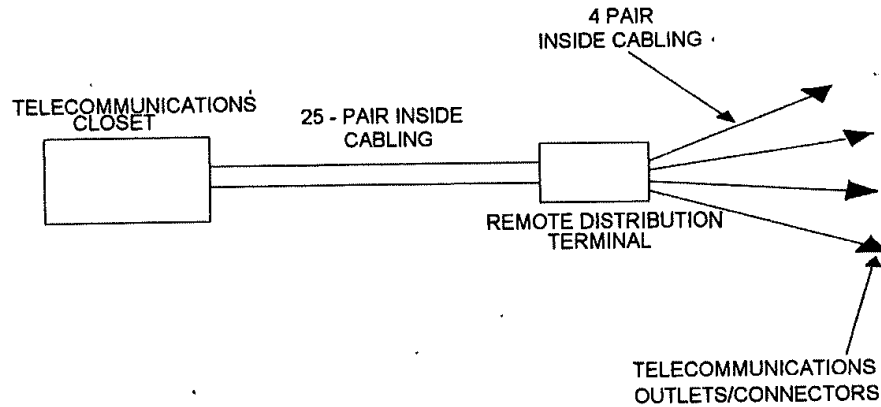


Figure G-1 Multipair Cable Configuration

G.2.3 Multiuser Telecommunications Outlet/Connector

Multiuser telecommunications outlet/connector may be advantageous in open office spaces where open systems furniture is expected to be moved or reconfigured routinely. A multiuser telecommunications outlet/connector facilitates the termination of multiple horizontal cables to a central location of a serving area in an open office space. The use of multiuser telecommunications outlet/connector will allow horizontal cabling to remain unchanged when the open office plan is changed. Equipment cables originating from the multiuser telecommunications outlet/connector may be routed in furniture raceways and connected to work area equipment.

The multiuser telecommunications outlet/connector should be located in an open system furniture area in a grid fashion so that each multiuser telecommunications outlet/connector will serve from 6 to 12 work areas. Based on a minimum requirement of 2 horizontal cables to each work area, the multiuser telecommunications outlet/connector should be capable of terminating up to 24 horizontal cables. Based on a 3 m (10 ft) square office space each multiuser telecommunications outlet/connector would serve an office space with a radius of 6 m (20 ft).

The multiuser telecommunications outlet/connector should be readily accessible and its location visibly marked allowing for ease of routine maintenance and reconfiguration. The equipment cables connecting the multiuser telecommunications outlet/connector to the work areas should be labeled on both ends. The end of the equipment cables at the multiuser telecommunications outlet/connector should be labeled with the work area it serves, and the end at the work area should be labeled with the telecommunications outlet/connector identifier and a port identifier.

G.2.4 75 Ω Coaxial Cable

This media is effective in video and broadband applications from 5 MHz to 1 GHz. Standards to reference include IEEE 802.4 (broadband applications), IEEE 802.7 specifications, ANSI T1.404 (DS3), and CATV applications.

G.2.5 50 Ω Coaxial Cable

This media should meet the requirements specified in IEEE 802.3 (10Base2).

G.3 Backbone Cabling**G.3.1 100 Ω STP Cable**

The cable used in the backbone cabling system generally contains several pairs. The cable may have an overall shield. Internal shielding such as individual pair shields or "D" or "T" screen compartment shielding are sometimes used.

The shield or shields should be grounded. The equipment manufacturers recommendations should be followed concerning specific installations. It is not desirable that the shield be terminated on connector pins. Shield continuity should be provided external to the connector housing.

G.3.2 Other Multimode Optical Fiber Cables

Four (4) multimode optical fiber sizes have been recognized in an earlier ANSI/EIA-492-A000 Standard. No multimode optical fiber is optimum for all applications. However, the 62.5/125 μm Graded Index optical fiber is the most optimum for applications perceived at this time (see section 12). Widespread use of this optical fiber size will permit the transportability of terminals within and between buildings.

Other multimode fibers are 200/230 μm Step and Graded Index Optical Fiber, 100/140 μm Graded Index Optical Fiber and 50/125 μm Graded Index Optical Fiber. Advantages claimed for 200/230 μm and 100/140 μm optical fiber are more power coupled into the optical fiber from LED sources and less precision required for connectors and splices. The 50/125 μm optical fiber has the greatest information transfer capacity and was the first to be used in the telephone network. For specialized systems applications, tradeoff analysis may indicate that one of these latter three (3) sizes may be optimum. However, such special applications do not meet the requirements of this standard.

G.3.3 75 Ω Coaxial Cable

This media is effective in video and broadband applications from 5 MHz to 1 GHz. Standards to reference include IEEE 802.4 broadband applications, IEEE 802.7 specifications, ANSI T1.404 (DS3) and CATV applications.

For CATV backbone applications semirigid trunk cables are often utilized. These cables are available in sizes from 12.7 mm (0.500 in.) up to 28.6 mm (1.125 in.) in diameter over the solid aluminum outer conductor. A plastic jacket over the outer conductor is optional.

G.3.4 50 Ω Coaxial Cable

This media should meet the requirements specified in IEEE 802.3 (10Base5).

Annex H (informative) Optical Fiber Link Performance Testing

This annex is informative only and is not part of the standard.

H.1 General

This annex describes the minimum recommended performance testing criteria for an optical fiber cabling system installed in compliance with this standard. The objective of this annex is to provide to users recommended field test procedures and acceptance values. This annex will address the testing and link performance requirements of both single-mode and 62.5/125 μm optical fiber systems both in the horizontal and the backbone network.

H.2 Link Segment

An optical fiber link segment is defined as the passive cabling network, to include cable, connectors, and splices (if present), between two optical fiber patch panels (connecting hardware) as indicated in figure H-1. A typical horizontal link segment is from the telecommunications outlet/connector to the horizontal cross-connect. There are three typical backbone link segments: main cross-connect to intermediate cross-connect, main cross-connect to horizontal cross-connect, or intermediate cross-connect to horizontal cross-connect. As figure H-1 illustrates, the test includes the representative connector performance at the connecting hardware associated with the mating of patch cords. It does not, however, include the performance of the connector at the equipment interface.

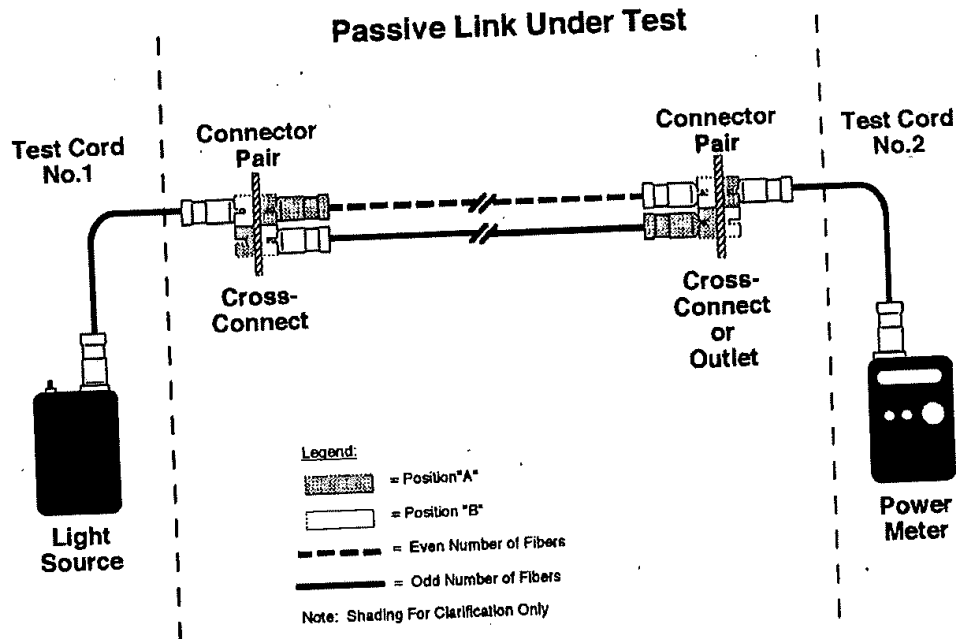


Figure H-1 Passive Link

NOTES:

- 1 Optical power budgets specified in application standards, such as FDDI, 10Base-F, and others, include the optical loss of the connector at the equipment interface.
- 2 If the desired system link is created by the concatenation of two (2) or more passive link segments, i.e., a cross-connect patch cord linking cross-connects together, the expected attenuation for the system link is the sum of the concatenated passive link segment attenuation's.

H.3 Link Segment Performance

The single performance parameter necessary for performance testing, when installing components compliant with this standard, is link attenuation. Bandwidth (62.5/125 μm) and dispersion (single-mode) are important performance parameters, but because they can not be adversely affected by installation practices, they should be tested by the fiber manufacturer and do not require testing in the field.

The acceptable link attenuation for a 62.5/125 μm horizontal optical fiber cabling system is based on the maximum 90 m (295 ft) distance. The link attenuation equation in H.3.3 is provided to determine "acceptable link performance" for 62.5/125 μm and single-mode backbone cabling systems. This equation calculates link attenuation for backbone link segments based upon fiber type, cable type, wavelength, link distance and number of splices. Additionally, graphs of link attenuation are included in figures H-2 and H-3.

Link attenuation has been based on the connectivity requirements of this standard and the use of the One Reference Jumper Method specified by ANSI/TIA/EIA-526-14A, Method B and ANSI/TIA/EIA-526-7, Method A.1. The user should follow the procedures established by these standards to accurately conduct performance testing.

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.

H.3.1 Horizontal Link Measurement

The horizontal optical fiber cabling link segments need to be tested at only one (1) wavelength. Because of the short length of cabling [90 m (295 ft) or less], attenuation deltas due to wavelength are insignificant. The horizontal link should be tested at 850 nm or 1300 nm in one direction in accordance with ANSI/EIA/TIA-526-14A, Method B, One Reference Jumper. The attenuation test results should be less than 2.0 dB. This value is based on the loss of two (2) connector pairs, one (1) pair at the telecommunications outlet/connector and one (1) pair at the horizontal cross-connect, plus 90 m (295 ft) of optical fiber cable.

NOTE - Link attenuation has been based upon the use of a light source categorized by a Coupled Power Ratio (CPR) of Category 2, Underfilled, per Annex B of ANSI/EIA/TIA-526-14A. The use of a light source categorized as Category 1, Overfilled, may provide results higher than the 2.0 dB. The user is advised to consult ANSI/EIA/TIA-526-14A specifically Annex B and C, for further information concerning the affects of Modal Power Distribution (MPD) and CPR.

H.3.2 Backbone Link Measurement

The backbone optical fiber cabling link segment should be tested in one direction at both operating wavelengths to account for attenuation deltas associated with wavelength. Single-mode backbone links should be tested at 1310 nm and 1550 nm in accordance with ANSI/TIA/EIA-526-7, Method A.1, One Reference Jumper. 62.5/125 μ m backbone links should be tested at 850 nm and 1300 nm in accordance with ANSI/EIA/TIA-526-14A, Method B, One Reference Jumper. Because backbone length and the potential number of splices vary depending upon site conditions, the link attenuation equation should be used to determine acceptance values based upon this standard's component requirement at each of the applicable wavelengths.

H.3.3 Link Attenuation Equation and Graphs

Link attenuation is calculated as:

Link Attenuation = Cable Attn + Connector Attn + Splice Attn

Cable Attn (dB) = Attenuation Coefficient (dB/km) • Length (Km)

Attenuation Coefficient

3.75 dB/km @ 850 nm for 62.5/125 μ m

1.5 dB/km @ 1300 nm for 62.5/125 μ m

0.5 dB/km @ 1310 nm for single-mode outside plant cable

0.5 dB/km @ 1550 nm for single-mode outside plant cable
 1.0 dB/km @ 1310 nm for single-mode inside plant cable
 1.0 dB/km @ 1550 nm for single-mode inside plant cable

Connector Attn (dB) = number of connector pairs • connector loss (dB)

$$= 2 \bullet 0.75 \text{ dB}$$

$$= 1.5 \text{ dB}$$

Splice Attn (dB) = number of splices (S) • splice loss (dB)

$$= S \bullet 0.3 \text{ dB}$$

Figure H-2 is a graph for 62.5/125 μm backbone cabling depicting link attenuation based on wavelength and distance and two connector pairs. The graph does not account for any splice loss. If the link contains splices, add 0.3 dB for each splice in a link.

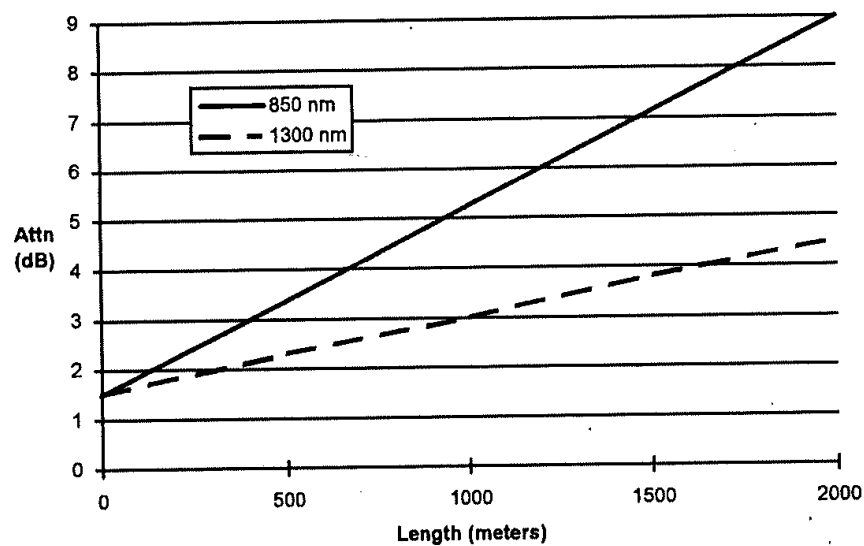


Figure H-2 62.5/125 μm Backbone Cabling: Link Attenuation Based on Distance

Figure H-3 is a graph for single-mode backbone cabling depicting $P_{\text{acceptance}}$ based on cable type, i.e., outside plant or inside plant, distance and two connector pairs. The graph does not account for any splice loss. If the link contains splices, add 0.3 dB for each splice in the link. If the link consists of both inside and outside plant cables, then the equation should be used based on the length of each of the cable types.

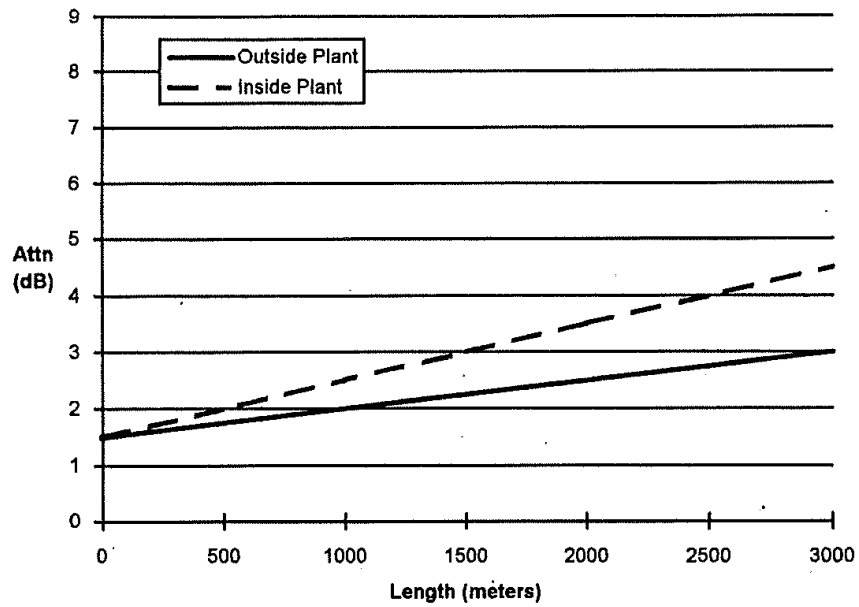


Figure H-3 Single-mode Backbone Cabling: Link Attenuation Based on Distance

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Annex J (informative) Bandwidth Considerations

This annex is informative only and is not part of the standard.

J.1 General

Digital equipment data rates are typically specified in Megabits per second (Mb/s). Bandwidth for cabling and connecting hardware is typically specified in Megahertz (MHz). These terms are not the same but interrelated. The purpose of this annex is to provide information of a tutorial nature on the definitions of MHz and Mb/s, and their use in UTP channel performance design specifications (see informative Annex E).

J.2 Sinusoidal Signals

The frequency specification in MHz is often confused with Mb/s. Hertz, abbreviated Hz, is the international unit of measurement of frequency. Frequency is the number of times a sine-wave goes through its complete cycle per second. A frequency of 1,000,000 Hz is typically expressed as 1 MHz. Figure J-1 illustrates a sinusoidal voltage that repeats itself every 100 nanoseconds; a frequency of 10 MHz.

The average power of a sine-wave can be represented in the frequency domain as the area under the spectral density curve plotted as a function of frequency. As shown in figure J-1 the sinusoidal voltage has one positive frequency component.

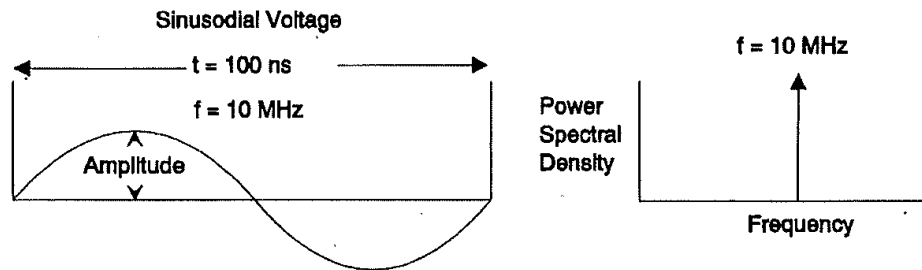


Figure J-1 Sinusoidal Voltage: (Frequency = 10 MHz)

The attenuation and NEXT loss for cabling and connecting hardware are commonly derived from swept frequency measurements. The specifications range from 0.1 MHz to 100 MHz. The attenuation values in table 10-3 represent the loss of a sinusoidal voltage at the specified frequency measured at the output of 100 m (328 ft) of cable terminated in its characteristic impedance.

J.3 Digital Signals

Digital signals represent the transformation of information into discrete voltage levels. Baud rate is the unit of signaling speed, on the physical media, equal to the number of discrete conditions or signal events per second. Bit is an abbreviation for binary digit. Bit rate is the number of bits transferred per unit time, usually expressed in bits per second or in millions of bits per second (Mb/s). Figure J-2 diagrams the signaling reference points.

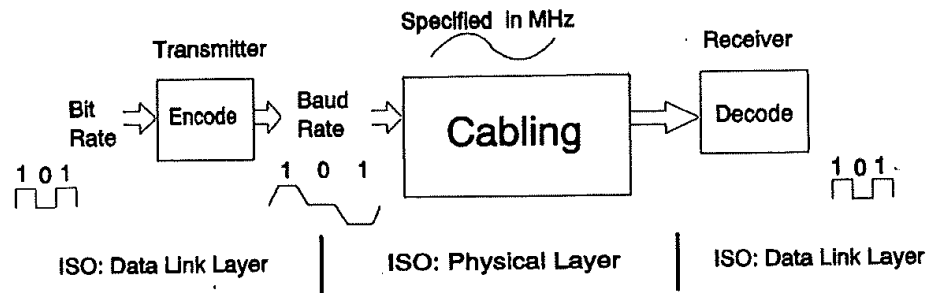


Figure J-2 Network Topology

The attenuation incurred when the discrete voltage levels are transmitted through a channel comprised of cable and connecting hardware are related to the shape and repetition of the encoded signal. These signals can be represented as a set of harmonically related sine-waves.

Figure J-3 shows the frequency spectrum of the related sine-wave components of a Manchester-Encoded Signal. Ethernet (802.3) and Token Ring (802.5) both employ a form of Manchester Coding. The attenuation incurred by a digital signal is not only at its fundamental frequency but also at the frequencies of the related sine-wave components. The signal bandwidth is the range of related sine-wave components (frequencies) which characterize the digital signal.

A Manchester encoded sequence of random bits, more representative of network signaling traffic, would produce a continuous frequency spectra. Digital system design includes characterization of a statistical worst-case signal bandwidth in order to specify requirements for the channel bandwidth. Proper operation of the digital system occurs only when the channel bandwidth exceeds the signal bandwidth.

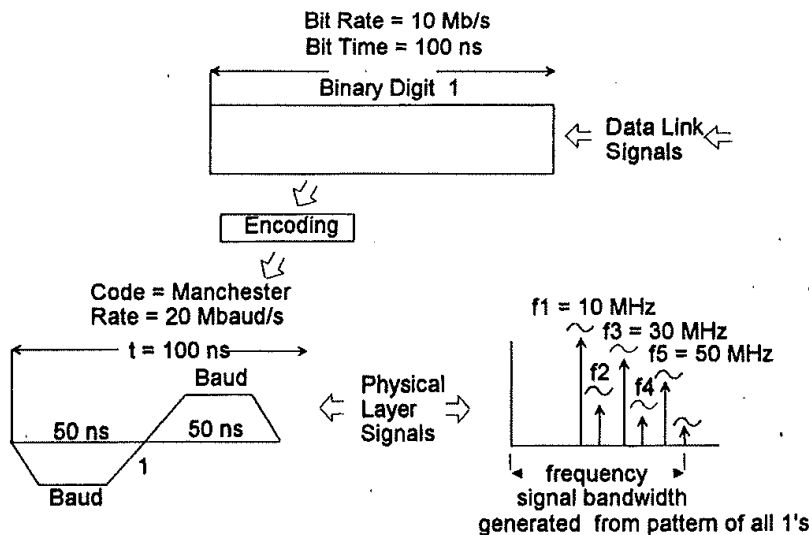


Figure J-3 Manchester Encoded Signal

J.4 UTP Channel Performance

The UTP channel performance specified in informative Annex E is determined from transmission measurements on cables and connecting hardware. These measurements are performed in the frequency domain, i.e., the UTP channel performance parameters are expressed as a function of frequency in MHz (tables E-1 and E-2). The range of frequencies that can be successfully transmitted for a given distance [e.g., 100 m (328 ft)] determines the available bandwidth in MHz for a specified channel.

There are different criteria that can be used to determine the available bandwidth. One such criterion is the level of minimum receive signal at the output of a channel relative to the peak noise level. Attenuation-to-Crosstalk Ratio (ACR) excludes noise from sources external to the channel, i.e., all noise except crosstalk noise.

To ensure an acceptable bit error rate (BER), the signal should be a reasonable replica of the transmitted signal. Attenuation is a decrease in signal magnitude. Also, the higher frequency components of the digital signal incur more attenuation over a given UTP channel (table E-1). The net effect is a reduction in amplitude and a change in shape of the transmitted signal as it appears at the receiver. Additionally, NEXT noise adds abrupt variations in the signal magnitude. The reliability of the receiver to detect changes in the signal waveform are affected by these signal impairments.

For some digital systems a minimum ACR of 12-16 dB is considered a practical limit to ensure an acceptable BER.

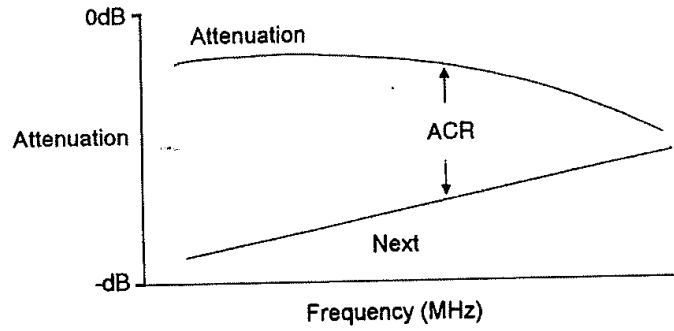


Figure J-4 Attenuation-to-Crosstalk Ratio

NOTE - The term ACR is also referred to as Near-End-Crosstalk-to-Insertion Loss Ratio (NIR) in some application standards.

Annex K (informative) Bibliography

This annex is informative only and is not part of the standard.

This annex contains information on the documents that are related to or have been referenced in this document. Many of the documents are in print and are distributed and maintained by national or international standards organizations. These documents can be obtained through contact with the associated standards body or designated representatives. The applicable electrical code in the United States is the National Electrical Code.

- ANSI/EIA/TIA-526-7, *Optical Power Loss Measurements of Installed Single-Mode Fiber Cable Plant*
- ANSI/EIA/TIA-526-14, *Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant*
- ANSI/EIA/TIA-604-2, *Focus to FOCUS, Fiber Optic Connector Intermateability Standard*
- ANSI/IEEE C 62.11, *Metal Oxide Surge Arrestors for AC Power Circuits*
- ANSI X3.166-1990, *ANSI Standard for Token Ring FDDI Physical Layer Medium Dependent (PMD)*
- ASTM B539-90, *Measuring Contact Resistance of Electrical Connections (Static Contacts)*
- EIA-492A000, *Sectional Specification for Class Ia Multimode, Graded-Index Optical Waveguide Fibers*
- EIA/TIA TSB-31, *FCC 47 CFR 68, Rationale and Measurement Guidelines*
- Federal Communications Commission (FCC) Washington D.C., *"The Code of Federal Regulations, FCC 47 CFR 68 (1982 issue or latest revision)"*
- FIPS PUB 174, *Commercial Building Telecommunications Wiring Standard*
- IEEE 802.3-1990 (also known as ANSI/IEEE Std 802.3-1990 or ISO 8802-3: 1990 (E), *Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*
- IEEE 802.4, *Standard for Local Area Network Token Passing Bus Access Method, Physical Layer Specification*
- IEEE 802.5-1992 (also known as ANSI/IEEE Std 802.5-1992), *Token Ring Access Method and Physical Layer Specifications*
- IEEE 802.7, (also known as) *Recommended Practices for Broadband Local Area Networks*
- NEMA-250-1985, *Enclosures for Electrical Equipment (1000 Volts Maximum)*

- NQ-EIA/IS-43AH, Cable for LAN Twisted Pair Data Communications-Detail Specification for Type 8, Undercarpet Cable, September 1988
- Society of Cable Television Engineers, Inc., Document #IPS-SP-001, *Flexible RF Coaxial Dropcable Specification*
- UL 444-90, *UL Standard for Safety Communications Cables*

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

ANSI

American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
USA
(212) 642-4900

ASTM

American Society for Testing and Materials (ASTM)
1916 Race Street
Philadelphia, PA 19103
USA
(215) 299-5400

Belcore

Belcore Customer Service
8 Corporate Place Room 3C-183
Piscataway, NJ 08854-4156
USA
(800) 521-2673

CSA

Canadian Standards Association (CSA)
178 Rexdale Blvd.
Rexdale (Toronto), Ontario
Canada M9W 1R3
(416) 747-4363

EIA/TIA

Electronic Industries Association (EIA)
2500 Wilson Blvd., Suite 400
Arlington, VA 22201-3836
USA
(703) 907-7500

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

FCC

Federal Communications Commission (FCC)
Washington, DC 20554
USA
(301) 725-1585

Federal and Military Specifications

US Department of Commerce
National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
USA

ICEA

Insulated Cable Engineers Association, Inc. (ICEA)
PO Box 440
South Yarmouth, MA 02664
USA
(508) 394-4424

IEC

International Electrotechnical Commission (IEC)
Sales Department
PO Box 131
3 rue de Varembe
1211 Geneva 20
Switzerland
+41 22 34 01 50

NOTE: Also obtainable from ANSI

IEEE

The Institute of Electrical and Electronic Engineers, Inc (IEEE)
IEEE Service Center
445 Hoes Ln. PO Box 1331
Piscataway, NJ 08855-1331
USA
(201) 981-0060

IPC

The Institute for Interconnecting and Packaging Electronic Circuits
3451 Church Street
Evanston, IL 60203
USA

ISO

International Organization for Standardization (ISO)
1, Rue de Varembe
Case Postale 56
CH-1211 Geneva 20
Switzerland
+41 22 34 12 40

NOTE: Also obtainable from ANSI

NEMA

National Electrical Manufacturers Association (NEMA)
2101 L Street
Washington, D.C. 20037
USA
(202) 457-8400

NIST (source for FIPS PUB)

National Institute for Standards and Technologies
Gaithersburg, MD 20899
USA
(301) 975-2833

NFPA

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269
USA

SCTE

Society of Cable TV Engineers
669 Exton Commons
Exton, PA 19380
USA

UL

Underwriters Laboratories, Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062
USA
(312) 272-8800

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