Telecommunications Industry Association (TIA) **TR-42.7-2020-10-0xx**
For Virtual, October, 2020

TITLE:	**Balanced Single Twisted-Pair Telecommunications Cabling and Components Standard**
PROJECT NUMBER (PN):	**PN-568.5**
DRAFT Number	**Draft 1.6**
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ABSTRACT: Draft 1.6 Incorporates committee ballot comment resolution to d1.5a , October Virtual TR-42.7 meeting

Revision history:

Initial draft, Monday, August 14, 2017.
Second draft 0.2, Friday, August 25, 2017 after partial review of draft 0.1 during TR-42.7 568.5 single pair TG teleconference 08-15-2017.
Third draft 0.3 Thursday, August 31st, after review of draft 0.2 during TR-42.7 568.5 single pair TG teleconference.
Draft 0.4 Monday, January 22, 2018, Updated channel and cable specs to reflect 802.3cg, 802.3bp and TIA Cat6A requirements for 1000 m, 15 m, and 100 m channel configurations. Incorporated same into cable requirements. Added connecting hardware requirements. Added 1000 m modeling configuration to Annex A.

Draft 0.5 Wednesday, February 21, 2018.Incorporated online comments from face to face meeting, Jan, 30th 2018.

Draft 0.5a Thursday, February 22, 2018. Incorporated online comments from teleconference of single pair TG meeting, February 22, 2018.
Draft 0.5b Tueday, April 24, 2018 Document reviewed online and performance parameters updated to current. Added placeholders for testing annexes

Draft 0.5c. Tuesday May 29, 2018, Added table rows for 40m reach. Added Annexes for test and measurement requirements as annexes A, B, C. Updated component return loss values according to contribution TR427-2018-0600xx_Vaden_RL_models.pdf

Draft 0.5d Friday, June 8, 2018, Formatted clauses and tables in the added annexes. Deleted Annex A, General measurement requirements. Updated tables and figures to include 40 m reach objective. Cleaned up text in Annex B to correctly describe single pair measurement systems. General formatting and cleanup.

Draft 0.5e Thursday, June 14, 2018, Implemented updated return loss requirements tables for channel, cable and connectors per committee consensus (see TR42.7-2018-06-050b-RLmodels.docx). Updated 15m topology diagram to include four connectors per committee resolution 06-13-18 during draft review.

Draft 0.6, 0.7 October 30th, 2018, Updates recorded online during TIA TR-42.7 October meeting, Mesa, AZ, Updates agreed to during meeting and applied afterword: Insertion of Table A1. Balun requirements. Various editorial fixes and updates. Added a table of common mode reference impedances.

Draft 0.7a January 8, 2019, Implement changes agreed to during December 4th 2018 teleconference. Use connecting hardware designation where appropriate, rewrite annex B text to indicate 50 Ohm common mode terminations for all measurement results. Add Figure B.5. Redraw figures B.10 through B.13 into block diagram style. Edit Annex C. to simplify and specify 50 Ohm CM terminations.

Draft 0.8 January 8, 2019 Reviewed in teleconference. Minor editorial changes. minor figure updates. Accepted edits.

Draft 0.8a January 30, 2019 Implement editorial changes noted during January 29 Orlando TR-42.7 meeting. Various changes in preparation for mock ballot. Added clause C.3, SP3 channel modeling configurations.

Draft 0.8b January 31, 2019, replaced balun characteristics table in Annex A.

Draft 0.9 October 9 2019, Incorporate mock ballot comment esolution from document 064d, September, 2019, Albuquerque.

Draft 1.0 Friday, February 14, 2020 Incorporating committee ballot comment resolution to draft 0.9a resolved at TR-42.7 meeting January 28, 29, 2020, New Orleans, La.
Draft 1.0 Wednesday, November 4, 2020 Incorporate Wayne Larsen edits 20200215 review of draft 1.doc.

Draft 1.5 Wednesday, June 17, 2020 Incorporating resolution of comments to ballot draft 1.0a TR-42.7 virtual meeting weeks of June 4-11th 2020.
Draft 1.5a Implemented edits from **20200617 errata.docx**. Document check by Wayne Larsen.
Draft 1.6 Tuesday October 27, 2020, Ballot comment resolution of draft 1.5a October 8th, 2020 Virtual TR-42.7 meeting. WL document check. Minor formatting fixes.

NOTICE

{TIA staff to insert applicable text here.}

Balanced single twisted-pair telecommunications cabling and components standard

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NO TABLE OF FIGURES ENTRIES FOUND.

LIST OF FIGURES

FOREWORD

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

This Standard was developed by TIA Subcommittee TR-42.7.

Approval of this Standard

This Standard was approved by TIA Sub-Committee TR-42.7, TIA Engineering Committee TR-42, and the American National Standards Institute (ANSI).

ANSI/TIA reviews standards every 5 years. At that time, standards are reaffirmed, 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.

Contributing Organizations

More than 50 organizations within the telecommunications industry contributed their expertise to the development of this Standard (including manufacturers, consultants, end users, and other organizations).

Documents superseded

This standard defines performance requirements for single pair twisted pair channels, permanent links, cables, connecting hardware, cords and measurement configurations. This standard does not supercede any previous standard but builds upon and augments the TIA 568 series of standards.

Relationship to other TIA standards and documents

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

- *Balance twisted pair cabling and components* (ANSI/TIA 568.2);
- *Generic Telecommunications Cabling for Customer Premises* (ANSI/TIA-568.0);
- *Commercial Building Telecommunications Cabling Standard* (ANSI/TIA-568.1);
- *Optical Fiber Cabling and Components Standard* (ANSI/TIA-568.3);
- *Broadband Coaxial Cabling and Components Standard* (ANSI/TIA-568.4);
- *Telecommunications Pathways and Spaces* (ANSI/TIA-569);
- *Residential Telecommunications Infrastructure Standard* (ANSI/TIA-570);
- *Administration Standard for Telecommunications Infrastructure* (ANSI/TIA-606);
- *Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises* (ANSI/TIA-607);
- *Telecommunications Infrastructure Standard for Data Centers* (ANSI/TIA-942);
- *Customer-Owned Outside Plant Telecommunications Infrastructure Standard* (ANSI/TIA-758);
- *Structured Cabling Infrastructure Standard for Intelligent Building Systems* (ANSI/TIA-862);
- *Healthcare Facility Telecommunications Infrastructure Standard* (ANSI/TIA-1179);
- *Telecommunications Infrastructure Standard for Educational Facilities* (ANSI/TIA-4966);
- *Telecommunications Physical Network Security Standard* (ANSI/TIA-5017)

In addition, the following documents may be useful to the reader:

- *National Electrical Safety Code® (NESC®)* (IEEE C 2);
- *National Electrical Code® (NEC®)* (NFPA 70)

Useful supplements to this Standard include the BICSI *Telecommunications Distribution Methods Manual,* the *Outside Plant Design Reference Manual,* and the *Information Technology Systems Installation Methods Manual*. These manuals provide practices and methods by which many of the requirements of this standard are implemented. Other references are provided in Annex E.

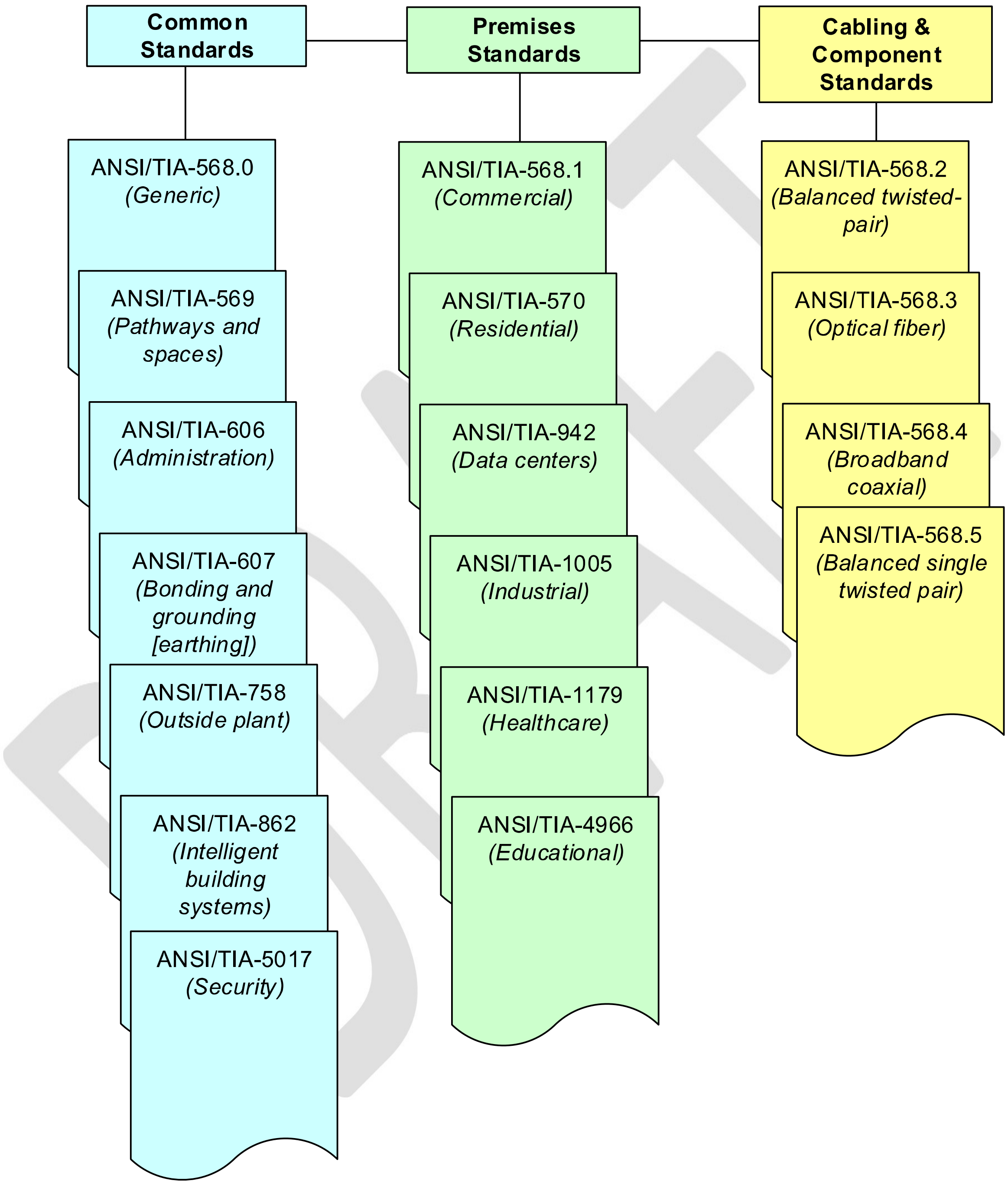


Figure 1 - Illustrative relationship between the TIA-568 series and other relevant TIA standards

Annexes

There are five annexes to this Standard. Annex A is normative and considered requirements of this Standard. Annexes B through E are informative and not considered requirements of this Standard.

Introduction

This Standard provides requirements and test procedures for 100 Ω balanced single twisted-pair cabling and components.

Purpose

This Standard specifies generic telecommunications cabling systems that will support a multi-product, multi-vendor environment. It also provides information that may be used for the design of telecommunications products.

The purpose of this Standard is to enable the planning and installation of a structured cabling system. 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 balanced single twisted-pair cabling system configurations and their respective components. In order to determine the requirements of a generic cabling system, performance requirements for various telecommunications services were considered.

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

Stewardship

Telecommunications infrastructure affects raw material consumption. The infrastructure design and installation methods also influence product life and sustainability of electronic equipment life cycling. These aspects of telecommunications infrastructure impact our environment. Since building life cycles are typically planned for decades, technological electronic equipment upgrades are necessary. The telecommunications infrastructure design and installation process magnifies the need for sustainable infrastructures with respect to building life, electronic equipment life cycling and considerations of effects on environmental waste. Telecommunications designers are encouraged to research local building practices for a sustainable environment and conservation of fossil fuels as part of the design process. TIA 5011 and TIA 5046 describe sustainability practices for manufacturers.

Specification of criteria

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

Mandatory criteria generally apply to protection, performance, administration and compatibility; they specify 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.

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

Metric equivalents of US customary units

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

Life of the Standard

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

1 SCOPE

This Standard specifies minimum requirements for balanced single twisted-pair telecommunications cabling (channels and permanent links) and components (cable, connectors, connecting hardware, and cords) that are used in commercial buildings and other similar environments. This Standard also specifies measurement procedures for all transmission parameters.

2 NORMATIVE REFERENCES

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ANSI/TIA-568.2 *Balanced Twisted-Pair Telecommunications Cabling and Components*

ANSI/TIA-606, *Administration Standard for Telecommunications Infrastructure*

ANSI/TIA-1183, *Measurement Methods and Test Fixtures For Balun-less Measurements Of Balanced Components And Systems*

ASTM D4565, *Standard Test Methods for Physical And Environmental Performance Properties of Insulations And Jackets For Telecommunications Wire And Cable*

ASTM D4566, *Standard Test Methods for Electrical Performance Properties of Insulations and Jackets for 640 Telecommunications Wire and Cable*

IEC 61156-11, *Multicore and symmetrical pair/quad cables for digital communications - Part 11: Symmetrical single pair cables with transmission characteristics up to 600 MHz - Horizontal floor wiring - Sectional specification*

IEC 61156-12, *Multicore and symmetrical pair/quad cables for digital communications – Part 12: Symmetrical single pair cables with transmission characteristics up to 600 MHz - work area wiring*

IEC 61156-13, *Multicore and symmetrical pair/quad cables for digital communications – Part 13: Symmetrical single pair cables with transmission characteristics up to 20 MHz – Horizontal floor wiring - Sectional specification*

IEC 61156-14, *Multicore and symmetrical pair/quad cables for digital communications – Part 14: Single-pair (flexible) cables related to IEC 61156-13* draft

IEC 62153-4-5, *Metallic communication cables test methods – Part 4-5: Electromagnetic compatibility (EMC) – Coupling or screening attenuation – Absorbing Clamp method,*

IEC 62153-4-9, *Metallic communication cables test methods – Part 4-9: Electromagnetic compatibility (EMC) – Coupling of screened balanced cables, triaxial method*

IEC 63171,

IEC 63171-1 *Connectors for electrical and electronic components – product requirements – Part 1: Detail specification for 2-way, shielded or unshielded, free and fixed connectors: mechanical mating information, pin assignment and additional requirements for TYPE 1 / Copper LC Style*

UL 444, *Communications Cables*

3 DEFINITIONS, ABBREVIATIONS AND ACRONYMS, UNITS OF MEASURE

3.1 General

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

3.2 Definitions

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

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

cable run: A length of installed media which may include other components along its path.

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

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

connecting hardware: A device providing cable terminations.

coupling attenuation: The ratio, in dB, of the transmitted power in the signal conductors and the maximum radiated peak power, conducted and generated by the excited common mode currents.

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

coverage area: The area served by a device.

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

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

equal level transverse conversion transfer loss: A calculation, expressed in dB, of the difference between measured TCTL and the differential mode insertion loss of the pair.

equipment cable; cord: A cable or cable assembly used to connect telecommunications equipment to horizontal or backbone cabling.

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

equipment outlet connector: Connecting hardware contained within the equipment outlet.

horizontal cabling: 1) The cabling between and including the telecommunications outlet/connector and the horizontal cross-connect. 2) The cabling between and including the building automation system outlet or the first mechanical termination of the horizontal connection point and the horizontal cross-connect.

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.

insertion loss: The signal loss resulting from the insertion of a component, or link, or channel, between a transmitter and receiver (often referred to as attenuation).

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

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 satiable for use in a specified manner.

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

outlet box (telecommunications): A housing used to hold telecommunications outlet/connectors.

outlet cable: A cable placed in a residential unit extending directly between the telecommunications outlet/connector and the distribution device.

outlet/connector (telecommunications): The fixed connector in an equipment outlet.

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

return loss: A ratio expressed in dB of the power of the outgoing signal to the power of the reflected signal.

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

sheath: See **cable sheath**.

shield: A metallic layer placed around a conductor or group of conductors.

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

transfer impedance: A measure of shielding performance determined by the ratio of the voltage on the conductors enclosed by a shield to the surface currents on the outside of the shield.

transverse conversion loss: A ratio, expressed in dB, of the measured common mode voltage on a pair relative to the differential mode voltage on the same pair applied at the same end.

transverse conversion transfer loss: A ratio, expressed in dB, of the measured common mode voltage on a pair relative to the differential mode voltage applied at the opposite end of the same pair.

3.3 Acronyms and abbreviations

ANEXT	Alien Near End Crosstalk
ANSI	American National Standards Institute
ASTM	American Society For Testing and Materials
CM	Common mode
DCR	Dc resistance
DM	Differential mode
DUT	Device under test
EIA	Electronic Industries Alliance
ELTCTL	Equal level transverse conversion transfer loss
EO	Equipment outlet
FEXT	Far-end crosstalk
F/UTP	Foil (surrounding) unscreened twisted-pairs
ICEA	Insulated Cable Engineers Association
IEC	International Electrotechnical Commission
PSAACRF	Power sum attenuation to alien crosstalk ratio, far-end
PSANEXT	Power sum alien near-end crosstalk
TCL	Tranverse conversion loss
TCTL	Transverse conversion transfer loss
TIA	Telecommunications Industry Association
UL	Underwriters Laboratories
UTP	Unshielded twisted-pair

3.4 Units of measure

dB	decibel
°C	degree Celsius
ºF	degrees Fahrenheit
ft	feet, foot
in	inch
kHz	kilohertz
MHz	megahertz

m	meter
mm	millimeter
mV	millivolt
N	newton
ns	nanoseconds
Ω	ohm
pF	picofarad
lbf	pound-force
V	volt

3.5 Variables

f	Frequency, in MHz

4 Single pair categories

Transmission performance depends upon the characteristics of cable, connecting hardware, cords, the total number of connections, and the care in which they are installed and maintained. This Standard provides minimum cabling and component performance criteria as well as procedures for component and cabling performance validation. The requirements in this Standard are for 100 Ω balanced single twisted-pair cabling and components. Information regarding recognized categories of balanced single twisted-pair cabling is shown in table 1.

Table 1 - Balanced single twisted-pair categories

Category	Channel reach	Frequency range, MHz
SP1-1000	**1000 m**	**0.1 - 20**
SP1-400	**400 m**	**0.1 - 20**

5 Mechanical requirements

This clause contains the mechanical performance specifications for 100 Ω balanced single twisted-pair cabling and components.

5.1 Channel mechanical performance

The mechanical performance of channels is achieved through the use of compliant components.

5.2 Permanent link mechanical performance

The mechanical performance of permanent links is achieved through the use of compliant components.

5.3 Horizontal cable (cabling subsystem 1) mechanical performance

Single pair horizontal cable shall consist of one balanced twisted-pair of 18 AWG to 26 AWG thermoplastic insulated solid or stranded copper conductors enclosed by a thermoplastic jacket. Other wire sizes are outside the scope of this Standard. Copper clad conductors are not allowed. The pair may or may not have a shield. Horizontal cables shall comply with the mechanical performance requirements, testing and test methods in IEC 61156-13 for cables and IEC 61156-14 for cordage.

5.3.1 Insulated conductor

The diameter of the insulated conductor shall be 2.6 mm (0.100 in) maximum.

5.3.2 Insulated conductor color code

The insulated conductor color coding shall comply with table 2.

Table 2 - Insulated conductor color codes

Pair designation[1)]	Color code (Abbreviation) Option 1
Pair 1	White/Blue or White- (Wh/BL[2)] or Wh) Blue - (BL)[2)]

1) See figure 2 for corresponding connecting hardware pair assignment.

2) A Color marking is optional on white conductor and a white marking is optional on blue conductor. Stripe or band marking shall cover not more than 30% of insulation surface.

5.3.3 Horizontal cable diameter

The diameter of the completed cable shall be less than or equal to 8.0 mm (0.315 in).

NOTE – Larger diameter cables may not be compatible with certain designs of single pair connecting hardware. Compatibility with connecting hardware should be considered

5.3.4 Cable breaking strength

The minimum breaking strength of the cable is measured in accordance with ASTM D4565. The minimum breaking strength for a single balanced twisted-pair cable shall meet or exceed the values listed in table 3. However, higher values may be used when tension limits are provided by the cable manufacturer.

Table 3 - Single Pair Minimum breaking strength

Conductor Size AWG	Minimum breaking strength N (lbf)
26	63 (14)
24	100 (22)
23	126 (28)
22	159 (36)
20	317 (71)
18	400 (90)

5.3.5 Cable bend radius

Twisted-pair cables shall withstand a bend radius of 4x (TBD) cable diameter for UTP constructions and 8x (TBD) cable diameter for screened constructions, at a temperature of -20 °C ± 1 °C, without jacket, insulation, or shield (if applicable) cracking, when tested in accordance with ASTM D4565, Wire and Cable Bending Test.

For certain applications (e.g., pre-cabling buildings in cold climate), the use of cables with a lower temperature bending performance of -30 °C ± 1 °C should be considered.

5.3.6 Cable performance marking

Single pair cables shall be marked with their appropriate category designation, See table 1.

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.

5.3.7 Cable core wrap

The core may be covered with one or more layers of dielectric material.

5.3.8 Cable core shield (screened only)

An electrically continuous shield shall be applied over the core, or core wrap if one is present.

5.3.9 Cable dielectric strength

The cable shall meet the dielectric strength requirements of UL-444.

5.4 Cord cable mechanical performance

Cord cable shall meet the requirements in section 5.3 for horizontal cable with the additions and exceptions in this clause.

5.4.1 Cord cable general

Copper clad conductors are not allowed. Cord cables shall comply with the mechanical performance requirements, testing and test methods of IEC 61156-14.

5.4.2 Cord cable flex life (screened only)

Cables used for 100 Ω screened cords shall meet the transfer impedance requirements of this document after being subjected to 500 flex cycles. Flex tests shall be performed on a minimum of 1/3 meter (13 in) lengths of un-terminated cables. The cable sample shall be clamped to a rotatable arm and suspended between two 51 mm (2 in) diameter mandrels located to either side of the center of arm rotation and spaced so as to touch but not hold the cable sample. A weight exerting greater than 10 N (2 lbf) shall be attached to the free end of the cable. A flex cycle shall consist of one + 90° rotation around each of the two mandrels, and the cycling rate shall be 10 cycles ± 2 cycles per minute.

5.5 Connecting hardware mechanical performance

5.5.1 Connecting hardware environmental compatibility

Connecting hardware used to terminate to 100 Ω balanced single twisted-pair cabling shall be functional for continuous use over the temperature range from -10 °C to 60 °C. Connecting hardware shall be protected from physical damage and from direct exposure to moisture or corrosive elements. This protection may be accomplished by installation indoors or in an appropriate enclosure for the environment.

5.5.2 Connecting hardware mounting

Connecting hardware used to terminate to 100 Ω balanced single twisted-pair cabling should be designed to provide flexibility for mounting on walls, in racks or on other types of distribution frames and standard mounting hardware. Equipment outlet/connectors shall be securely mounted at planned locations. Cables intended for future connections shall be covered with a faceplate that identifies the outlet box for telecommunications use.

5.5.3 Connecting hardware design

Cross-connect hardware used to terminate to 100 Ω balanced twisted-pair cabling shall be designed to provide:

a) a means to cross-connect cables with patch cords,
b) a means to connect premises equipment to the cabling,
c) a means to identify circuits for administration in accordance with ANSI/TIA-606,
d) a means to use standard colors as specified in ANSI/TIA-606 to functionally identify mechanical termination fields,
f) a means of handling wire and cable to permit orderly management,
g a means of access to monitor or test cabling and premises equipment, and
h) a 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.

Horizontal Connection Points (HCP) and equipment outlet/connectors used to terminate to 100 Ω balanced single twisted-pair cabling shall be designed to provide:

a) appropriate mechanical terminations for single pair cable runs, and
b) conductor identification to promote pin-pair practices consistent with clause 5.5.4.

Connecting hardware used to terminate to 100 Ω balanced single twisted-pair cabling shall not result in or contain polarity reversals (also called tip/ring reversals).

5.5.4 Outlet/connector

The IEC 63171-1 connector should be used at the equipment outlet and is recommended to be used throughout the channel where connectors are required.

Note: The colors indicated are the wire insulation colors not the pin colors.

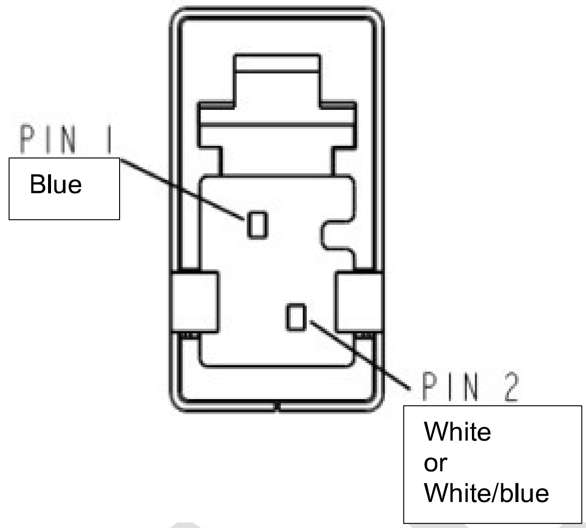


Figure 2 - Outlet configuration

5.5.5 Performance marking

Performance marking of connecting hardware is not required.

5.5.6 Connecting hardware reliability

To assure reliable operation over the usable life of the cabling system, the connecting hardware used to terminate to 100 Ω balanced twisted-pair cabling shall meet all reliability requirements of IEC 63171 (TBD). This document specifies test procedures and performance requirements for contact resistance, transfer impedance (screened only), insulation resistance, durability, environmental conditioning and other tests designed to assure consistently dependable operation.

5.5.7 Connecting hardware shield mating interface (screened only)

The shields of shielded single pair connectors (plugs and jacks) shall be designed to ensure shield continuity when mated. The shield mating interface for the recommended connector is specified in IEC 63171-1.

5.5.8 Connecting hardware shield continuity (screened only)

For shielded systems, effective shielding requires that all cabling components be shielded, and that all shields be bonded in accordance with ANSI/TIA-607.

6 Balanced single twisted-pair transmission requirements

6.1 General

Clause 6 contains the transmission performance specifications for 100 Ω balanced single twisted-pair cabling and components.

Transmission parameters are applicable to channels, permanent links, cables, cords, and connecting hardware. Clause 6 describes the transmission parameters and develops the applicable generic equations for each parameter. Laboratory measurements shall be in accordance with Annex A (except as noted in this clause) and conformance determined at both ends or in both directions.

For field test requirements see ANSI/TIA-5071.

6.1.1 Coupling attenuation

Coupling attenuation for single pair cabling shall be measured, over the specified frequency range of the cabling category, in accordance with IEC 62153-4-7 or IEC 62153-4-9 when using the triaxial method for components and cabling; or in accordance with IEC 62153-4-5 or IEC 62153-4-14 when using the absorbing clamp method for components and cabling.

6.1.2 PSANEXT loss

PSANEXT loss takes into account the combined alien near end crosstalk (statistical) on a victim from all disturbing sources operating simultaneously. PSANEXT loss is calculated as a power sum on the victim from disturbing sources as shown in equation (1).

$$PSANEXT = -10\log\left(\sum_{i=1}^{N} 10^{-\frac{ANEXT_i}{10}}\right) \ dB \qquad (1)$$

where:

N is the total number of disturbing devices under test (DUT).

$ANEXT_i$ is the measured ANEXT loss, in dB, of the victim DUT from DUT i.

i is the number of an external disturbing DUT.

6.1.3 PSAFEXT loss

PSAFEXT loss takes into account the combined alien far end crosstalk (statistical) on a victim pair from all disturbing sources operating simultaneously. PSAFEXT loss is calculated as a power sum on the victim from disturbing sources as shown in equation (2).

$$PSAFEXT = -10\log\left(\sum_{i=1}^{N} 10^{-\frac{AFEXT_i}{10}}\right) \ dB \qquad (2)$$

where:

N is the total number of disturbing devices under test (DUT).

$AFEXT_i$ is the measured AFEXT loss, in dB, of the victim DUT pair from the disturbing pair of DUT i.

i is the number of an external disturbing DUT.

6.2 Balanced single twisted-pair channel requirements

This clause contains the transmission performance specifications for balanced single twisted-pair channels. Transmission requirements that reference SP1 apply to both SP1-400 and SP1-1000 categories.

6.2.1 Channel configuration

The channel test configurations are illustrated in figures 3 and 4. See Annex C for worst case modeling configurations.

The SP1-1000 single pair channel topology shall consist of a maximum of 10 connectors, cables and cords/cables as shown in figure 3.

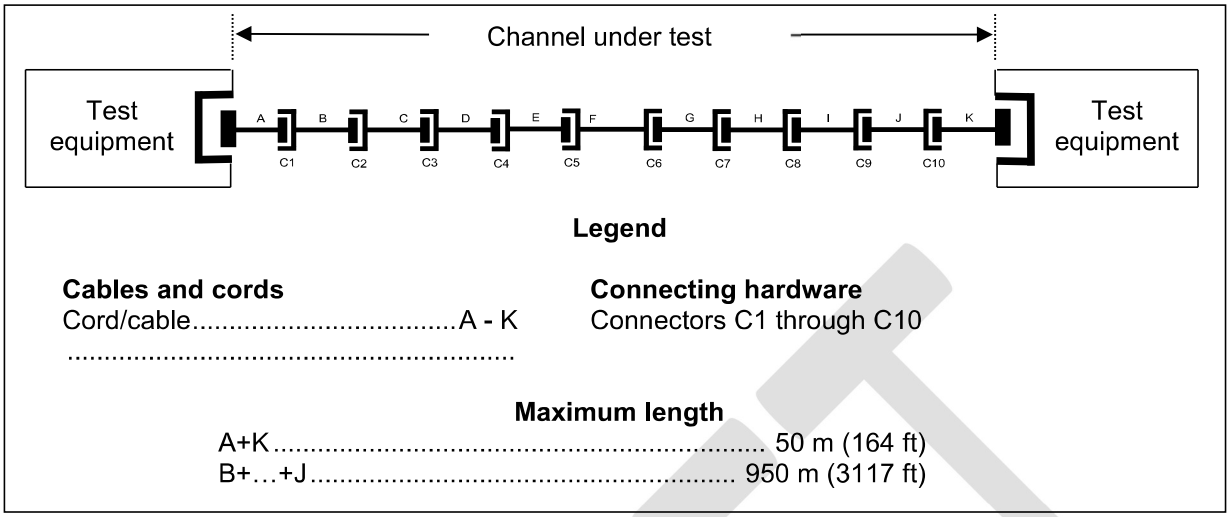


Figure 3 - Schematic representation of a SP1-1000 channel test configuration

The SP1-400 single pair channel topology shall consist of a maximum of 5 connectors, cables and cords/cables as shown in figure 4.

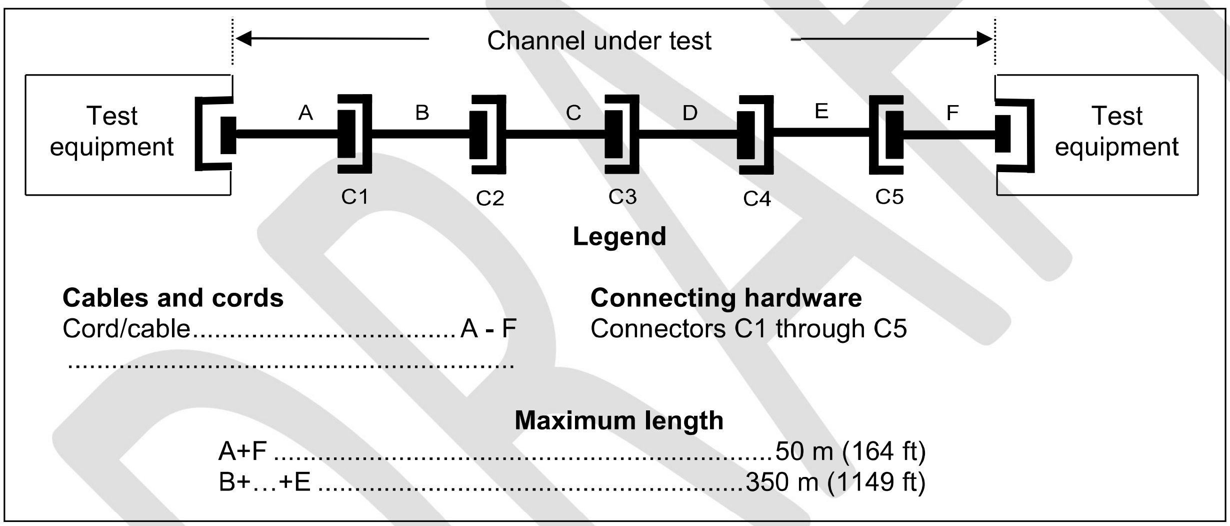


Figure 4 - Schematic representation of a SP1-400 channel test configuration

6.3 Channel transmission performance

6.3.1 Channel DC loop resistance

DC loop resistance for SP1 single pair channels shall not exceed the values of table 4 at 20 °C. Refer to TIA TSB-184-A for additional information on channel resistance related to guidance on delivering power.

Table 4 - SP1 channel DC loop resistance

Category	Channel length m	DCR @20 C Ω
SP1-1000	1000	50.6
SP1-400	400	61.5

6.3.2 Channel DC resistance unbalance

The DC resistance unbalance between the two conductors of a single pair channel shall not exceed 3 % of the DC loop resistance or 0.200 Ω, whichever is greater.

6.3.3 Channel mutual capacitance

Mutual capacitance is not specified for channels.

6.3.4 Channel capacitance unbalance: pair-to-ground

Capacitance unbalance is not specified for channels.

6.3.5 Channel characteristic impedance and structural return loss (SRL)

Characteristic impedance and structural return loss (SRL) are not applicable for channels.

6.3.6 Channel return loss

Channel return loss shall meet or exceed the values determined using the equations shown in Table 5 for all specified frequencies.

Table 5 - Channel return loss

	Frequency (MHz)	Return loss (dB)
SP1	$0.1 \leq f < 0.5$ $0.5 \leq f \leq 20$	9+8f 13.0

The channel return loss values in Table 6 are provided for information only.

Table 6 - Minimum channel return loss

Frequency (MHz)	SP1 (dB)
0.1	9.8
0.5	13.0
0.772	13.0
1.00	13.0
2.00	13.0
4.00	13.0
8.00	13.0
10.00	13.0
16.00	13.0
20.00	13.0

6.3.7 Channel insertion loss

SP1-1000 and SP1-400 single pair channel insertion loss limits are derived from equation (8).

$$InsertionLoss_{channel} = 10 \cdot (InsertionLoss_{conn}) + (InsertionLoss_{SP1\_cable-1000m})\ dB \qquad (8)$$

Clause 6.6.6 defines cable insertion loss.

$InsertionLoss_{conn}$ is the insertion loss of connecting hardware.

$$InsertionLoss_{conn} = 0.02\sqrt{f} \qquad (9)$$

Channel insertion loss shall meet or be less than the values determined using the equations shown in table 7 for all specified frequencies.

Table 7 - Channel insertion loss

	Frequency (MHz)	Insertion loss (dB)
SP1-1000	$0.1 \le f \le 20$	$10 \cdot (1.23\sqrt{f} + 0.01f + \frac{0.2}{\sqrt{f}}) + 10 \cdot 0.02\sqrt{f}$
SP1-400	$0.1 \le f \le 20$	$4 \cdot (1.82\sqrt{f} + 0.0091f + \frac{0.25}{\sqrt{f}}) + 5 \cdot 0.02\sqrt{f}$

The channel insertion loss values in table 8 are provided for information only.

Table 8 - Maximum channel insertion loss

Frequency (MHz)	SP1-1000 (dB)	SP1-400 (dB)
0.1	10.3	5.5
0.5	11.7	6.7
0.772	13.3	7.7
1.00	14.6	8.4
2.00	19.3	11.2
4.00	26.4	15.4
8.00	36.9	21.5
10.00	41.2	24.0
16.00	52.1	30.4
20.00	58.3	34.0

NOTES,

1 The insertion loss of the channel does not take into consideration the measurement floor of the connecting hardware insertion loss requirement.

2 The channel insertion loss requirement is derived using the insertion loss contribution of 10 connections.

3 The SP1-1000 cable insertion loss requirement is used to determine the channel insertion loss requirement which applies to both channels.

6.3.8 Channel TCL

Channel TCL shall meet or exceed the values determined using the equations shown in Table 9 for all specified frequencies. Calculations that result in single pair channel TCL values greater than 46 dB shall revert to a requirement of 46 dB minimum.

Note: TCL and LCL parameters have reciprocity. LCL can be determined using a TCL measurement.

Table 9 - channel TCL

	Frequency (MHz)	TCL (dB)
SP1	$0.1 \leq f \leq 20$	47 – 15log(f) (TBD)

The channel TCL values in Table 10 are provided for information only.

Table 10 - Minimum channel TCL

Frequency (MHz)	SP1 (dB)
0.1	46.0
0.5	46.0
0.772	46.0
1.00	46.0
2.00	42.5
4.00	38.0
8.00	33.5
10.00	32.0
16.00	28.9
20.00	27.5

6.3.9 Channel TCTL

Channel TCTL shall meet or exceed the values determined using the equations shown in Table 11 for all specified frequencies. TCTL values greater than 46 dB shall revert to a requirement of 46 dB minimum.

Note: TCTL and LCTL parameters have reciprocity. LCTL can be determined using a TCTL measurement.

Table 11 - Channel TCTL

	Frequency (MHz)	TCTL (dB)
SP1	$0.1 \leq f \leq 20$	47 – 15log(f) (TBD)

The single pair channel TCTL values in Table 12 are provided for information only.

Table 12 - Minimum channel TCTL

Frequency (MHz)	SP1 (dB)
0.1	46.0
0.5	46.0
0.772	46.0
1.00	46.0
2.00	42.5
4.00	38.0
8.00	33.5
10.00	32.0
16.00	28.9
20.00	27.5

6.3.10 Channel coupling attenuation

Coupling attenuation performance of channels is assured through the use of compliant cables and components, and correct installation.

6.3.11 Channel propagation delay

Channel propagation delay shall meet or be less than the value shown in Table 13.

Table 13 - Channel propagation delay

	Frequency (MHz)	Propagation delay (ns)
SP1	$0.1 \le f \le 20$	5559

6.3.12 Channel ANEXT loss

ANEXT loss is not specified for channels.

6.3.13 Channel PSANEXT loss

Channel PSANEXT loss shall meet or exceed the values determined using the equations shown in table 14. Calculations that result in channel PSANEXT loss values greater than 67 dB shall revert to a requirement of 67 dB minimum.

Table 14 - Channel PSANEXT loss

	Frequency (MHz)	PSANEXT loss (dB)
SP1	$0.1 \le f \le 20$	$37.5 - 17\log(f/20)$

The channel PSANEXT loss values in Table 15 are provided for information only.

Table 15 - Minimum channel PSANEXT loss

Frequency (MHz)	SP1 (dB)
0.1	67.0
0.5	64.7
0.772	61.5
1.00	59.6
2.00	54.5
4.00	49.4
8.00	44.3
10.00	42.6
16.00	39.1
20.00	37.5

6.3.14 Channel AFEXT loss

AFEXT loss is not specified for channels.

6.3.15 Channel PSAFEXT loss

Channel PSAFEXT loss shall meet or exceed the values determined using the equations shown in Table 16. Calculations that result in channel PSAFEXT loss values greater than 67 dB shall revert to a requirement of 67 dB minimum.

Table 16 - SP1 channel PSAFEXT

	Frequency (MHz)	PSAFEXT (dB)
SP1	$0.1 \le f \le 20$	$38-18\log(f/20)$

The SP1 channel PSAFEXT values in Table 17 are provided for information only.

Table 17 - Minimum SP1 channel PSAFEXT

Frequency (MHz)	SP1 (dB)
0.1	67.0
0.5	66.8
0.772	63.4
1.00	61.4
4.00	50.6
8.00	45.2
10.00	43.4
16.00	39.7
20.00	38.0

6.4 Balanced single twisted pair permanent link requirements

This clause contains the transmission performance specifications for balanced single twisted-pair permanent links.

6.4.1 Permanent link configuration

The permanent link test configurations are illustrated in figures 3 and 4. See Annex C for worst case modeling configurations.

The SP1-1000 single pair permanent link topology shall consist of a maximum of 9 connectors, and lengths of cables as shown in Figure 5.
Note: The permanent link excludes the extra connection needed by a cross-connect.

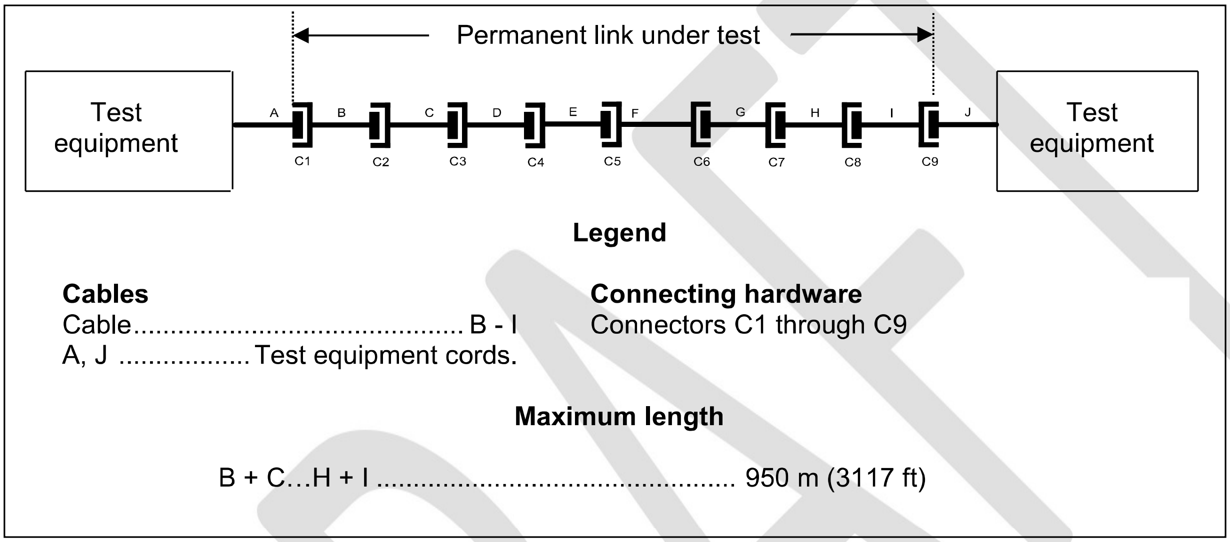


Figure 5 - Schematic representation of a SP1-1000 permanent link nine connector test configuration

The SP1-400 single pair permanent link topology shall consist of a maximum of 4 connectors, and lengths of cables as shown in figure Figure 6

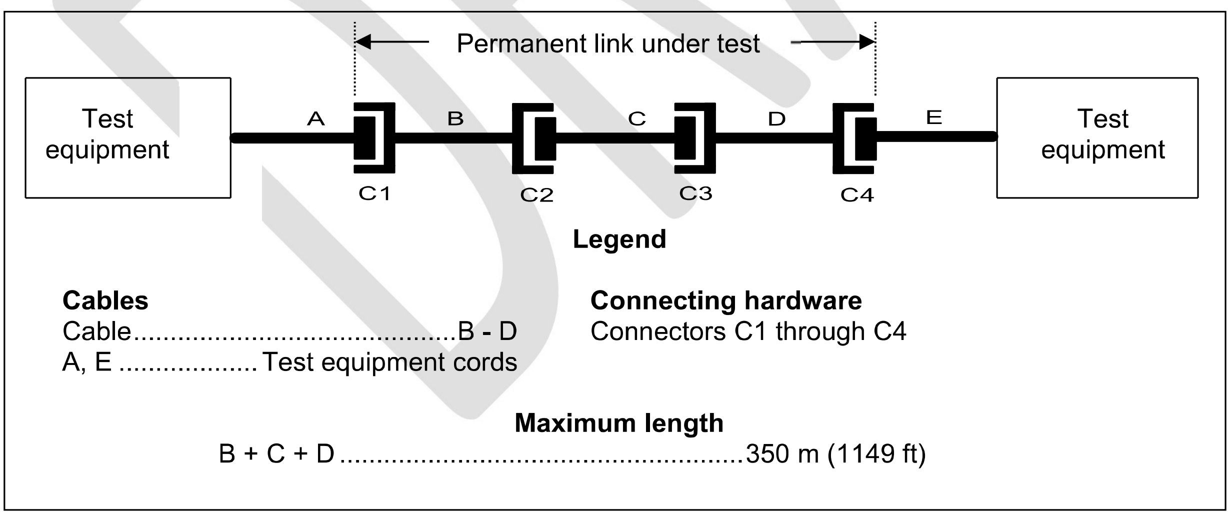


Figure 6 - Schematic representation of a SP1- 400 permanent link 4 connector configuration

6.5 Permanent link transmission performance

6.5.1 Permanent link DC loop resistance

DC loop resistance for SP1 single pair permanent links shall not exceed the values of table 18 at 20 °C. Refer to TIA TSB-184-A for additional information on permanent link resistance related to guidance on delivering power.

Table 18 - SP1 permanent link DC loop resistance

Category	Permanent link length m	DCR @20 C Ω
SP1-1000	950	47.9
SP1-400	350	53.7

6.5.2 Permanent link DC resistance unbalance

The DC resistance unbalance between the two conductors of a single pair permanent link shall not exceed 3 % or 0.200 Ω, whichever is greater.

6.5.3 Permanent link mutual capacitance

Mutual capacitance is not specified for permanent links.

6.5.4 Permanent link capacitance unbalance: pair-to-ground

Capacitance unbalance is not specified for permanent links.

6.5.5 Permanent link characteristic impedance and structural return loss (SRL)

Characteristic impedance and structural return loss (SRL) are not applicable for permanent links.

6.5.6 Permanent link return loss

Permanent link return loss shall meet or exceed the values determined using the equations shown in table 19 for all specified frequencies.

Table 19 - Permanent link return loss

	Frequency (MHz)	**Return loss (dB)**
SP1	$0.1 \le f < 0.5$ $0.5 \le f \le 20$	9+8f 13.0

The permanent link return loss values in table 20 are provided for information only.

Table 20 - Minimum permanent link return loss

Frequency (MHz)	**SP1 (dB)**
0.1	9.8
0.5	13.0
0.772	13.0
1.00	13.0
2.00	13.0
4.00	13.0
8.00	13.0
10.00	13.0
16.00	13.0
20.00	13.0

6.5.7 Permanent link insertion loss

SP1 single pair permanent link insertion loss limits are derived from equation (9).

$$InsertionLoss_{channel} = 9 \cdot (InsertionLoss_{conn}) + (InsertionLoss_{SP1\_cable-950m})\ dB \qquad (10)$$

Clause 6.6.6 defines cable insertion loss.

$InsertionLoss_{conn}$ is the insertion loss of connecting hardware.

$$InsertionLoss_{conn} = 0.02\sqrt{f} \qquad (11)$$

And

Permanent link insertion loss shall meet or be less than the values determined using the equations shown in table 21 for all specified frequencies.

Table 21 - Permanent link insertion loss (TBD)

	Frequency (MHz)	Insertion loss (dB)
SP1-1000	$0.1 \le f \le 20$	$9.5 \cdot (1.23\sqrt{f} + 0.01f + \frac{0.2}{\sqrt{f}}) + 9 \cdot 0.02\sqrt{f}$
SP1-400	$0.1 \le f \le 20$	$3.5 \cdot (1.82\sqrt{f} + 0.0091f + \frac{0.25}{\sqrt{f}}) + 4 \cdot 0.02\sqrt{f}$

The permanent link insertion loss values in table 22 are provided for information only.

Table 22 - Maximum permanent link insertion loss

Frequency (MHz)	SP1-1000 (dB)	SP1-400 (dB)
0.1	9.8	4.8
0.5	11.1	5.8
0.772	12.7	6.7
1.00	13.9	7.4
2.00	18.3	9.8
4.00	25.1	13.5
8.00	35.0	18.8
10.00	39.1	21.0
16.00	49.5	26.5
20.00	55.4	29.7

NOTES,

1. The insertion loss of the permanent link does not take into consideration the measurement floor of the connecting hardware insertion loss requirement.
2. The permanent link insertion loss requirement is derived using the insertion loss contribution of 9 connections.
3. The SP1-1000 and SP1-400 permanent link insertion loss requirements are different. The SP1-400 requirement allows for the addition of 50 m of SP1-400 cable while meeting the channel requirement and the SP1-1000 requirement allows 50 m of SP1-1000 cable.

6.5.8 Permanent link TCL

Permanent link TCL shall meet or exceed the values determined using the equations shown in table 23 for all specified frequencies. Calculations that result in single pair permanent link TCL values greater than 46 dB shall revert to a requirement of 46 dB minimum.

Note: TCL and LCL parameters have reciprocity. LCL can be determined using a TCL measurement.

Table 23 - permanent link TCL

	Frequency (MHz)	TCL (dB)
SP1	$0.1 \leq f \leq 20$	47 – 15log(f) (TBD)

The permanent link TCL values in table 24 are provided for information only.

Table 24 - Minimum permanent link TCL

Frequency (MHz)	SP1 (dB)
0.1	46.0
0.5	46.0
0.772	46.0
1.00	46.0
2.00	42.5
4.00	38.0
8.00	33.5
10.00	32.0
16.00	28.9
20.00	27.5

6.5.9 Permanent link TCTL

Permanent link TCTL shall meet or exceed the values determined using the equations shown in table 25 for all specified frequencies. TCTL values greater than 46 dB shall revert to a requirement of 46 dB minimum.

Table 25 – Permanent link TCTL

	Frequency (MHz)	TCTL (dB)
SP1	$0.1 \leq f \leq 20$	47 – 15log(f) (TBD)

The single pair permanent link TCTL values in table 26 are provided for information only.

Table 26 – Minimum permanent link TCTL

Frequency (MHz)	SP1 (dB)
0.1	46.0
0.5	46.0
0.772	46.0
1.00	46.0
2.00	42.5
4.00	38.0
8.00	33.5
10.00	32.0
16.00	28.9
20.00	27.5

6.5.10 Permanent link coupling attenuation

Coupling attenuation performance of permanent links is assured through the use of compliant cables and components, and correct installation.

6.5.11 Permanent link propagation delay

Permanent link propagation delay shall meet or be less than the value shown in table 27 for the specified frequency ranges.

Table 27 - Permanent link propagation delay

	Frequency (MHz)	Propagation delay (ns)
SP1	$0.1 \le f \le 20$	5273 (TBD)

6.5.12 Permanent link ANEXT loss

ANEXT loss is not specified for permanent links.

6.5.13 Permanent link PSANEXT loss

Permanent link PSANEXT loss shall meet or exceed the values determined using the equations shown in table 28. Calculations that result in permanent link PSANEXT loss values greater than 67 dB shall revert to a requirement of 67 dB minimum.

Table 28 - Permanent link PSANEXT loss

	Frequency (MHz)	PSANEXT loss (dB)
SP1	$0.1 \le f \le 20$	$37.5 - 17\log(f/20)$

The permanent link PSANEXT loss values in table 29 are provided for information only.

Table 29 - Minimum permanent link PSANEXT loss

Frequency (MHz)	SP1 (dB)
0.1	67.0
0.5	64.7
0.772	61.5
1.00	59.6
2.00	54.5
4.00	49.4
8.00	44.3
10.00	42.6
16.00	39.1
20.00	37.5

6.5.14 Permanent link AFEXT loss

AFEXT loss is not specified for permanent links.

6.5.15 Permanent link PSAFEXT loss

Permanent link PSAFEXT loss shall meet or exceed the values determined using the equations shown in table 30. Calculations that result in permanent link PSAFEXT loss values greater than 67 dB shall revert to a requirement of 67 dB minimum.

Table 30 - SP1 permanent link PSAFEXT

	Frequency (MHz)	PSAFEXT (dB)
SP1	$0.1 \le f \le 20$	$38-18\log(f/20)$

The SP1 permanent link PSAFEXT values in table 31 are provided for information only.

Table 31 - Minimum SP1 permanent link PSAFEXT

Frequency (MHz)	SP1 (dB)
0.1	67.0
0.5	66.8
0.772	63.4
1.00	61.4
4.00	50.6
8.00	45.2
10.00	43.4
16.00	39.7
20.00	38.0

6.6 Cable transmission performance

Cable measurements are made on a 100 m sample. The cable requirements and tests are designed to assure the performance of permanent links up to the specified lengths of 1000 m and 400 m.

DC loop resistance, loop inductance, and capacitance should be met by the applicable specifications for the application/s intended. In the absence of specific guidance, the values in table 36 are recommended for qualification where required.

Table 32 - Cable parameters at 1 KHz and 20 °C

Parameter	Minimum Value	Maximum Value
DC Loop Resistance	15 Ω/km (TBD)	150ohm/km (TBD)
Loop Inductance	0.4 mH/km (TBD)	1mH/km (TBD)
Capacitance	45 nF/km (TBD)	200nF/km (TBD)

6.6.1 Cable DC resistance

For single pair cable, DC resistance shall not exceed the values in table 33 per 100 m (328 ft) for each conductor when measured in accordance with ASTM D4566 at or corrected to a temperature of 20 °C.

Table 33 - Cable DC resistance per 100 m

AWG	Ω per 100 m
18	2.33
20	3.71
22	5.90
23	7.44
24	9.38
26	14.9

6.6.2 Cable DC resistance unbalance

DC resistance unbalance shall not exceed 4 % at 20 degrees C when measured accordance with ASTM D4566. This is equivalent to 2 % when measured in accordance with IEC 61156-1.

6.6.3 Cable mutual capacitance

Mutual capacitance shall be measured in accordance with ASTM D4566.

The mutual capacitance of a single pair cable pair at 1 kHz, measured at or corrected to a temperature of 20 °C, should not exceed 5.6 nF per 100 m (328 ft).

6.6.4 Cable capacitance unbalance: pair-to-ground

Capacitance unbalance to ground is not specified for cables.

6.6.5 Cable return loss

Single pair cable return loss shall meet or exceed the values determined using the equations shown in Table 34 for all specified frequencies. Single pair cable return loss is measured on 100 m samples.

Table 34 - Cable return loss

	Frequency (MHz)	**Return loss (dB)**
SP1	$0.1 \le f < 10$ $10 \le f \le 20$	20+5log(f) 25

The cable return loss values in Table 35 are provided for information only.

Table 35 - Minimum cable return loss

Frequency (MHz)	**SP1 (dB)**
0.1	15.0
0.5	18.5
0.772	19.4
1.00	20.0
2.00	21.5
4.00	23.0
8.00	24.5
10.00	25.0
16.00	25.0
20.00	25.0

6.6.6 Cable insertion loss

Insertion loss shall be measured on a 100 m sample at 20 ± 3 °C or corrected to a temperature of 20 °C using the correction factors specified in this clause. The insertion loss for UTP cables shall be adjusted at elevated temperatures using a factor of 0.4 % increase per °C from 20 °C to 40 °C and 0.6% increase per °C for temperatures from 40 °C to 60 °C. The insertion loss for screened cables shall be adjusted at elevated temperatures using a factor of 0.2% increase per °C from 20 °C to 60 °C.
Single pair cable insertion loss shall meet or be less than the values determined using the equations shown in table 36 for all specified frequencies. The table specifies insertion loss requirements for sample lengths of 100 m.

Table 36 - Cable insertion loss (100 m)

	Frequency (MHz)	Insertion loss (dB)
SP1-1000	$0.1 \leq f \leq 20$	$(1.23\sqrt{f} + 0.01 \cdot f + \frac{0.2}{\sqrt{f}})$
SP1-400	$0.1 \leq f \leq 20$	$(1.82\sqrt{f} + 0.0091 \cdot f + \frac{0.25}{\sqrt{f}})$ (TBD)

The maximum single pair cable insertion loss values in Table 37 are provided for information only.

Table 37 - Maximum cable insertion loss for 100 meter sample

Frequency (MHz)	SP1-1000 (dB)	SP1-400 (dB)
0.1	1.0	1.4
0.5	1.2	1.6
0.772	1.3	1.9
1.00	1.4	2.1
2.00	1.9	2.8
4.00	2.6	3.8
8.00	3.6	5.3
10.00	4.1	5.9
16.00	5.1	7.5
20.00	5.7	8.4

6.6.7 Cable TCL

Cable TCL shall meet or exceed the values determined using the equations shown in Table 38 for all specified frequencies. Calculations that result in single pair cable TCL values greater than 50 dB shall revert to a requirement of 50 dB minimum. Compliance to these requirements is intended to be verified by laboratory measurements.

Note: TCL and LCL parameters have reciprocity. LCL can be determined using a TCL measurement.

Table 38 - Cable TCL

	Frequency (MHz)	TCL (dB)
SP1	$0.1 \leq f \leq 20$	50 – 15log(f) (TBD)

The cable TCL values in Table 39 are provided for information only.

Table 39 - Minimum cable TCL

Frequency (MHz)	SP1 (dB)
0.1	50.0
0.5	50.0
0.772	50.0
1.00	50.0
2.00	45.5
4.00	41.0
8.00	36.5
10.00	35.0
16.00	31.9
20.00	30.5

6.6.8 Cable TCTL

Cable TCTL shall meet or exceed the values determined using the equations shown in Table 40 for all specified frequencies. Calculations that result in single pair cable TCTL values greater than 50 dB shall revert to a requirement of 50 dB minimum. Compliance to these requirements is intended to be verified by laboratory measurements.

Table 40 - Cable TCTL

	Frequency (MHz)	TCTL (dB)
SP1	$0.1 \le f \le 20$	$50 - 15\log(f)$ (TBD)

The single pair cable TCTL values in Table 41 are provided for information only.

Table 41 - Minimum cable TCTL

Frequency (MHz)	SP1 (dB)
0.1	50.0
0.5	50.0
0.772	50.0
1.00	50.0
4.00	41.0
8.00	36.5
10.00	35.0
16.00	31.9
20.00	30.5

6.6.9 Cable coupling attenuation

Cable coupling attenuation shall meet or exceed the values determined using the equations shown in Table 42 for all specified frequencies. Coupling attenuation requirements apply only to shielded cables.

Table 42 - Cable coupling attenuation

	Frequency (MHz)	Coupling attenuation (dB)
SP1	$0.1 \leq f < 20$	60 (TBD)

6.6.10 Cable propagation delay

Cable propagation delay shall meet or be less than 534 + 36/sqrt(f) ns per 100 m.

6.6.11 Cable ANEXT loss

ANEXT loss is not specified for cables.

6.6.12 Cable PSANEXT loss

Cable PSANEXT loss is specified for 100 m single pair cables. The 100 m single pair cable PSANEXT loss shall meet or exceed the values determined using the equations shown in Table 43. Calculations that result in 100 m cable PSANEXT loss values greater than 67 dB shall revert to a requirement of 67 dB minimum.

Table 43 - Cable PSANEXT loss

	Frequency (MHz)	PSANEXT loss (dB)
SP1	$0.1 \leq f \leq 20$	$37.5 - 17\log(f/20)$

The single pair cable PSANEXT loss values in Table 44 are provided for information only.

Table 44 - Minimum 100 m cable PSANEXT loss

Frequency (MHz)	SP1 (dB)
0.1	67
0.5	64.7
0.772	61.5
1.00	59.6
2.00	54.5
4.00	49.4
8.00	44.3
10.00	42.6
16.00	39.1
20.00	37.5

6.6.13 Cable AFEXT loss

AFEXT loss is not specified for cables.

6.6.14 Cable PSAFEXT loss

Cable PSAFEXT loss is specified for 100 m single pair cables. The 100 m single pair cable PSAFEXT loss shall meet or exceed the values determined using the equations shown in Table 45. Calculations that result in 100 m cable PSANEXT loss values greater than 67 dB shall revert to a requirement of 67 dB minimum.

Table 45 - SP1 cable PSAFEXT

	Frequency (MHz)	PSAFEXT (dB)
SP1	$0.1 \leq f \leq 20$	$38\text{-}18\log(f/20)$

The SP1 single pair cable PSAFEXT values in Table 46 are provided for information only.

Table 46 - Minimum SP1 cable PSAFEXT

Frequency (MHz)	SP1 (dB)
0.1	67.0
0.5	66.8
0.772	63.4
1.00	61.4
4.00	50.6
8.00	45.2
10.00	43.4
16.00	39.7
20.00	38.0

6.7 Bundled cable transmission performance

The individual cables within a bundled cable shall meet the requirements in clause 6.6 of this Standard after bundle formation.

6.8 Connecting hardware transmission performance

Compliance to the requirements of this clause shall ensure that connecting hardware installed in accordance with ANSI/TIA-568.0 will have minimal effects on cable performance. These requirements are applicable to individual connectors and connector assemblies that include, but are not limited to, single pair outlet/connectors, patch panels, consolidation points, transition points, and cross-connect blocks.

Unless otherwise specified, all connecting hardware shall be tested in a mated state.

6.8.1 Mated connecting hardware DC resistance

Input to output DC resistance shall be measured in accordance with IEC 63171-1.

Each signal path shall not exceed 200 mΩ. Shield path, if present, shall not exceed 100 mΩ.

6.8.2 Connecting hardware DC contact resistance

Shield contact resistance is specified in IEC 63171-1 and signal contact resistance in IEC 63171-1.

6.8.3 Connecting hardware DC resistance unbalance

DC resistance unbalance is specified in IEC 63171-1.

6.8.4 Connecting hardware mutual capacitance

Mutual capacitance is not specified for single pair connecting hardware.

6.8.5 Connecting hardware capacitance unbalance: pair-to-ground

Capacitance unbalance to ground is not specified for single pair connecting hardware.

6.8.6 Connecting hardware characteristic impedance and structural return loss (SRL)

Characteristic impedance and structural return loss are not specified for connecting hardware.

6.8.7 Connecting hardware return loss

Connecting hardware return loss shall meet or exceed the values determined using the equations shown in Table 47 for all specified frequencies.

Table 47 - Connecting hardware return loss

Permanent link category	Frequency (MHz)	Return loss (dB)
SP1	$0.1 \leq f \leq 15$ $15 < f \leq 20$	40 $38 - 20\log(f/20)$

The connecting hardware return loss values in Table 48 are provided for information only.

Table 48 - Single pair minimum connecting hardware return loss

Frequency (MHz)	SP1 dB
0.1	40.0
0.5	40.0
0.772	40.0
1.00	40.0
2.00	40.0
4.00	40.0
8.00	40.0
10.00	40.0
16.00	39.9
20.00	38.0

6.8.8 Connecting hardware insertion loss

Single pair connecting hardware insertion loss shall meet or be less than the values determined using the equations shown in Table 49 for all specified frequencies. Calculations that result in insertion loss values less than 0.05 dB shall revert to a requirement of 0.05 dB maximum.

Table 49 - Connecting hardware insertion loss

Channel category	Frequency (MHz)	Insertion loss (dB)
SP1	$0.1 \le f \le 20$	$0.02\sqrt{f}$

The connecting hardware insertion loss values in Table 50 are provided for information only.

Table 50 - Maximum connecting hardware insertion loss

Frequency (MHz)	SP1 dB
0.1	0.05
0.5	0.05
0.772	0.05
1.00	0.05
2.00	0.05
4.00	0.05
8.00	0.06
10.00	0.06
16.00	0.08
20.00	0.09

6.8.9 Connecting hardware TCL

Single pair connecting hardware TCL shall meet or exceed the values determined using the equations shown in Table 51 for all specified frequencies. Single pair connecting hardware TCL values greater than 50 dB shall revert to a requirement of 50 dB minimum.

Table 51 - Connecting hardware TCL

Channel category	Frequency (MHz)	TCL (dB)
SP1	$0.1 \le f \le 20$	68-20log(f)

The connecting hardware TCL values in Table 52 are provided for information only.

Table 52 - Minimum connecting hardware TCL

Frequency (MHz)	SP1 dB
0.1	50.0
0.5	50.0
0.772	50.0
1.00	50.0
2.00	50.0
4.00	50.0
8.00	49.9
10.00	48.0
16.00	43.9
20.00	42.0

6.8.10 Connecting hardware TCTL

Connecting hardware TCTL shall meet or exceed the values determined using the equations shown in Table 53 for all specified frequencies. Calculations that result in single pair connecting hardware TCTL values greater than 50 dB shall revert to a requirement of 50 dB minimum.

Table 53 - Connecting hardware TCTL

Channel category	Frequency (MHz)	TCTL (dB)
SP1	$0.1 \le f \le 20$	50

The connecting hardware TCTL values in Table 54 are provided for information only.

Table 54 - Minimum connecting hardware TCTL

Frequency (MHz)	SP1 dB
0.1	50.0
0.5	50.0
0.772	50.0
1.00	50.0
2.00	50.0
4.00	50.0
8.00	50.0
10.00	50.0
16.00	50.0
20.00	50.0

6.8.11 Connecting hardware ELTCTL

ELTCTL is not specified for connecting hardware.

6.8.12 Connecting hardware coupling attenuation (screened only)

Single pair connecting hardware coupling attenuation is assumed to be met whenever the channel coupling attenuation requirement is met.

6.8.13 Connecting hardware propagation delay

Single pair connecting hardware propagation delay of each installed mated connection is assumed to not exceed 2.5 ns from 0.1 MHz to the highest referenced frequency.

6.8.14 Connecting hardware transfer impedance (screened only)

The shield transfer impedance of single pair screened connecting hardware, measured in accordance with IEC 60512-26-100, test 26e shall not exceed the values determined using Table 55. Values smaller than 40 mΩ shall revert to 40 mΩ.

Table 55 - Connecting hardware transfer impedance (screened only)

Frequency (MHz)	**Z_{Tconn} (mΩ)**
$0.1 \le f \le 10$	$\le 50 \cdot f^{0.3}$
$10 < f \le 20$	$\le 10 \cdot f$

Where:

Z_{Tconn} is the transfer impedance of the connecting hardware shield.

The values in Table 56 are derived from Table 55 and are provided for information only.

Table 56 - Maximum connecting hardware transfer impedance

Frequency (MHz)	**SP1** (mΩ)
0.1	40
0.5	41
0.772	46
1.00	50
2.00	62
4.00	76
8.00	93
10.00	100
16.00	160
20.00	200

Compliant transfer impedance performance of cables and single pair connecting hardware is not sufficient to ensure proper link and channel transfer impedance. Cable shields shall be terminated to the connecting hardware shields following manufacturer's instructions.

6.8.15 Connecting hardware ANEXT loss

ANEXT loss is not specified for single pair connecting hardware.

6.8.16 Connecting hardware PSANEXT loss

Connecting hardware PSANEXT loss shall meet or exceed the value shown in Table 57.

Table 57 - Connecting hardware PSANEXT loss

Channel category	Frequency (MHz)	PSANEXT loss (dB)
SP1	$0.1 \leq f \leq 20$	67

6.8.17 Connecting hardware AFEXT loss

AFEXT loss is not specified for single pair connecting hardware.

6.8.18 Connecting hardware PSAFEXT loss

Connecting hardware PSAFEXT loss shall meet or exceed the values shown in Table 58.

Table 58 - Connecting hardware PSAFEXT loss

Channel category	Frequency (MHz)	PSAFEXT loss (dB)
SP1	$0.1 \leq f \leq 20$	67

Annex A (normative) – Cabling and component test procedures

A.1 General

This document describes the general configuration of and requirements for laboratory test equipment for measurement of generic single pair copper cabling components and systems. The equipment configurations described are for measurement of cabling devices consisting of one pair of wires which present to the test equipment 4 ports for measurement divided into 2 ports at a defined near (local) end and 2 ports at a defined far (remote) end. For practical purposes all 4 ports connect to a single network analyzer for measurement, so the remote end is not physically removed from the local end. The least number of network analyzer ports considered in this standard is two, with external switching or manual connections to adapt the network analyzer to the cabling under test. The maximum (ideal) number of network analyzer ports considered here is 8, which would provide a fully calibrated measurement environment for two single-pair devices. In this document, the cable, channel, or other device under test will be referred to as the DUT.

The test fixtures described in this document are designed to present a generic interface between cabling devices which present twisted pair wires to the test interface with a multi-port network analyzer. The test system may also include an intermediate RF switch to adapt the number of network analyzer ports to the number of DUT ports. The multi-port (4 port) network analyzer allows for the elimination of balun transformers from the measurement path of devices that are designed for differential signaling. The network analyzer can drive any single-ended 50 Ω port, measure response from any single-ended 50 Ω port and calculate the response in terms of mixed mode (differential and common mode) signaling environment. Some network analyzers provide true differential signaling on port pairs. Full characterization of a two-port differentially signaled DUT is possible through stimulus and measurement of the four-port single-ended S-parameters. The results include not only the commonly specified differential S-parameters (insertion loss, return loss) and mixed mode S-parameters (TCL, TCTL), but also common mode parameters such as common mode insertion loss and common mode return loss. In addition, the four port S-parameter data may be post-processed to provide equivalent test results for different mixed mode environments, for example different common mode impedances.

The requirements for the measurement system apply up to the highest frequency of the category of the device being measured.

Balunless methods are specified in this document. Other measurement methods that are demonstrated to show equivalence to the methods in this annex are allowed. The test methods described in ANSI/TIA-568.2-D and ANSI/TIA-1183-A may be used. When this is done, the fixture accuracy requirements from those documents at 1 MHz also apply from 0.1 to 1 MHz. The single pair is treated as pair 1 of the four-pair cabling system and the relevant parameters are tested.
Test equipment that incorporates baluns in the signal path may also be used. When baluns are used in test equipment, their performance characteristics shall comply with table A.1.

Table A.1 - Test balun performance characteristics 0.1 MHz to 20 MHz

Parameter	Frequency (MHz)	Value
Impedance, primary 1)	$0.1 \leq f \leq 20$	50 Ω unbalanced
Impedance, secondary	$0.1 \leq f \leq 20$	100 Ω balanced
Insertion loss	$0.1 < f \leq 20$	1.0 dB maximum
Return loss, bi-directional 2)	$0.1 < f \leq 20$	20 dB minimum
Return loss, common mode 2)	$0.1 < f \leq 20$	20 dB minimum
Power rating	$0.1 \leq f \leq 20$	0.1 watt minimum
Longitudinal balance 2)	$0.1 \leq f \leq 20$	60 dB minimum
Output signal balance 2)	$0.1 \leq f \leq 20$	50 dB minimum
Common mode rejection 2)	$0.1 \leq f \leq 20$	50 dB minimum

1) Primary impedance may differ, if necessary, to accommodate analyzer outputs other than 50 Ω.
2) Measured per ITU-T (formerly CCITT) Recommendation G.117 with the network analyzer calibrated using a 50 Ω load.

A.2 Test configurations

The basic test configurations in this document show connections between a four-port network analyzer and a 4 port DUT. The 50 Ω ports of the network analyzer are connected directly to each of the active pin-pair(s) of the DUT under test. Far end ports which are not connected to the network analyzer are terminated with resistor terminations.

Resistor terminations may terminate far end ports. The optimal measurement configuration is for each of the ports of the device under test to be terminated with a network analyzer port. This allows for the residual effects of the terminations to be compensated through calibration. For a four port measurement, this allows fully calibrated measurements on a one pair DUT. The measurements that can be made on a single pair include insertion loss, return loss, TCL, TCTL, and delay. Measurements of two DUT's would include alien crosstalk between the two DUT's, near end and far end, in addition to the above parameters. This would require 8 ports to be connected to an 8 port network analyzer for fully calibrated measurements.

A.3 Test configurations specifications

Figure A.1, shows measurement configurations for an eight port DUT for measurement of all parameters of two single pair DUT's including alien crosstalk couplings between DUTs. In this configuration, external switches connect the four measurement ports to the network analyzer. Far end ports are terminated within the external switch modules. Figures A.2 through A.5 show measurement configurations using a four port network analyzer and externally applied termination resistors at the far end ports in some configurations. The four-port network analyzer excites and monitors on four 50 Ω single-ended ports. The measurement results are defined in terms of single-ended 50 Ω S-parameters. These test configurations are used to extract the full 8 by 8 S-parameter matrix to fully characterize the 8 port DUT, and can be expressed using appropriate algorithms to calculate the response with mixed mode terminations specified for the cabling system.

When two single-ended ports are combined, forming the equivalent of one 100 Ω differential port in a mixed mode environment, the differential impedance between the signal pins will be 100 Ω and the common mode impedance with respect to ground will be 25 Ω. This common mode impedance differs from the 50 Ω common mode impedance specified in the ANSI/TIA 568.2 standard. Measurement results shall be post-processed to obtain results consistent with this standard's requirements, see ANSI/TIA-1183. Typical 4 port network analyzers make single ended measurements that are transformed into mixed mode results within the network analyzer. Some network analyzers allow for normalizing the common mode impedance. If the far ends of a single pair DUT are not available locally for direct connection to the network analyzer, they should be terminated with resistor terminations that provide the desired 50 Ω common mode reference impedance. Care should be taken to ensure that all single-ended transmission paths through switching, cables and fixtures exhibit suitable insertion loss and return loss characteristic as required by this standard.

Measurement of all 8 ports of the DUT require either the use of a switching matrix between the network analyzer and the DUT as shown in Figure A.1 or successive re-positioning of the DUT input and output port connections until all port combinations are tested. If a switching matrix is used, it shall be configurable to allow all 8 ports to be connected either as inputs, outputs, or terminations. It is assumed that calibration at the DUT test interface will correct for impairments in the switching and cabling. A unique calibration for each signal path is required. For some shielded single pair systems it can be demonstrated that alien crosstalk couplings between DUTs are at or below the level of measurement floor. In this case, all necessary single pair DUT measurements may be made with the four port network analyzer in a fully calibrated mode.

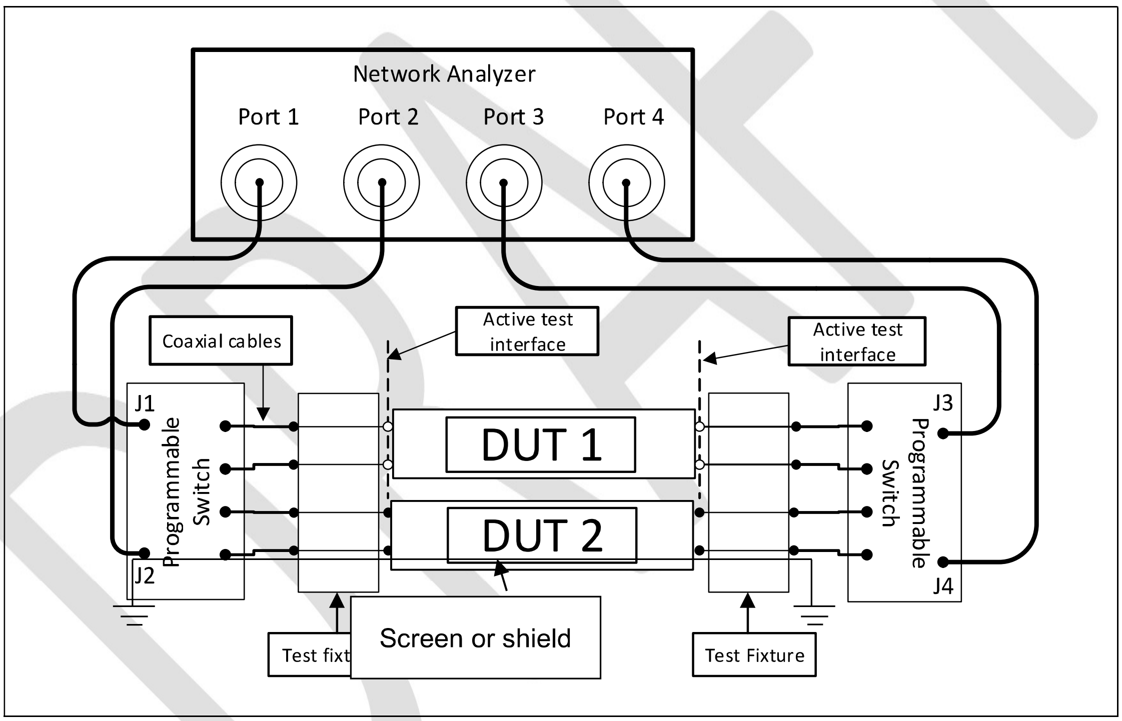


Figure A.1 - Test system diagram for four port network analyzer

Note: The two programmable switches illustrated in figure A.1 may be combined into a single programmable switch, enabling any input port to be connected to any output port.
Figure A.2 shows the laboratory measurement configuration using a four port network analyzer. In this configuration the network analyzer is calibrated using 50 Ω to ground loads and is configured to apply a 100 Ω DM/25 Ω CM balun at the test interface (either by within the VNA set up or by postprocessing). Results taken using the configuration shown in Figure A.2 shall be postprocessed to convert to the reference impedance of 100 Ω DM/50 Ω CM using the technique provided by TIA-1183.

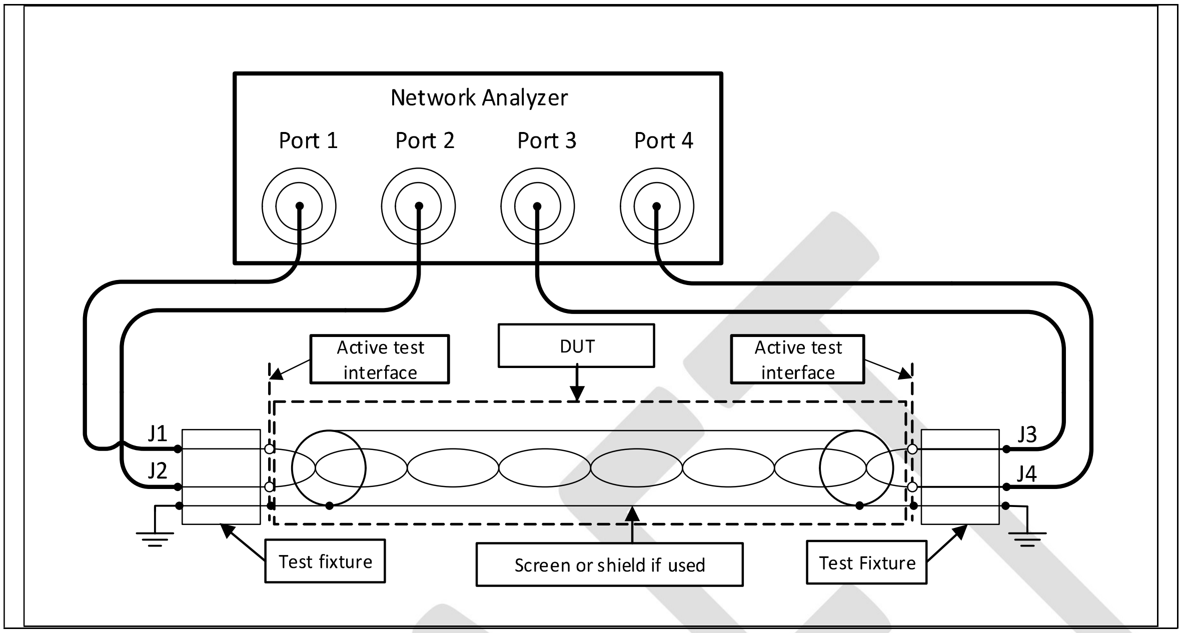


Figure A.2 - Laboratory test configuration for cable and channel insertion loss, return loss, TCL, TCTL, and propagation delay.

Figure A.3 shows the laboratory measurement configuration for measurement of alien crosstalk between DUTs. In this configuration the network analyzer is calibrated using 50 Ω to ground loads and is configured to apply a 100 Ω DM/50 Ω CM balun at the test interface (either by within the VNA set up or by postprocessing). Figure A.3 shows 100 Ω DM/25 Ω CM termination which may be used for convenience, 100 Ω DM/50 Ω CM terminations may also be used. It is assumed for Alien crosstalk measurements the difference between these terminations is negligible.

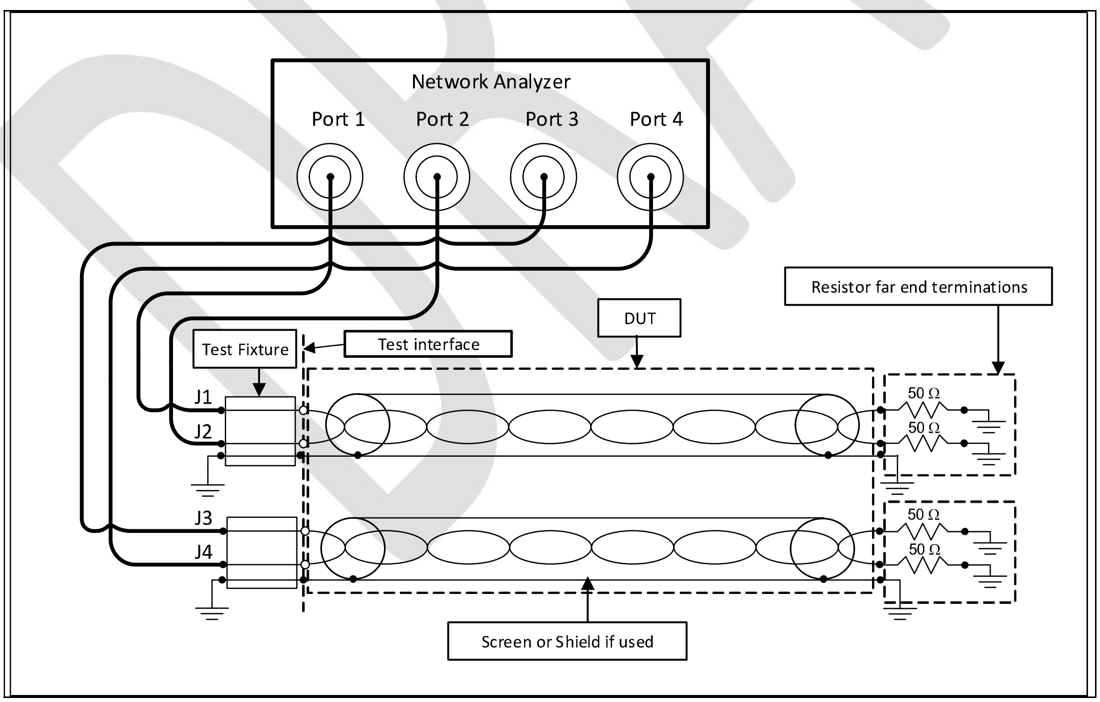


Figure A.3 - Laboratory test configuration for alien NEXT loss between DUTs

The configuration of either figure A.4 or A.5 may also be used for measurement of return loss and TCL (LCL) of the pairs under test.

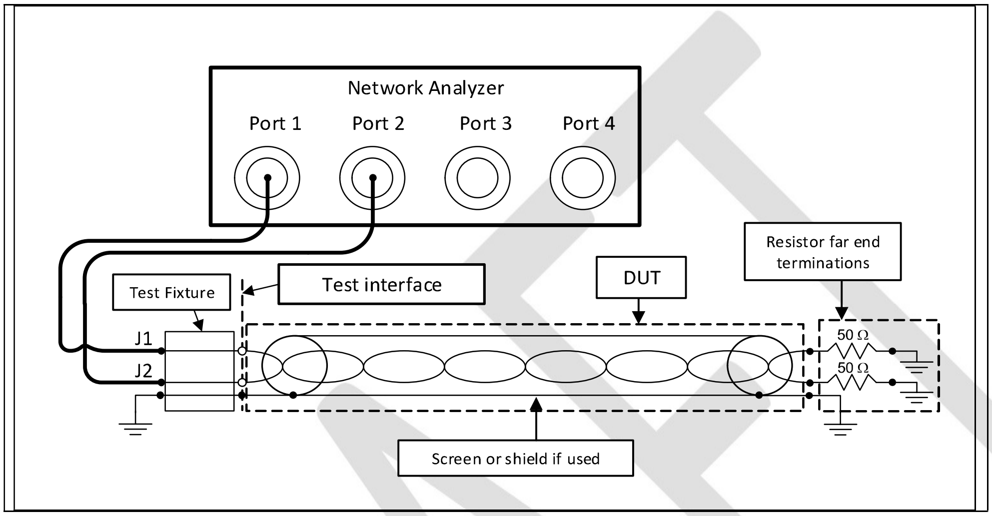


Figure A.4 - Two port test configuration with 25 Ohm common mode termination.

Measurements using the configuration shown in figure A.4 shall be post processed to convert to the reference impedance of 100 Ω DM/50 Ω CM using the technique provided by ANSI/TIA-1183. This will require further measurement of all six combinations of 2 port configurations across the 4 ports.

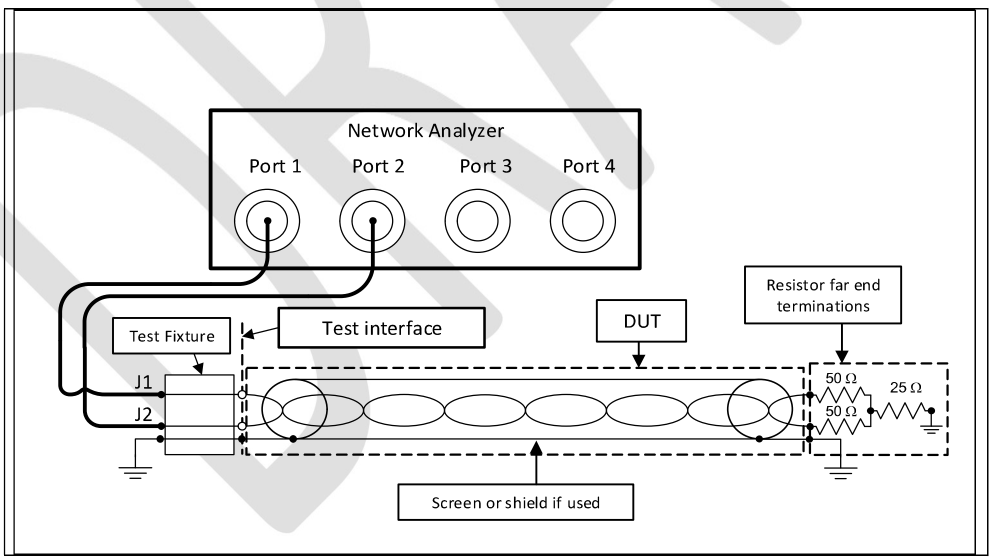


Figure A.5 - Two port test configuration with 50 Ohm common mode termination.

When using the configuration shown in figure A.5 the near end impedance shall be matched to the far end termination, either by VNA setup, or by post processing. Results are in the reference impedance of 100 Ω DM and 50 Ω CM.

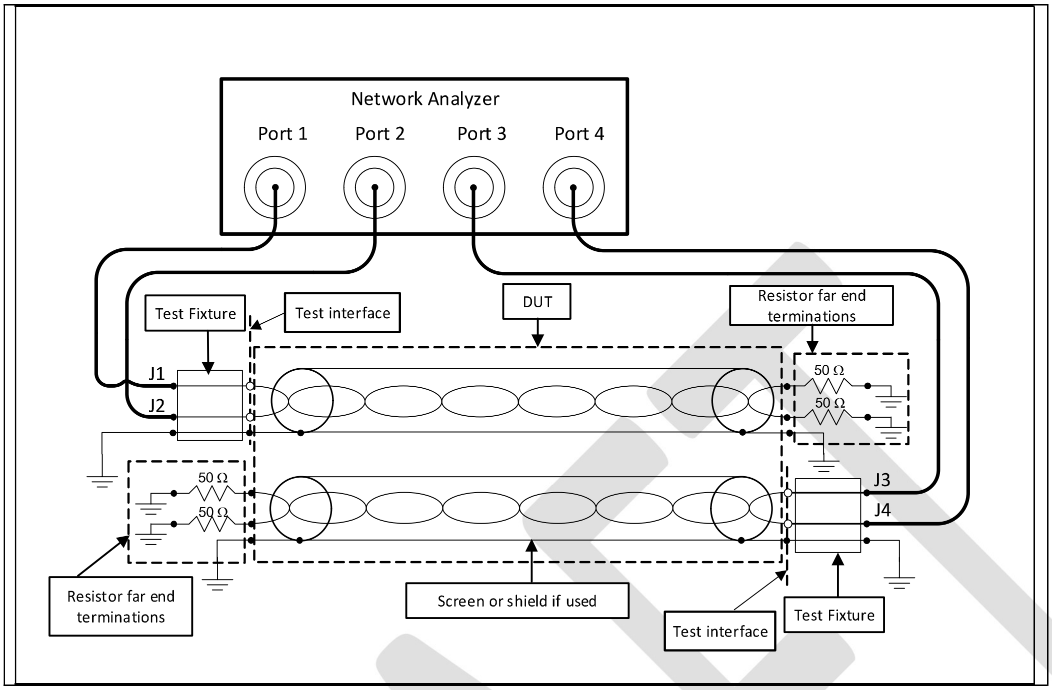


Figure A.6 - Laboratory test configuration for alien FEXT loss between two DUTs.

A.4 Alien crosstalk test configurations

See ANSI/TIA 568.2 for general guidance on arrangement of cables and connectors for alien crosstalk testing. Cables are arranged in a 6 around 1 configuration. Connectors are arranged in an 8 around 1 configuration with two corner connectors in the array removed.

A.5 Application of calibration standards

When open, load, short and thru calibration reference artifacts are applied directly to the test fixture interface with no intermediary adapters as shown in figure A.7 through A.10, respectively, the calibration plane will be located at the ends of the sockets of the DUT adapter. There are six combinations of through measurements needed to complete the calibration of four SE ports. Through calibration standards which are designed to have a 50 **Ω** impedance should be used for each of the six combinations. When each pair of differential ports is fully characterized, it will be calibrated not only for differential measurements, IL_{DD}, RL_{DD}, but also for mixed mode measurements, TCL, TCTL, and common mode measurements, such as RL_{CC} and IL_{CC}.
Examples of application of calibration reference load artifacts for calibration are shown in figures A.7 through A.10.

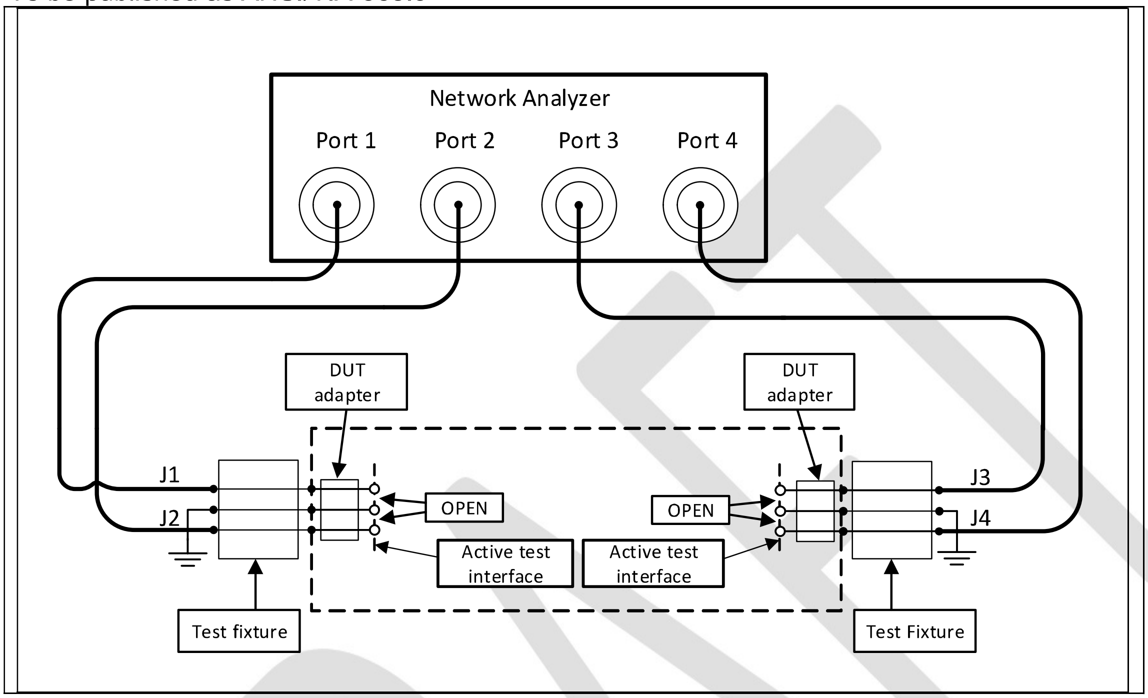


Figure A.7 - Open calibration

The open calibration reference load artifact is identical to the DUT adapter, and replaces the DUT adapter for calibration. Alternatively, the DUT adapter may be used as the open calibration reference artifact.

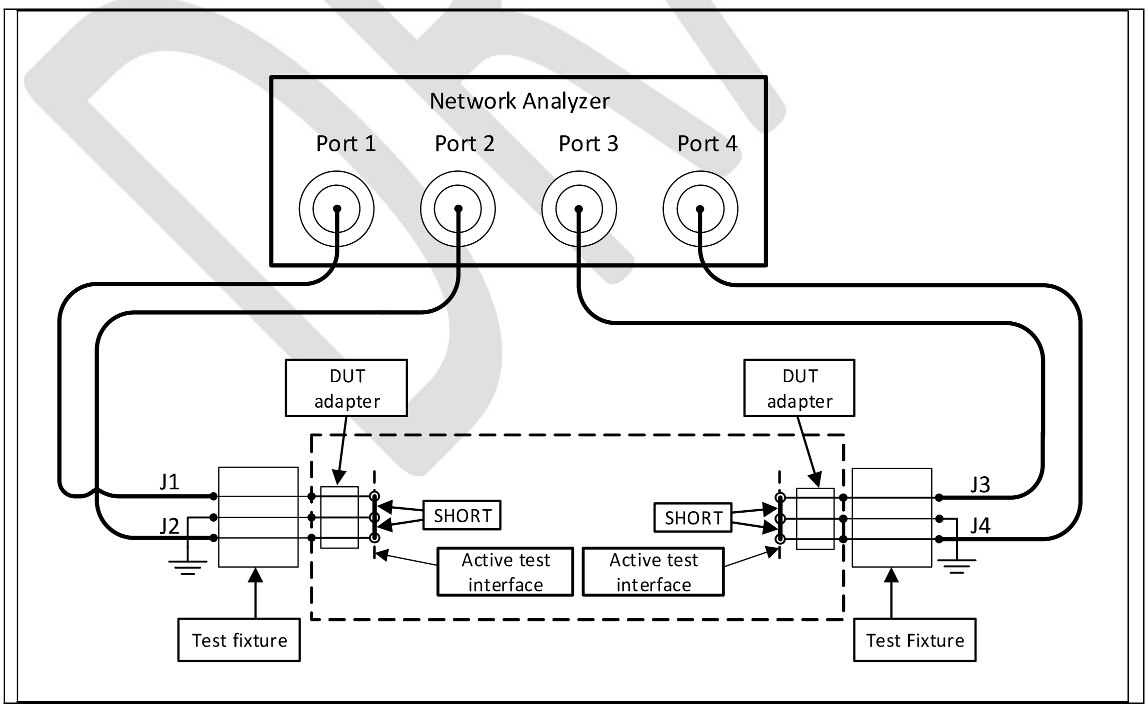


Figure A.8 - Short calibration

The short calibration reference load artifact replaces the DUT adapter during the calibration process.

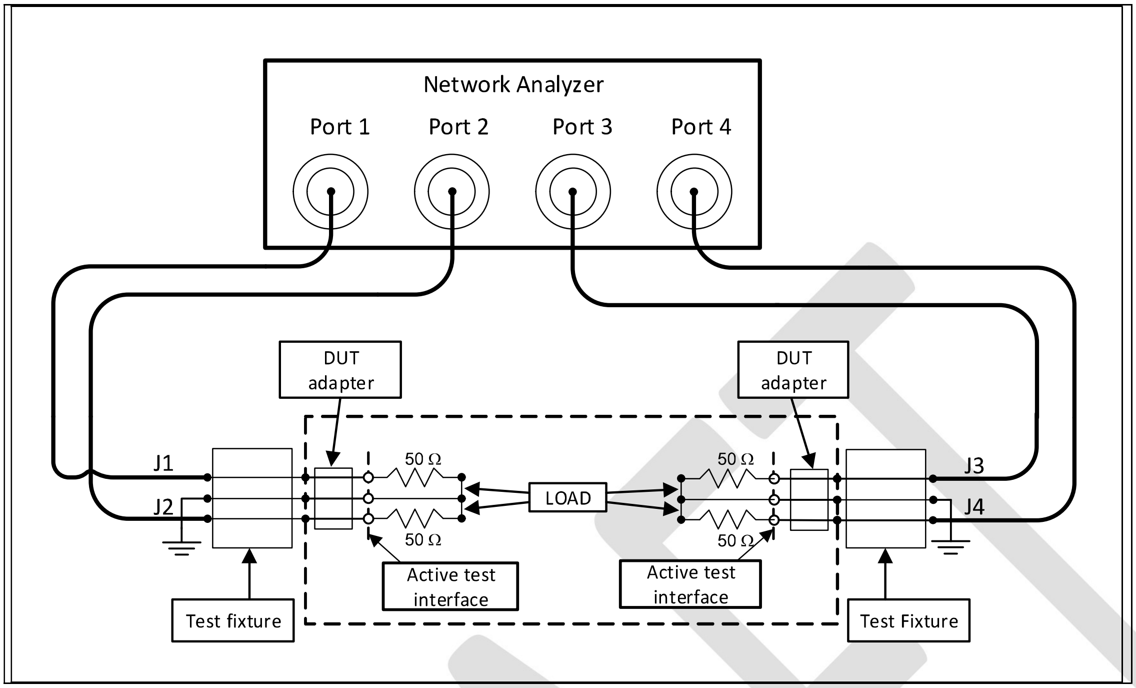


Figure A.9 - Load calibration

The load calibration reference load artifact replaces the DUT adapter during the calibration process.

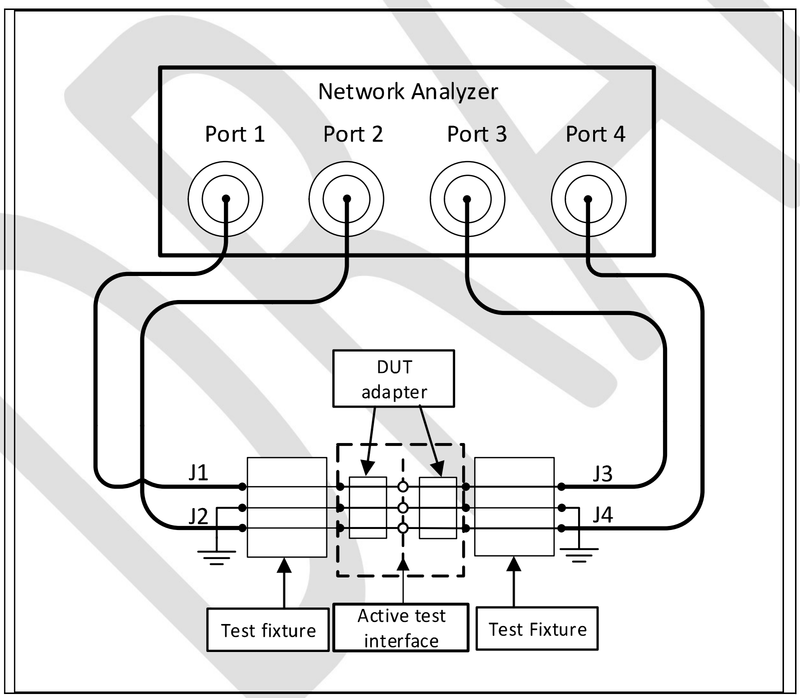


Figure A.10 - Thru calibration configuration

In this example, the open, short, load, and through calibration artifacts are made from the same PCB design as the DUT interface adapter PCB so that they may replace it during calibrations with minimal effect on accuracy.

The through calibration reference artifact is placed onto the DUT adapter during the calibration process.

Annex B (informative) – PoDL application support information

This annex provides informative information about IEEE 802.3 single-pair powering applications.

Maximum channel lengths are limited by the channel DC resistance (DCR) or the application insertion loss (IL), whichever is more restrictive. Channel DC resistance is a function of the cable DCR, connector DCR, number of connectors, and the maximum allowed loop resistance for the PoDL power class.

Class power requirements matrix for PSE, PI, and PD for PoDL classes 10 through 15

Table B.1 - PoDL power classes

Class	10	11	12	13	14	15
$V_{PSE(max)}$ (V)	30	30	30	58	58	58
$I_{PI(max)}$(mA)	92	240	632	231	600	1579
$P_{PD(max)}$ (W)	1.23	3.2	8.4	7.7	20	52
DCR (Ω)	65	25	9.5	65	25	9.5

Note: For further information, see IEEE Std 802.3cg-2019 Table 146B-1.

$$Lmax = (MaxLoopR - (\#connections \times 2 \times Rconn))/(2 \times Rcable/100) \quad (12)$$

Where:
Lmax = Max. channel length(m)
MaxLoopR = Maximum loop resistance (DCR value in Table B.1)
Rconn = Mated Connection DC resistance (see 6.8.1)
Rcable = Cable DC resistance (see Table 37)

Tables B.2 through B.4 show the maximum channel lengths of cabling for PoDL power classes for different wire gauges (AWG) and number of connectors. All tables assume the same wire gauge is used for the entire channel. The values in these tables are for 20°C. When the cabling system is to be operated at higher temperatures, the temperature effects should be considered.

When the cabling system is to be operated at temperatures greater than 20°C, the maximum channel lengths must be reduced by 0.4% for each °C above 20 °C at which the channel is operated.

Example: Class 13 (7.7W) Channel with 5 connectors using 23 AWG cable
Max. Channel length @ 20°C = 423m

Max. Channel length @ 45°C = 423 x ((1-0.004 x (45-20))
= 423 (0.9)
= 380.7m

Table B.2

POWER CLASS 10 & 13 (1.23W / 7.7W)

Max. Channel length(m) versus # of Connectors

AWG	2	3	4	5	6	7	8	9	10
18	1000[2]	1000[2]	1000[2]	1000[2]	1000[2]	1000[2]	1000[2]	1000[2]	1000[2]
20	793[2]	793[2]	793[2]	793[2]	793[2]	793[2]	793[2]	793[2]	793[2]
22	544	541	537	534	531	527	524	520	517
23	431	429	426	423	421	418	415	413	410
24	342	340	338	336	334	332	329	327	325
26	215	214	212	211	210	208	207	206	204

Note 1: Channels that exceed 400m or have more than 5 connections do not comply with the SP1-400 channel topology requirements (shown in gray).
Note 2: Maximum channel length determined by Insertion Loss limit

Table B.3

POWER CLASS 11 & 14 (3.2W / 20W)

Max. Channel length(m) versus # of Connectors

AWG	2	3	4	5	6	7	8	9	10
18	519	511	502	494	485	476	468	459	451
20	326	321	315	310	305	299	294	288	283
22	205	202	198	195	192	188	185	181	178
23	163	160	157	155	152	149	147	144	141
24	129	127	125	123	120	118	116	114	112
26	81	80	78	77	76	74	73	72	70

Note 1: Channels that exceed 400m or have more than 5 connections do not comply with the SP1-400 channel topology requirements (shown in gray).

Table B.4

POWER CLASS 12 & 15 (8.4W / 52W)

Max. Channel length(m) versus # of Connectors

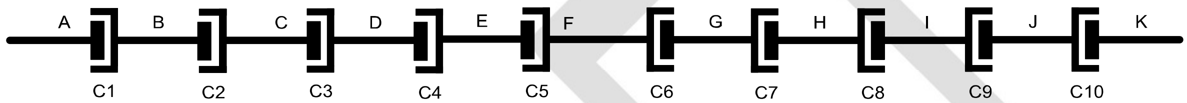
AWG	2	3	4	5	6	7	8	9	10
18	187	178	170	161	152	144	135	127	118
20	117	112	106	101	96	90	85	80	74
22	74	70	67	64	60	57	53	50	47
23	58	56	53	50	48	45	42	40	37
24	46	44	42	40	38	36	34	31	29
26	29	28	26	25	24	22	21	20	18

Note 1: Channels that exceed 400m or have more than 5 connections do not comply with the SP1-400 channel topology requirements (shown in gray).

Annex C (informative) - Modeling configurations

C.1 SP1-1000 channel modeling configurations

Figure C.1 shows two channel modeling configurations that are used for worst-case analysisof the SP1-1000 channel.

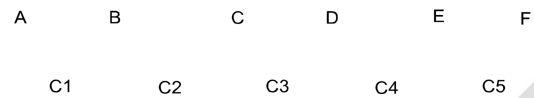


ID	Description	Channel modeling configuration	
		1	2
A	Cable	25 m	5 m
C1	Connector	P	P
B	Cable	125 m	10 m
C2	Connector	P	P
C	Cable	100 m	10 m
C3	Connector	P	P
D	Cable	100 m	10 m
C4	Connector	P	P
E	Cable	100 m	10 m
C5	Connector	P	P
F	Cable	100 m	10 m
C6	Connector	P	P
G	Cable	100 m	10 m
C7	Connector	P	P
H	Cable	100 m	10 m
C8	Connector	P	P
I	Cable	100 m	10 m
C9	Connector	P	P
J	Cable	125 m	10 m
C10	Connector	P	P
K	Cable	25 m	5 m
P = Present in this channel model N/P = Not Present in this Channel model			

Figure C.1 - SP1-1000 channel modeling configuration

C.2 SP1-400 channel modeling configurations

Figure C.2 shows two channel modeling configurations that are used for worst-case analysis of the SP1-400 channel.



ID	Description	Channel modeling configuration	
		1	**2**
A	Cable	25 m	5 m
C1	Connector	P	P
B	Cable	87.5 m	10 m
C2	Connector	P	P
C	Cable	87.5 m	10 m
C3	Connector	P	P
D	Cable	87.5 m	10 m
C4	Connector	P	P
E	Cable	87.5 m	10 m
C5	Connector	P	P
F	Cable	25 m	5 m
P = Present in this channel model N/P = Not Present in this Channel model			

Figure C.2 - SP1-400 channel modeling configuration

Annex D (informative) - Application support considerations.

Table D.1 shows a compatibility matrix of applications with the channels defined in this standard.

Table D.1 - Applications compatibility matrix

Channel	SP1-1000	SP1-400
Max Length, meters	1000	400
Frequency Range, MHz	0.1 – 20	0.1 – 20
Based on Electrical Spec	10Base-T1L	10Base-T1L
10BASE-T1L	Supported	Supported
10BASE-T1S	Supported	Supported

Annex E (informative) - Bibliography

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/ICEA S-84-608, *Telecommunications Cable, Filled Polyolefin Insulated Copper Conductor*

ANSI INCITS 166, *Information Systems - Fibre Data Distributed Interface (FDDI) - Token Ring Physical Layer Medium Dependent (PMD)*

ANSI/TIA-568.0-D, *Generic Telecommunications Cabling for Customer Premises*

ANSI/TIA-5071, *Requirements for Field Test Instruments and Measurements for Balanced Single Twisted-Pair Cabling*

ANSI/TIA-570-C, *Residential Telecommunications Cabling Standard*

IEEE Std 802.3™*, IEEE Standard for Ethernet*

IEC 60603-7 Ed. 3.1, *Connectors for electronic equipment - Part 7: Detail specification for 8-way, unshielded, free and fixed connectors*

IEC 60603-7-1 Ed. 3.0, *Connectors for electronic equipment - Part 7-1: Detail specification for 8-way, shielded, free and fixed connectors*

IEC 60603-7-81, *Connectors for Electronic Equipment - Part 7-81: Detail Specification for 8-way, Shielded, Free and Fixed Connectors, for Data Transmissions with Frequencies up to 2000 MHz*

IEC 60603-7-82, *Connectors for Electronic Equipment - Part 7-82: Detail Specification for 8-way, 12 Contacts, Shielded, Free and Fixed Connectors, for Data Transmission with Frequencies up to 2000 MHz*

IEC 61156-1, *Multicore and symmetrical pair/quad cables for digital communications - Part 1: Generic specification*

IEC 61156-9, *Multicore and Symmetrical Pair/Quad Cables for Digital Communications - Part 9: Cables for Channels with Transmission Characteristics up to 2 GHz - Sectional Specification*

IEC 61156-10, *Multicore and Symmetrical Pair/Quad Cables for Digital Communications - Part 10: Cables for Cords with Transmission Characteristics up to 2 GHz - Sectional Specification*

IEC 61935-2, *Specification for the Testing of Balanced and Coaxial Information Technology Cabling - Part 2: Cords as Specified in ISO/IEC 11801 and Related Standards*

IEC TS 62153-4-1, *Metallic Communication Cable Test Methods - Part 4-1: Electromagnetic Compatibility (EMC) - Introduction to Electromagnetic Screening Measurements*

IEC 62153-4-3, *Metallic Communication Cable Test Methods - Part 4-3: Electromagnetic compatibility (EMC) – Surface transfer impedance – Triaxial method*

IEC 62153-4-11, *Metallic Communication Cable Test Methods - Part 4-11: Electromagnetic Compatibility (EMC) - Coupling Attenuation or Screening Attenuation of Patch Cords, Coaxial Cable Assemblies, Pre-connectorized Cables - Absorbing Clamp Method*

IEC 62153-4-12, *Metallic Communication Cable Test Methods - Part 4-12: Electromagnetic Compatibility (EMC) - Coupling Attenuation or Screening Attenuation of Connecting Hardware - Absorbing Clamp Method*

IEC 62153-4-13, *Metallic Communication Cable Test Methods - Part 4-13: Electromagnetic Compatibility (EMC) - Coupling Attenuation of Links and Channels (Laboratory Conditions) - Absorbing Clamp Method*

IEC 62153-4-14, *Metallic Communication Cable Test Methods - Part 4-14: Electromagnetic Compatibility (EMC) - Coupling Attenuation of Cable Assemblies (Field Conditions) - Absorbing Clamp Method*

IEC 62153-4-15, *Metallic Communication Cable Test Methods - Part 4-15: Electromagnetic Compatibility (EMC) - Test Method for Measuring Transfer Impedance and Screening Attenuation or Coupling Attenuation with Triaxial Cell*

IEC 60189-1, *Low-Frequency Cables and Wires with PVC Insulation and PVC Sheath - Part 1: General Test and Measuring Methods*

IEC 60352-3, *Solderless Connections - Part 3: Solderless Accessible Insulation Displacement Connections - General Requirements, Test Methods and Practical Guidance*

IEC 60352-4, *Solderless Connections - Part 4: Solderless Non-accessible Insulation Displacement Connections - General Requirements, Test Methods and Practical Guidance*

IEC 60352-6, *Solderless Connections - Part 6: Insulation Piercing Connections - General Requirements, Test Methods and Practical Guidance*

IEC 60603-7-2, *Connectors for Electronic Equipment – Part 7-2: Detail Specification for 8-way, Unshielded, Free and Fixed Connectors, for Data Transmissions with Frequencies up to 100 MHz*

IEC 60603-7-3, *Connectors for Electronic Equipment – Part 7-3: Detail Specification for 8-way, Shielded, Free and Fixed Connectors, for Data Transmissions with Frequencies up to 100 MHz*

IEC 61156-1, *Multicore and Symmetrical Pair/Quad Cables for Digital Communications – Part 1: Generic Specification,*

IEC 61156-11, *Multicore and symmetrical pair/quad cables for digital communications - Part 11: Symmetrical single pair cables with transmission characteristics up to 600 MHz - Horizontal floor wiring - Sectional specification*

IEC 61156-12, *Multicore and symmetrical pair/quad cables for digital communications – Part 12: Symmetrical single pair cables with transmission characteristics up to 600 MHz - work area wiring.*

IEC 61156-13, *Multicore and symmetrical pair/quad cables for digital communications – Part 13: Symmetrical single pair cables with transmission characteristics up to 20 MHz – Horizontal floor wiring - Sectional specification*

IEC 61156-14, *Multicore and symmetrical pair/quad cables for digital communications – Part 13: Symmetrical single pair cables with transmission characteristics up to 20 MHz – flexible cables - Sectional specification (TBD)*

IEC 62153-4-3, *Metallic Communication Cables Test Methods – Part 4-3: Electromagnetic Compatibility (EMC) – Surface Transfer Impedance – Triaxial Method*

IEC 63171 (draft) *Connectors for Electrical and Electronic Equipment – Shielded or unshielded free and fixed connectors for balanced single-pair data transmission with current carrying capacity; General requirements and tests*

ISO/IEC 11801-1, *Information technology - Generic cabling for customer premises - Part 1: General requirements*

ISO/IEC TS 29125 Amd1 *Information technology - Telecommunications cabling requirements for remote powering of terminal equipment*

TIA TSB-31-D, *Telecommunications Telephone Terminal Equipment Rationale and Measurement Guidelines for U.S. Network Protection*

TIA TSB-184-A, *Guidelines for Supporting Power Delivery over Balanced Twisted-Pair Cabling*

UL 444, *UL Standard for Safety Communications Cables*

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

ANSI
www.ansi.org
ASTM
www.astm.org
BICSI
www.bicsi.org
CENELEC
www.cenelec.eu
CSA
www.csa.ca
FCC
www.fcc.gov
ICEA
www.icea.net
IEC
www.iec.ch
IEEE
www.ieee.org
Global Engineering Documents
www.global.ihs.com
TIA
www.tiaonline.org
UL
www.ul.com
ISO/IEC
www.jtc1.org
FCC
www.fcc.gov
ICEA
www.icea.net
IEC
www.iec.ch
IEEE
www.ieee.org
Global Engineering Documents
www.global.ihs.com
Telcordia Technologies (formerly Bellcore)
www.telcordia.com
TIA
www.tiaonline.org
UL
www.ul.com