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INTERNATIONAL STANDARD

**Information technology – Generic cabling for customer premises –
Part 1: General requirements**

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FOREWORD

1) ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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International Standard ISO/IEC 11801-1 was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

This first edition, together with ISO/IEC 11801-2, cancels and replaces ISO/IEC 11801:2002, Amendment 1:2008 and Amendment 2:2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) standard re-structured to contain those elements and requirements, that are common to generic cabling systems (in application fields such as offices and industrial premises), namely requirements for common elements of topology and transmission performance of channels, links and related components;
b) addition of balanced cabling channel and link Classes BCT-B, I and II;
c) addition of coaxial cabling channel and link Class BCT-C;
d) addition of balanced cabling component requirements for Categories BCT-B, 8.1 and 8.2;

e) addition of coaxial cabling component requirements for Category BCT-C;

f) addition of cabled optical fibre Categories OS1a and OM5;

g) removal of optical fibre classes;

h) cabled optical fibre Categories OM1, OM2 and OS1 have been moved to an informative annex.

This International Standard has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the ISO/IEC 11801 series, published under the general title *Information technology – Generic cabling for customer premises*, can be found on the IEC website.

The contents of the corrigendum of April 2018 have been included in this copy.

INTRODUCTION

This document contains general requirements in support of the other premises-specific referenced cabling design documents developed by ISO/IEC JTC 1/SC 25 including ISO/IEC 11801-2, ISO/IEC 11801-3, ISO/IEC 11801-4, ISO/IEC 11801-5, ISO/IEC 11801-6, related Technical Specifications and Technical Reports (including the ISO/IEC TR 11801-99xx series, ISO/IEC TR 24704, ISO/IEC TR 24750 and ISO/IEC TS 29125).

This document specifies a multi-vendor cabling system which may be implemented with material from single or multiple sources, and is related to:

a) International Standards for cabling components developed by technical committees of the IEC, for example copper cables and connectors as well as optical fibre cables and connectors (see Clause 2 and bibliography);

b) standards for the testing of installed cabling (see Clause 2 and bibliography);

c) applications developed by technical committees of the IEC, by subcommittees of ISO/IEC JTC 1, by study groups of ITU-T, for example for LANs and ISDN, and by IEEE 802;

d) planning and installation guides and other standards which take into account the needs of specific applications for the configuration and the use of cabling systems on customer premises (e.g. ISO/IEC 14709 series, ISO/IEC 14763 series, ISO/IEC 30129, and ISO/IEC 18598).

Physical layer requirements for the applications listed in Annex E have been analysed to determine their compatibility with cabling classes specified in this document. These application requirements, together with statistics concerning premises-specific topologies and cabling models of the supported standards, have been used to develop the requirements for balanced, coaxial and optical fibre cabling.

As a result, generic cabling defined within this document:

1) specifies balanced cabling channel and link Classes A, B, C, D, E, E_A, F, F_A, I and II meeting both the requirements of standardized applications and to support the development and implementation of future applications;

2) specifies balanced cabling channel and link Class BCT-B to support the delivery of BCT applications;

3) specifies coaxial cabling channel and link Class BCT-C to support the delivery of BCT applications;

4) specifies optical fibre cabling meeting the requirements of standardized applications and exploiting component capabilities to ease the implementation of applications developed in the future;

5) invokes component requirements and specifies cabling implementations that ensure performance of links and of channels that meet or exceed the requirements for cabling classes.

Figure 1 shows the schematic and contextual relationships between the standards relating to information technology cabling produced by ISO/IEC JTC 1/SC 25, namely the ISO/IEC 11801 series of standards for generic cabling design, standards for the installation, operation and administration of generic cabling and for testing of installed generic cabling.

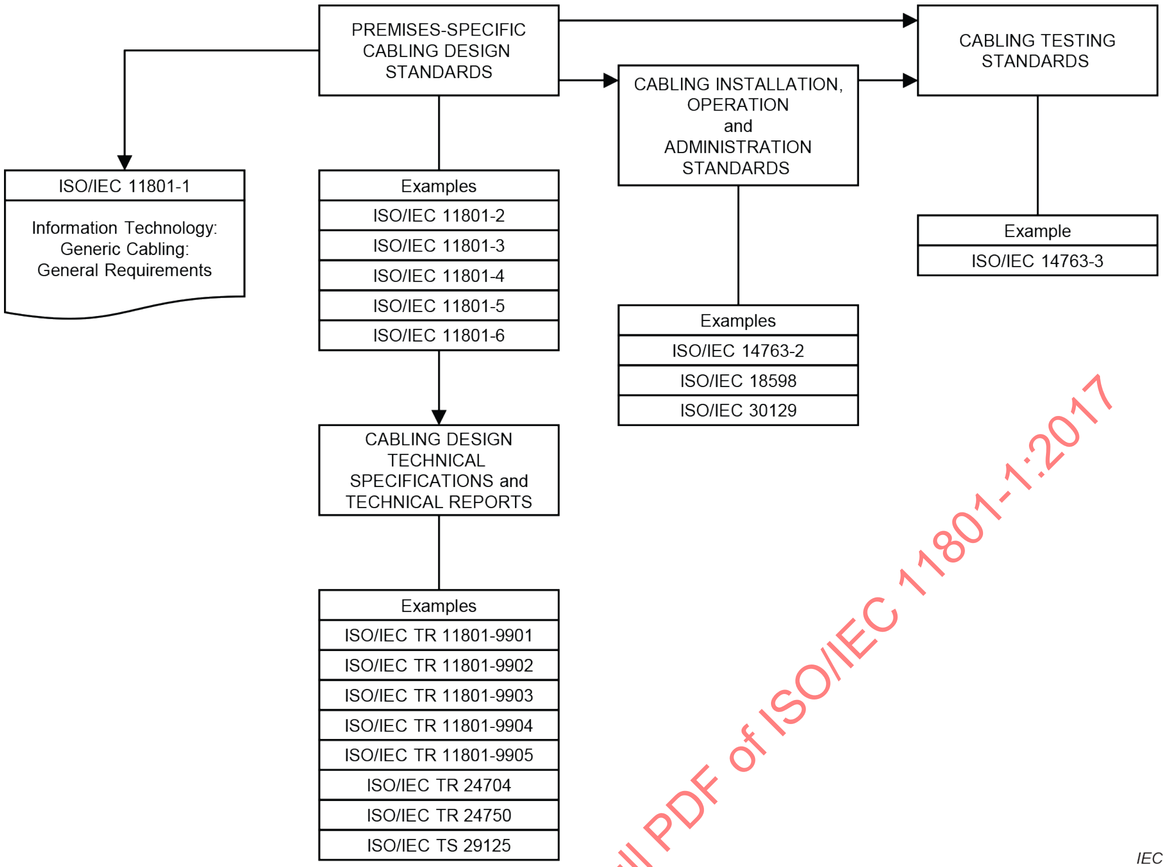


Figure 1 – Relationships between the generic cabling documents produced by ISO/IEC JTC 1/SC 25

This document refers to International Standards for components and test methods wherever appropriate International Standards are available.

INFORMATION TECHNOLOGY – GENERIC CABLING FOR CUSTOMER PREMISES –

Part 1: General requirements

1 Scope

This part of ISO/IEC 11801 specifies requirements that are common to the other parts of the ISO/IEC 11801 series. Cabling specified by this document supports a wide range of services including voice, data, and video that may also incorporate the supply of power.

This document specifies:

a) the fundamental structure and configuration of generic cabling requirements within the types of premises defined by the other parts of the ISO/IEC 11801 series,

b) channel transmission and environmental performance requirements,

c) link performance requirements,

d) backbone cabling reference implementations in support of the parts of the ISO/IEC 11801 series,

e) component performance requirements, referring to available International Standards for components and test methods where appropriate,

f) test procedures to verify conformance to the cabling transmission performance requirements of the ISO/IEC 11801 series.

NOTE This document does not contain specific conformance requirements. The cabling design documents supported by ISO/IEC 11801-1 incorporate the requirements of this document as part of their individual conformance requirements.

In addition, this document provides information regarding the applications supported by the cabling channels.

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.

IEC 60352-2, *Solderless connections – Part 2: Crimped connections – General requirements, test methods and practical guidance*

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 60352-5, *Solderless connections – Part 5: Press-in 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 60352-7, *Solderless connections – Part 7: Spring clamp connections – General requirements, test methods and practical guidance*

IEC 60352-8, *Solderless connections – Part 8: Compression mount connections – General requirements, test methods and practical guidance*

IEC 60512-4-1, *Connectors for electronic equipment – Tests and measurements – Part 4-1: Voltage stress tests – Test 4a: Voltage proof*

IEC 60512-4-2, *Connectors for electronic equipment – Tests and measurements – Part 4-2: Voltage stress tests – Test 4b: Partial discharge*

IEC 60512-6-2, *Connectors for electronic equipment – Tests and measurements – Part 6-2: Dynamic stress tests – Test 6b: Bump*

IEC 60512-6-3, *Connectors for electronic equipment – Tests and measurements – Part 6-3: Dynamic stress tests – Test 6c: Shock*

IEC 60512-6-4, *Connectors for electronic equipment – Tests and measurements – Part 6-4: Dynamic stress tests – Test 6d: Vibration (sinusoidal)*

IEC 60512-11-4, *Connectors for electronic equipment – Tests and measurements – Part 11-4: Climatic tests – Test 11d: Rapid change of temperature*

IEC 60512-11-7, *Connectors for electronic equipment – Tests and measurements – Part 11-7: Climatic tests – Test 11g: Flowing mixed gas corrosion test*

IEC 60512-11-9, *Connectors for electronic equipment – Tests and measurements – Part 11-9: Climatic tests – Test 11i: Dry heat*

IEC 60512-11-10, *Connectors for electronic equipment – Tests and measurements – Part 11-10: Climatic tests – Test 11j: Cold*

IEC 60512-11-12, *Connectors for electronic equipment – Tests and measurements – Part 11-12: Climatic tests – Test 11m: Damp heat, cyclic*

IEC 60512-16-4, *Connectors for electronic equipment – Tests and measurements – Part 16-4: Mechanical tests on contacts and terminations – Test 16d: Tensile strength (crimped connections)*

IEC 60512-17-4, *Connectors for electronic equipment – Tests and measurements – Part 17-4: Cable clamping tests – Test 17d: Cable clamp resistance to cable torsion*

IEC 60512-19-3, *Electromechanical components for electronic equipment – Basic testing procedures and measuring methods – Part 19: Chemical resistance tests – Section 3: Test 19c – Fluid resistance*

IEC 60512-23-3, *Electromechanical components for electronic equipment – Basic testing procedures and measuring methods – Part 23-3: Test 23c: Shielding effectiveness of connectors and accessories*

IEC 60512-99-001, *Connectors for electronic equipment – Tests and measurements – Part 99-001: Test schedule for engaging and separating connectors under electrical load – Test 99a: Connectors used in twisted pair communication cabling with remote power*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

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

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

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 transmission with frequencies up to 100 MHz*

IEC 60603-7-4, *Connectors for electronic equipment – Part 7-4: Detail specification for 8-way, unshielded, free and fixed connectors, for data transmissions with frequencies up to 250 MHz*

IEC 60603-7-5, *Connectors for electronic equipment – Part 7-5: Detail specification for 8-way, shielded, free and fixed connectors, for data transmissions with frequencies up to 250 MHz*

IEC 60603-7-7, *Connectors for electronic equipment – Part 7-7: Detail specification for 8-way, shielded, free and fixed connectors for data transmission with frequencies up to 600 MHz*

IEC 60603-7-41, *Connectors for electronic equipment – Part 7-41: Detail specification for 8-way, unshielded, free and fixed connectors, for data transmissions with frequencies up to 500 MHz*

IEC 60603-7-51, *Connectors for electronic equipment – Part 7-51: Detail specification for 8-way, shielded, free and fixed connectors, for data transmissions with frequencies up to 500 MHz*

IEC 60603-7-71, *Connectors for electronic equipment – Part 7-71: Detail specification for 8-way, shielded, free and fixed connectors, for data transmission with frequencies up to 1 000 MHz*

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 2 000 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 2 000 MHz*

IEC 60793-1-40, *Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation*

IEC 60793-2-10, *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*

IEC 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

IEC 60794-1-21, *Optical fibre cables – Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical test methods*

IEC 60794-1-22, *Optical fibre cables – Part 1-22: Generic specification – Basic optical cable test procedures – Environmental test methods*

IEC 60794-2, *Optical fibre cables – Part 2: Indoor cables – Sectional specification*

IEC 60794-2-51, *Optical fibre cables – Part 2-51: Indoor cables – Detail specification for simplex and duplex cables for use in cords for controlled environment*

IEC 60794-3, *Optical fibre cables – Part 3: Outdoor cables – Sectional specification*

IEC 60794-5, *Optical fibre cables – Part 5: Sectional specification – Microduct cabling for installation by blowing*

IEC 60966-2-4, *Radio frequency and coaxial cable assemblies – Part 2-4: Detail specification for cable assemblies for radio and TV receivers – Frequency range 0 MHz to 3 000 MHz, IEC 61169-2 connectors*

IEC 60966-2-5, *Radio frequency and coaxial cable assemblies – Part 2-5: Detail specification for cable assemblies for radio and TV receivers – Frequency range 0 MHz to 1 000 MHz, IEC 61169-2 connectors*

IEC 60966-2-6, *Radio frequency and coaxial cable assemblies – Part 2-6: Detail specification for cable assemblies for radio and TV receivers – Frequency range 0 MHz to 3 000 MHz, IEC 61169-24 connectors*

IEC 61076-2-101, *Connectors for electronic equipment – Product requirements – Part 2-101: Circular connectors – Detail specification for M12 connectors with screw-locking*

IEC 61076-2-109, *Connectors for electronic equipment – Product requirements – Part 2-109: Circular connectors – Detail specification for connectors with M 12 × 1 screw-locking, for data transmission frequencies up to 500 MHz*

IEC 61076-3-104, *Connectors for electrical and electronic equipment – Product requirements – Part 3-104: Detail specification for 8-way, shielded free and fixed connectors for data transmissions with frequencies up to 2 000 MHz*

IEC 61076-3-106, *Connectors for electronic equipment – Product requirements – Part 3-106: Rectangular connectors – Detail specification for protective housings for use with 8-way shielded and unshielded connectors for industrial environments incorporating the IEC 60603-7 series interface*

IEC 61076-3-110, *Connectors for electronic equipment – Product requirements – Part 3-110: Detail specification for shielded, free and fixed connectors for data transmission with frequencies up to 3 000 MHz*

IEC 61156 (all parts), *Multicore and symmetrical pair/quad cables for digital communications*

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

IEC 61156-2, *Multicore and symmetrical pair/quad cables for digital communications – Part 2: Symmetrical pair/quad cables with transmission characteristics up to 100 MHz – Horizontal floor wiring – Sectional specification*

IEC 61156-3, *Multicore and symmetrical pair/quad cables for digital communications – Part 3: Work area cable – Sectional specification*

IEC 61156-4, *Multicore and symmetrical pair/quad cables for digital communications – Part 4: Riser cables – Sectional specification*

IEC 61156-5:2009, *Multicore and symmetrical pair/quad cables for digital communications – Part 5: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz – Horizontal floor wiring – Sectional specification*
IEC 61156-5:2009/AMD1:2012

IEC 61156-5-1, *Multicore and symmetrical pair/quad cables for digital communications – Part 5-1: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz – Horizontal floor wiring – Blank detail specification*

IEC 61156-6, *Multicore and symmetrical pair/quad cables for digital communications – Part 6: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz – Work area wiring – Sectional specification*

IEC 61156-6-1, *Multicore and symmetrical pair/quad cables for digital communications – Part 6-1: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz – Work area wiring – Blank detail specification*

IEC 61156-7, *Multicore and symmetrical pair/quad cables for digital communications – Part 7: Symmetrical pair cables with transmission characteristics up to 1 200 MHz – Sectional specification for digital and analog communication cables*

IEC 61156-9:2016, *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 61169-2, *Radio-frequency connectors – Part 2: Sectional specification – Radio frequency coaxial connectors of type 9,52*

IEC 61169-24, *Radio-frequency connectors – Part 24: Sectional specification – Radio frequency coaxial connectors with screw coupling, typically for use in 75 Ω cable networks (type F)*

IEC 61196-1, *Coaxial communication cables – Part 1: Generic specification – General, definitions and requirements*

IEC 61196-6, *Coaxial communication cables – Part 6: Sectional specification for CATV drop cables*

IEC 61196-7, *Coaxial communication cables – Part 7: Sectional specification for cables for BCT cabling in accordance with ISO/IEC 15018 – Indoor drop cables for systems operating at 5 MHz – 3 000 MHz*

IEC 61300-2-1, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-1: Tests – Vibration (sinusoidal)*

IEC 61300-2-4, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-4: Tests – Fibre/cable retention*

IEC 61300-2-5, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-5: Tests – Torsion*

IEC 61300-2-9, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-9: Tests – Shock*

IEC 61300-2-18, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-18: Tests – Dry heat – High temperature endurance*

IEC 61300-2-22, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-22: Tests – Change of temperature*

IEC 61300-2-34, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-34: Tests – Resistance to solvents and contaminating fluids of interconnecting components and closures*

IEC 61300-2-44, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-44: Tests – Flexing of the strain relief of fibre optic devices*

IEC 61300-2-46, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-46: Tests – Damp heat, cyclic*

IEC 61753-1, *Fibre optic interconnecting devices and passive components – Performance standard – Part 1: General and guidance for performance standards*

IEC 61753-021-2, *Fibre optic interconnecting devices and passive components – Performance standard – Part 021-2: Grade C/3 single-mode fibre optic connectors for category C – Controlled environment*

IEC 61753-022-2, *Fibre optic interconnecting devices and passive components – Performance standard – Part 022-2: Fibre optic connectors terminated on multimode fibre for category C – Controlled environment*

IEC 61754 (all parts), *Fibre optic interconnecting devices and passive components – Fibre optic connector interfaces*

IEC 61754-20-100, *Fibre optic interconnecting devices and passive components – Part 20-100: Interface standard for LC connectors with protective housings related to IEC 61076-3-106*

IEC 61935-1, *Specification for the testing of balanced and coaxial information technology cabling – Part 1: Installed balanced cabling as specified in ISO/IEC 11801 and related standards*

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 62012-1, *Multicore and symmetrical pair/quad cables for digital communications to be used in harsh environments – Part 1: Generic specification*

IEC 62664-1-1, *Fibre optic interconnecting devices and passive components – Fibre optic connector product specifications – Part 1-1: LC-PC duplex multimode connectors terminated on IEC 60793-2-10 category A1a fibre*

ISO 4892-1*, Plastics – Methods of exposure to laboratory light sources – Part 1: General guidance*

ISO 4892-2*, Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

ISO/IEC 14763-2, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*

ISO/IEC 14763-3, *Information technology – Implementation and operation of customer premises cabling – Part 3: Testing of optical fibre cabling*

3 Terms, definitions, abbreviations and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
administration
methodology defining the documentation requirements of a cabling system and its containment, the labelling of functional elements and the process by which moves, additions and changes are recorded

3.1.2
alien crosstalk
signal coupling from a disturbing pair of a channel to a disturbed pair of another channel

Note 1 to entry: This also applies to the signal coupling from a disturbing pair within a link or component, used to create a channel, to a disturbed pair within a link or component, used to create another channel.

Note 2 to entry: This is also known as exogenous crosstalk.

3.1.3
alien far-end crosstalk loss
signal coupling between a disturbing pair of a channel and a disturbed pair of another channel, measured at the far-end

Note 1 to entry: This also applies to the measurement of the signal coupling between a disturbing pair within a link or component, used to create a channel, and a disturbed pair within a link or component, used to create another channel.

Note 2 to entry: This is also known as exogenous far-end crosstalk loss.

3.1.4
alien near-end crosstalk loss
signal coupling between a disturbing pair of a channel and a disturbed pair of another channel, measured at the near-end

Note 1 to entry: This also applies to the measurement of signal coupling between a disturbing pair within a link or component, used to create a channel, and a disturbed pair within a link or component, used to create another channel.

Note 2 to entry: This is also known as exogenous near-end crosstalk loss.

3.1.5
application
system, including its associated transmission and power feeding method, which is supported by telecommunications cabling

3.1.6
attenuation
decrease in magnitude of power of a signal in transmission between points

Note 1 to entry: Attenuation indicates the total losses on cable, expressed as the ratio of power output to power input.

3.1.7
attenuation to alien crosstalk ratio at the far-end
difference, in decibels, between the alien far-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbed pair in another channel

Note 1 to entry: This also applies to the calculation using the alien far-end crosstalk loss from a disturbing pair within a link or component, used to create a channel, and the insertion loss of a disturbed pair within a link or component, used to create another channel.

Note 2 to entry: This is also known as attenuation to exogenous crosstalk ratio at the far-end.

3.1.8
attenuation to crosstalk ratio at the far-end
difference, in decibels, between the far-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbed pair of the same channel

Note 1 to entry: This also applies to the calculation using the far-end crosstalk loss from a disturbing pair within a link or component, used to create a channel, and the insertion loss of a disturbed pair within the link or component, of the same channel.

3.1.9
attenuation to crosstalk ratio at the near-end
difference, in decibels, between the near-end crosstalk loss from a disturbing pair of a channel and the insertion loss of a disturbed pair of the same channel

Note 1 to entry: This also applies to the calculation using the near-end crosstalk loss from a disturbing pair within a link or component, used to create a channel, and the insertion loss of a disturbed pair within the link or component, of the same channel.

3.1.10
average power sum alien near-end crosstalk loss
calculated average of the power sum alien near-end crosstalk loss of the pairs of a disturbed channel

Note 1 to entry: This also applies to the calculation using the pairs within a link used to create a channel.

Note 2 to entry: This is also known as average power sum exogenous near-end crosstalk loss.

3.1.11
average power sum attenuation to alien crosstalk ratio far-end
calculated average of the power sum attenuation to alien crosstalk ratio at the far-end of the pairs of a disturbed channel

Note 1 to entry: This also applies to the calculation using the pairs within a link used to create a channel.

Note 2 to entry: This is also known as average power sum attenuation to exogenous crosstalk ratio far-end.

3.1.12
balanced cable
cable consisting of one or more metallic symmetrical cable elements (twisted pairs or quads)

3.1.13
broadcast and communications technologies
group of applications including radio and TV

3.1.14
building backbone cable
fixed cable connecting distributors within the building backbone cabling subsystem

3.1.15
building distributor
distributor in which the building backbone cable(s) terminate(s) and at which connections to the campus backbone cable(s) may be made

3.1.16
building entrance facility
facility that provides all necessary mechanical and electrical services and which complies with all relevant regulations, for the entry of telecommunications cables into a building

3.1.17
cable
assembly of one or more cable units in an overall sheath

3.1.18
cable element
smallest construction unit in a cable

EXAMPLE Balanced pair, quad, single fibre, or coaxial pair.

3.1.19
cable sharing
using a single cable to support the simultaneous transmission of more than one application

3.1.20
cable unit
single assembly of one or more cable elements of the same type

Note 1 to entry: The cable unit may have a screen.

3.1.21
cabling
system of telecommunications cables, cords and connecting hardware that supports the connection of information technology equipment

3.1.22
cabling design document
relevant International Standard or Technical Report for cabling design developed by ISO/IEC JTC 1/SC 25

3.1.23
campus
premises containing one or more buildings

3.1.24
campus backbone cable
fixed cable connecting distributors within the campus backbone cabling subsystem

3.1.25
campus distributor
distributor from which the campus backbone cabling starts

3.1.26
channel
transmission path connecting any two pieces of application-specific equipment

3.1.27
centralized optical fibre cabling
cabling technique that creates a combined backbone/horizontal channel from the equipment areas to the centralized cross-connect or interconnect by allowing the use of pull-through cables or splices

3.1.28
coaxial pair
uniform transmission line consisting of two cylindrical conductors with the same axis

[SOURCE: IEC 60050-704:1993, 704-02-05]

3.1.29
connecting hardware
device or combination of devices used to connect cables or cable elements

3.1.30
connection
mated device or combination of devices including terminations used to connect cables or cable elements to other cables, cable elements or application-specific equipment

3.1.31
connector
component normally attached to a cable or mounted on a piece of apparatus (excluding an adapter) for joining separable parts of a cabling system

3.1.32

3.1.33
consolidation point
connection point in the horizontal cabling subsystem between a floor distributor and a terminal equipment outlet

3.1.34
consolidation point cord
cabling between the consolidation point and the terminal equipment outlet(s)

3.1.35
consolidation point link
part of the permanent link between the floor distributor and the consolidation point, including the connecting hardware at each end

3.1.36
cord
cable, cable unit or cable element with a minimum of one termination

3.1.37
coupling attenuation
ratio, in decibels, of the differential power in the signal pairs to the power generated by the excited common mode currents

3.1.38
cross-connect
passive connection between cabling subsystems using a patch cord or jumper

3.1.39
cross-connection
connection by means of a cross-connect

3.1.40
data centre
structure, or group of structures, dedicated to the centralized accommodation, interconnection and operation of information technology and network telecommunications equipment providing data storage, processing and transport services, together with all the facilities and infrastructures for power distribution and environmental control, together with the necessary levels of resilience and security required to provide the desired service availability

Note 1 to entry: A structure can consist of multiple buildings and/or spaces with specific functions to support the primary function.

Note 2 to entry: The boundaries of the structure or space considered to be the data centre which includes the information and communication technology equipment and supporting environmental controls can be defined within a larger structure or building.

[SOURCE: ISO/IEC 30134-1:2016, 3.1.4]

3.1.41
distributor
functional element enabling the termination and connection of cabling subsystems to other cabling subsystems or transmission equipment

3.1.42
equipment cord
cord connecting one end of the cabling subsystem in a distributor to transmission equipment

3.1.43
equipment interface
point at which application-specific equipment can be connected to the generic cabling or network access cabling

3.1.44
external network interface
termination point providing demarcation of external telecommunications service provision

3.1.45
fixed connector
balanced cabling jack, coaxial adapter (integrated with or housing a coaxial free connector), or optical fibre adapter (integrated with or housing an optical fibre free connector)

3.1.46
free connector
balanced, coaxial, or optical fibre cabling plug

3.1.47
functional performance
level of transmission performance that is able to support the intended Class of applications

3.1.48
generic cabling
structured telecommunications cabling system, capable of supporting a wide range of standardized applications

3.1.49
hybrid cable
assembly of two or more cable units of different types in an overall sheath

3.1.50
information and communications technologies
group of applications using information and communications (telecommunications) technologies

3.1.51
information technologies
telecommunications
technology concerned with the transmission, emission and reception of signs, signals, writing, images and sounds by cable, radio, optical or other electromagnetic systems

3.1.52
insertion loss
loss incurred by inserting a device between a source and load of equal impedance

Note 1 to entry: The device itself may have a different impedance from the load and source impedance.

Note 2 to entry: The terms operational attenuation or operational insertion loss are sometimes associated with this definition.

3.1.53
insertion loss deviation
difference between the measured insertion loss of cascaded components and the insertion loss determined by the sum of the individual component insertion losses

3.1.54
interconnect
passive connection to a cabling subsystem not using a patch cord or jumper

3.1.55
interface
point at which connections are made to the generic cabling

3.1.56
jack
balanced cabling socket connector

3.1.57
jumper
cable, cable unit or cable element without connectors used for a cross-connection

3.1.58
keying
mechanical feature of a connector system, which guarantees polarization or prevents the connection to an incompatible socket or optical fibre adapter

3.1.59
link
transmission path between two cabling system interfaces, including the connections at each end

3.1.60
longitudinal conversion loss
logarithmic ratio, expressed in decibels, of the common mode injected signal at the near-end to the resultant differential signal at the near-end of a balanced pair

3.1.61
longitudinal conversion transfer loss
logarithmic ratio, expressed in decibels, of the common mode injected signal at the near-end to the resultant differential signal at the far-end of a balanced pair

3.1.62
multi-unit cable
balanced cable containing more than four pairs

3.1.63
network access cable
cable connecting an external network interface to a generic cabling distributor

3.1.64
operating temperature
stabilized temperature of the local environment, measured on the outside sheath of the cable, combining ambient temperature with any increase due to the application being supported

3.1.65
optical fibre cable
cable comprising one or more optical fibre cable elements

3.1.66
pair
two conductors of a balanced transmission line

EXAMPLE Twisted pair cable element or one side circuit in a quad cable element.

3.1.67
patch cord
cord used for a cross-connection

3.1.68
patch panel
panel at a distributor presenting the interface(s) of cabling subsystems to facilitate administrative moves and changes using patch cords or jumpers

Note 1 to entry: The panel also enables interfaces to be connected to transmission equipment using interconnect cords.

3.1.69
permanent link
transmission path between distributors or between distributor 1 and the terminal equipment outlet including the connections at both ends

Note 1 to entry: The permanent link does not include TE area cords, equipment cords, patch cords and jumpers, but includes the connection at each end. It can include an optional consolidation point.

3.1.70
power sum alien far-end crosstalk loss
power sum of the signal coupling between multiple disturbing pairs of one or more channels, links or components and a disturbed pair of another channel, link or component, measured at the far-end

Note 1 to entry: This is also known as power sum exogenous far-end crosstalk loss.

3.1.71
power sum alien near-end crosstalk loss
power sum of the signal coupling between multiple disturbing pairs of one or more channels, links or components and a disturbed pair of another channel, link or component, measured at the near-end

Note 1 to entry: This is also known as power sum exogenous near-end crosstalk loss.

3.1.72
power sum attenuation to alien crosstalk ratio at the far-end
difference, in decibels, between the power sum alien far-end crosstalk loss from multiple disturbing pairs of one or more channels, links or components and the insertion loss of a disturbed pair in another channel, link or component

Note 1 to entry: This is also known as power sum attenuation to exogenous crosstalk ratio at the far-end.

3.1.73
power sum attenuation to crosstalk ratio at the far-end
difference, in decibels, between the power sum far-end crosstalk loss from multiple disturbing pairs of a channel, link or component and the insertion loss of a disturbed pair in the same channel, link or component

3.1.74
power sum attenuation to crosstalk ratio at the near-end
difference, in decibels, between the power sum near-end crosstalk loss from multiple disturbing pairs of a channel, link or component and the insertion loss of a disturbed pair in the same channel, link or component

3.1.75
quad
cable element that comprises four insulated conductors twisted together

Note 1 to entry: Two diametrically facing conductors form a transmission pair also referred to as a side circuit.

3.1.76
requirement to be met by design
requirement which may be met by calculation and selection of appropriate materials and installation techniques, where either there is no test method specified that allows verification or there is no requirement for verification by testing

3.1.77
screened balanced cable
balanced cable with an overall screen and/or screens for the individual elements

3.1.78
side circuit
two diametrically facing conductors in a quad that form a pair

3.1.79
splice
joining of conductors or optical fibres, generally from separate sheaths

3.1.80
telecommunications outlet
terminal equipment outlet
fixed connecting device which provides an interface to the terminal equipment

Note 1 to entry: The term telecommunications outlet is used in some of the other parts of the ISO/IEC 11801 series, while the term terminal equipment outlet is used in this document.

3.1.81
terminal equipment
equipment at an outlet used to access information provided by transmission equipment

3.1.82
test interface
location where a connection between test equipment and the cabling to be tested occurs

3.1.83
tie cables
optional fixed cables connecting distributors of the same hierarchical level which are installed in addition to the basic hierarchical topology

3.1.84
transmission equipment
active equipment used to distribute information from distributors to other distributors and to outlets

3.1.85
transverse conversion loss
ratio between the common mode signal power and the injected differential mode signal power

3.1.86
twisted pair
cable element that consists of two insulated conductors twisted together in a determined fashion to form a balanced transmission line

3.1.87
unscreened balanced cable
balanced cable without any screens

3.2 Abbreviations

AACR-F	attenuation to alien crosstalk ratio at the far-end
AC	alternating current
ACR	attenuation to crosstalk ratio
ACR-F	attenuation to crosstalk ratio at the far-end

ACR-N	attenuation to crosstalk ratio at the near-end
AFEXT	alien far-end crosstalk (loss)
ANEXT	alien near-end crosstalk (loss)
APC	angled physical contact
ATM	asynchronous transfer mode
BCT	broadcast and communications technologies, sometimes referred to as HEM (home entertainment & multimedia)
BD	building distributor
BEF	building entrance facility
B-ISDN	broadband ISDN
BO	broadcast outlet
C	connection
CATV	community antenna television
CD	campus distributor
CP	consolidation point
CSMA/CD	carrier sense multiple access with collision detection
DAB	digital audio broadcasting
DC	direct current
DCE	data circuit terminating equipment
DRL	distributed return loss
DTE	data terminal equipment
DVB	digital video broadcasting
DVB–C	digital video broadcasting – cable
DVB–S	digital video broadcasting – satellite
DVB–T	digital video broadcasting – terrestrial
EI	equipment interface
ELTCTL	equal level TCTL
EMC	electromagnetic compatibility
EO	equipment outlet
EQP	transmission equipment
FEXT	far-end crosstalk (loss)
ffs	for further study
FOIRL	fibre optic inter-repeater link
IC	integrated circuit
ICT	information and communications technology
IDC	insulation displacement connection
IEC	International Electrotechnical Commission
IL	insertion loss
ILD	insertion loss deviation
IPC	insulation piercing connection
ISDN	integrated services digital network
ISO	International Organization for Standardization
IT	information technology

JTC	joint technical committee
LAN	local area network
LCL	longitudinal to differential conversion loss
LCTL	longitudinal to differential conversion transfer loss
LDP	local distribution point
Min.	minimum
N/A	not applicable
NEXT	near-end crosstalk (loss)
OF	optical fibre
PC	physical contact
PL	permanent link
PMD	physical media dependent sublayer
PS AACR-F	power sum attenuation to alien crosstalk ratio at the far-end
PS $AACR\text{-}F_{avg}$	average power sum attenuation to alien crosstalk ratio at the far-end
PS ACR	power sum attenuation to crosstalk ratio
PS ACR-F	power sum attenuation to crosstalk ratio at the far-end
PS ACR-N	power sum attenuation to crosstalk ratio at the near-end
PS AFEXT	power sum alien far-end crosstalk (loss)
PS $AFEXT_{norm}$	normalized power sum alien far-end crosstalk (loss)
PS ANEXT	power sum alien near-end crosstalk (loss)
PS $ANEXT_{avg}$	average power sum alien near-end crosstalk (loss)
PS FEXT	power sum FEXT (loss)
PS NEXT	power sum NEXT (loss)
PVC	polyvinyl chloride
RL	return loss
SC	subscriber connector (optical fibre connector)
SCP	service concentration point
SO	service outlet
TCL	transverse conversion loss
TCTL	transverse conversion transfer loss
TE	terminal equipment
TI	test interface
TO	telecommunications outlet
TP-PMD	twisted pair physical medium dependent
TV	television

NOTE The abbreviation “lg” in the formulas signifies “$\log_{10}$”.

3.3 Symbols

3.3.1 Variables

A	coefficient of transmission matrix
B	length of backbone cable or coefficient of transmission matrix
C	length of the CP cable, designation for connector, or coefficient of transmission matrix
D	coefficient of transmission matrix

F	combined length of patch cords/jumpers, equipment and work area cords
H	maximum length of the fixed horizontal cable
K	coefficient of cable attenuation increase
L	length of cable
l	number of the disturbing channel
N	number of disturbing channels
X	ratio of work area cable attenuation to fixed horizontal cable attenuation
Y	ratio of the CP cable attenuation to the fixed horizontal cable attenuation
Z	complex impedance
NVP	velocity relative to speed of light ($NVP = v/c$)
c	speed of light in vacuum
e	base of natural logarithm
f	frequency
i	current number of disturbing pair
j	imaginary operator
k	current number of disturbed pair
lg	log10
n	total number of pairs ($i \leq k \leq n$)
t	time
v	speed of propagation

3.3.2 Indices

C2	index to denominate a characteristic, measured from the connector at the floor distributor (second connector)
CH	index to denote the channel
CP	index to denote the consolidation point
PL	index to denominate a permanent link characteristic
avg	index to denominate average of the associated parameter across all of the pairs in the same channel or link
cable	index to denominate a cable characteristic
channel	index to denominate a channel characteristic
connector	index to denominate a connector characteristic
cord cable	index to indicate a characteristic of the cable used for cords
in	index to indicate an input condition
local	index to denominate a locally measured characteristic
norm	index to denominate scaling of the associated parameter
remote	index to denominate a characteristic measured at a distance
term	index to indicate a terminating condition

4 Conformance

This document does not contain specific cabling installation conformance requirements. The cabling design documents supported by this document incorporate the requirements of this document as part of their individual conformance requirements.

Annex A contains requirements and recommendations for testing of channels, and links in order to determine their conformance to the transmission performance requirements of the relevant cabling design documents.

5 Structure of generic cabling

5.1 Functional elements

The generic cabling specified by the cabling design standards features some or all of functional elements shown in Figure 2.

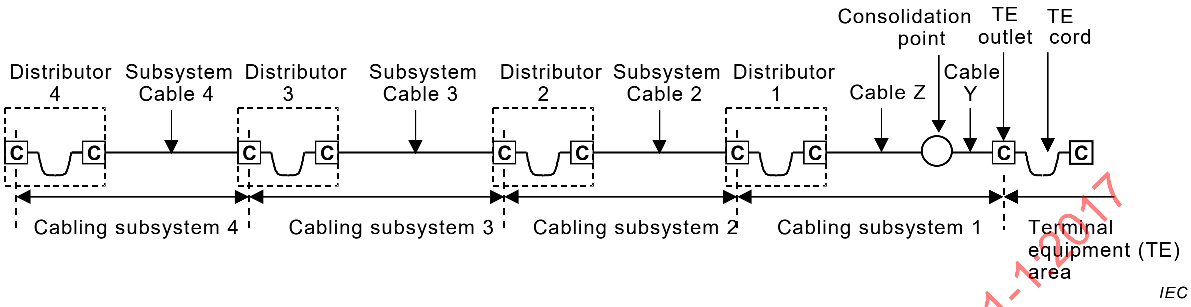


Figure 2 – General functional elements

These comprise

a) terminal equipment (TE) outlet,

b) consolidation point (CP),

c) subsystem cable 1 (divided into cable Y and cable Z if consolidation point is present),

d) distributor 1,

e) other subsystem cables (2, 3 and 4 in Figure 2),

f) other distributors (2, 3 and 4 in Figure 2).

Groups of these functional elements are connected together to form cabling subsystems.

NOTE The numbering of the cabling subsystems does not imply a hierarchy.

The presence of, and the terms applied to, each of the functional elements are specified in the cabling design standards.

Connections between cabling subsystems are either active, requiring application-specific equipment, or passive. Connection to application-specific equipment adopts either an interconnect or a cross-connect approach (see Figure 3 and Figure 4). Passive connections between cabling subsystems are generally achieved using cross-connections by way of either patch cords, jumpers or splices.

In the case of centralized cabling, passive connections in the distributors are achieved by using cross-connections or interconnections. In addition, for centralized optical fibre cabling, it is possible to create connections at the distributors using splices although this reduces the ability of the cabling to support re-configuration.

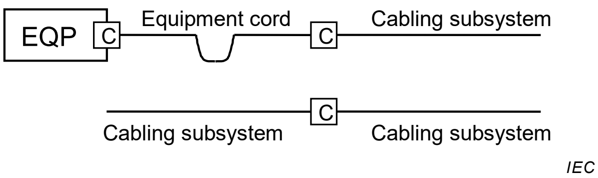


Figure 3 – Interconnect models

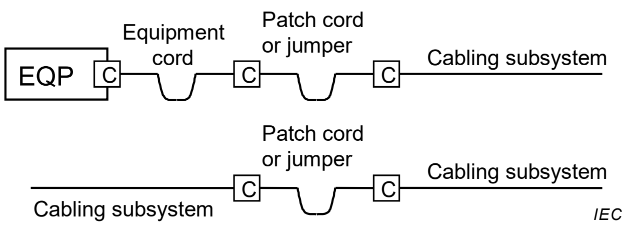


Figure 4 – Cross-connect models

5.2 Interfaces

Equipment interfaces to generic cabling are located at the ends of each subsystem. Any distributor may have an equipment interface to an external service at any port and may use either interconnects as shown in Figure 3 or cross-connects as shown in Figure 4. The consolidation point does not provide an equipment interface to the generic cabling system.

Figure 5 shows the potential equipment interfaces to the cabling subsystems.

Test interfaces to generic cabling are located at the ends of each subsystem and at consolidation points, where present. Figure 5 shows the potential test interfaces to the cabling subsystems.

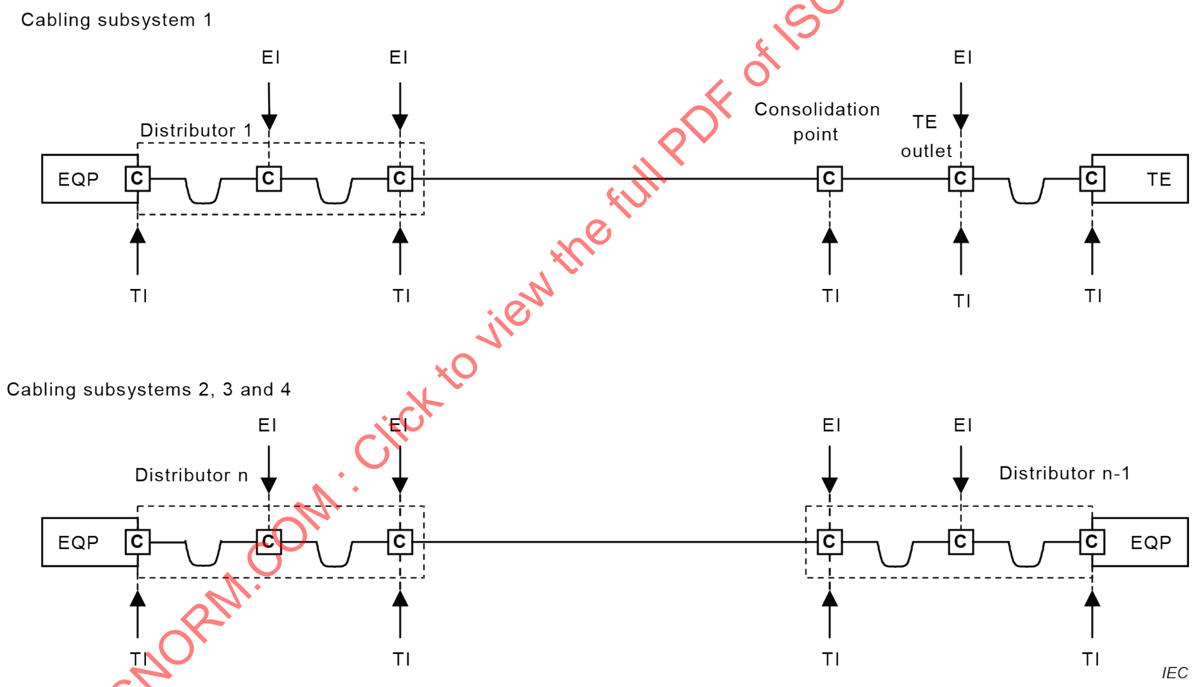


Figure 5 – Equipment and test interfaces

5.3 Cabling subsystems

5.3.1 Cabling subsystem 1

The cabling subsystem 1 extends from distributor 1 to the terminal equipment (TE) outlet(s) connected to it. The subsystem includes

a) the subsystem cable 1 (or cables Y and Z of Figure 2, if a consolidation point is supported by the cable design standard and is present),

b) jumpers and patch cords in distributor 1,

c) the mechanical termination of the subsystem cable 1 (or cable Y of Figure 2, if a consolidation point is supported by the cable design standard and is present) at the TE outlet,

d) the mechanical termination of the subsystem cable 1 at distributor 1 including the connecting hardware, for example of the interconnect or cross-connect (see Figure 3 and Figure 4),

e) a consolidation point (optional, if supported by the cable design standard),

f) the TE outlets.

Although terminal equipment cords and equipment cords are used to connect terminal and transmission equipment respectively to the cabling subsystem, they are not considered part of the cabling subsystem because they are application specific.

5.3.2 Cabling subsystems $n \geq 2$

The cabling subsystems n (for $n \geq 2$) extend from distributor n to distributor $n - 1$. When present, the subsystem includes

a) the cables n,

b) jumpers and patch cords in distributor n and distributor $n - 1$,

c) the connecting hardware on which the cables n are terminated (at distributor n and distributor $n - 1$).

Although equipment cords are used to connect the transmission equipment to the cabling subsystem, they are not considered part of the cabling subsystem because they can be application specific.

5.3.3 Common subsystems

5.3.3.1 General

The following subsystems and associated distributors are used in two or more parts of the ISO/IEC 11801 series and are detailed here to allow the relevant references to be made.

5.3.3.2 Campus backbone cabling subsystem

When present, the campus backbone cabling subsystem includes

a) the campus backbone cables,

b) components in building entrance facilities,

c) the jumper and patch cords at the campus and building distributors (usually located in separate buildings),

d) the connecting hardware on which the campus backbone cables are terminated (at the campus and building distributors).

5.3.3.3 Building backbone cabling subsystem

The building backbone cabling subsystem extends from building distributor to the following distributors connected to it:

a) in ISO/IEC 11801-2: floor distributor,

b) in ISO/IEC 11801-3: floor distributor,

c) in ISO/IEC 11801-4: primary home distributor,

d) in ISO/IEC 11801-6: service distributor.

When present, the building backbone cabling subsystem includes

1) the building backbone cables,

2) the jumper and patch cords at both distributors,

3) the connecting hardware on which the building backbone cables are terminated (at both distributors).

5.3.4 Tie cabling

Tie cables providing direct peer-to-peer connections between distributors are optional and, when provided, shall be in addition to that required for the basic hierarchical topology.

When present, the tie cabling includes

a) the tie cables,

b) the jumper and patch cords at both distributors,

c) the connecting hardware on which the tie cables are terminated (at both distributors).

5.3.5 Channel and permanent link

The transmission performance of generic cabling is detailed in Clauses 6 and 7, in terms of the channel and the permanent link.

The channel is the transmission path between equipment such as a LAN switch/hub (EQP in Figure 5) and the terminal equipment. A typical interconnect channel consists of cabling subsystem 1 together with the terminal equipment cord and equipment cord. A typical cross-connect channel consists of cabling subsystem 1 together with the terminal equipment cord, a patch cord or jumper, and equipment cord. Optional consolidation points may be used. For longer reach services the channel may be formed by the connection of two or more subsystems (including terminal equipment cords and equipment cords). The performance of the channel excludes the connections at the application-specific equipment.

A permanent link is the transmission path of an installed cabling subsystem including the connecting hardware at the ends of the installed cable. In cabling subsystem 1, the permanent link consists of the TE outlet, the optional consolidation point (if supported by the cabling design standard), subsystem cable 1 (or cables Y and Z of Figure 2, if a consolidation point is supported by the cable design standard and is present) and the termination of subsystem cable 1 at distributor 1. The permanent link includes the connections at the ends of the installed cabling.

6 Channel performance requirements

6.1 General

The performance of a channel is specified between connections to active equipment. The channel comprises only passive sections of cable, connecting hardware, terminal equipment cords, equipment cords and patch cords. The connections at the active equipment are not taken into account.

The required transmission performance Class of Clause 6 shall be met for all environmental classifications specified for the channel.

Application support depends on channel performance, which in turn depends on cable length, number of connections, and performance of the components within the environments to which the channel is subjected. It may be possible to achieve equivalent channel performance over greater lengths by the use of fewer connections or by using components with higher performance.

6.2 Environmental performance

6.2.1 General

The environmental performance specifications of channels are classified to cover the different conditions under which channels are required to operate.

The environmental classification described in 6.2.2 shall be used for the selection of components and/or the protection afforded to them.

It is possible for the different locations within a channel to be subject to different environments. For example, one end of a channel can be in an office area and the other end of the channel can be subjected to a more severe environment. The description of the channel environment shall be divided up accordingly.

Furthermore, the applicable environment is that local to the cabling components within the channel. The local environment may, where relevant, be created by installation techniques applied to the channel in order to mitigate more extreme environments than exist within the premises. With regard to temperature, the local environment is considered to be the operating temperature of the cabling.

6.2.2 Environmental classification

This document classifies the environment for generic cabling as defined in Table 1.

Certain environments (e.g. nuclear, chemical, fire, explosive, damage risk from animals, salt mist) demand additional requirements beyond those of 6.2. Further details on specific environments are given in ISO/IEC TR 29106.

Table 1 – Channel environments

	1	2	3
Mechanical rating	M_1	M_2	M_3
Ingress rating	I_1	I_2	I_3
Climatic rating	C_1	C_2	C_3
Electromagnetic rating	E_1	E_2	E_3

The definition of a given classification includes the definition of lower classifications, i.e. channels designed to operate under environmental conditions defined by M_2 shall continue to operate under environmental conditions defined by M_1.

Channel environments may be classified by using any combination of the MICE scheme, e.g. $M_1I_2C_3E_1$. Care should be taken to accurately classify the channel environment in such a way as to allow the selection of suitable components.

The criteria for the MICE classification are based on $M_xI_xC_xE_x$, where "x" can equal 1, 2 or 3 based on the severity of the environment. For example, a typical office space has a minimum requirement of $M_1I_1C_1E_1$.

The environmental Classes are defined in Table 2.

For each M, I, C or E group, the classification of a given environment is determined by the most demanding parameter within the M, I, C or E group. However, the selection of components shall be based on the specific demands of each of the parameters within the M, I, C or E group, which may be less demanding than the overall classification of the group.

Table 2 – Details of environmental classification

Mechanical	**M_1**	**M_2**	**M_3**
Shock/bump[a]			
Peak acceleration	40 ms^{-2}	100 ms^{-2}	250 ms^{-2}
Vibration			
Displacement amplitude (2 Hz to 9 Hz)	1,5 mm	7,0 mm	15,0 mm
Acceleration amplitude (9 Hz to 500 Hz)	5 ms^{-2}	20 ms^{-2}	50 ms^{-2}
Tensile strength	[b]	[b]	[b]
Crush	45 N over 25 mm (linear) min.	1 100 N over 150 mm (linear) min.	2 200 N over 150 mm (linear) min.
Impact	1 J	10 J	30 J
Bending, flexing and torsion	[b]	[b]	[b]
Ingress	**I_1**	**I_2**	**I_3**
Particulate ingress (max. diameter)	12,5 mm	50 µm	50 µm
Immersion	None	Intermittent liquid jet ≤ 12,5 l/min ≥ 6,3 mm jet > 2,5 m distance	Intermittent liquid jet ≤ 12,5 l/min ≥ 6,3 mm jet > 2,5 m distance and immersion (≤ 1 m for ≤ 30 min)
Climatic and chemical	**C_1**	**C_2**	**C_3**
Ambient temperature	−10 °C to +60 °C	−25 °C to +70 °C	−40 °C to +70 °C
Rate of change of temperature	0,1 °C per minute	1,0 °C per minute	3,0 °C per minute
Humidity	5 % to 85 % (non-condensing)	5 % to 95 % (condensing)	5 % to 95 % (condensing)
Solar radiation	700 Wm^{-2}	1 120 Wm^{-2}	1 120 Wm^{-2}
Liquid pollution[c] Contaminants	Concentration × 10^{-6}	Concentration × 10^{-6}	Concentration × 10^{-6}
Sodium chloride (salt/sea water)	0 g/m^3	< 0,3 g/m^3	< 0,3 g/m^3
Oil (dry-air concentration) (for oil types see [b])	0 mg/m^3	< 0,005 mg/m^3	< 0,5 mg/m^3
Sodium stearate (soap)	None	> 5 × 10^4 mg/m^3 aqueous non-gelling	> 5 × 10^4 mg/m^3 aqueous gelling
Detergent	None	ffs	ffs
Conductive materials	None	Temporary	Present
Gaseous pollution[c] Contaminants	Mean / Peak (Concentration × 10^{-6})	Mean / Peak (Concentration × 10^{-6})	Mean / Peak (Concentration × 10^{-6})
Hydrogen sulphide	< 0,003 mg/m^3/ < 0,01 mg/m^3	< 0,05 mg/m^3/ < 0,5 mg/m^3	< 10 mg/m^3/ < 50 mg/m^3
Sulphur dioxide	< 0,01 mg/m^3/ < 0,03 mg/m^3	< 0,1 mg/m^3/ < 0,3 mg/m^3	< 5 mg/m^3/ < 15 mg/m^3
Sulphur trioxide (ffs)	< 0,01 mg/m^3/ < 0,03 mg/m^3	< 0,1 mg/m^3/ < 0,3 mg/m^3	< 5 mg/m^3/ < 15 mg/m^3
Chlorine wet (> 50 % humidity)	< 0,000 5 mg/m^3/ < 0,001 mg/m^3	< 0,005 mg/m^3/ < 0,03 mg/m^3	< 0,05 mg/m^3/ < 0,3 mg/m^3

Chlorine dry (< 50 % humidity)	< 0,002 mg/m^3/ < 0,01 mg/m^3	< 0,02 mg/m^3/ < 0,1 mg/m^3	< 0,2 mg/m^3/ < 1,0 mg/m^3
Hydrogen chloride	– / < 0,06 mg/m^3	< 0,06 mg/m^3/ < 0,3 mg/m^3	< 0,6 mg/m^3/ 3,0 mg/m^3
Hydrogen fluoride	< 0,001 mg/m^3/ < 0,005 mg/m^3	< 0,01 mg/m^3/ < 0,05 mg/m^3	< 0,1 mg/m^3/ < 1,0 mg/m^3
Ammonia	< 1 mg/m^3/ < 5 mg/m^3	< 10 mg/m^3/ < 50 mg/m^3	< 50 mg/m^3/ < 250 mg/m^3
Oxides of nitrogen	< 0,05 mg/m^3/ < 0,1 mg/m^3	< 0,5 mg/m^3/ < 1 mg/m^3	< 5 mg/m^3/ < 10 mg/m^3
Ozone	< 0,002 g/m^3/ < 0,005 g/m^3	< 0,025 g/m^3/ < 0,05 g/m^3	< 0,1 g/m^3/ < 1 g/m^3
Electromagnetic	**E_1**	**E_2**	**E_3**
Electrostatic discharge – Contact (0,667 µC)	4 kV	4 kV	4 kV
Electrostatic discharge – Air (0,132 µC)	8 kV	8 kV	8 kV
Radiated RF – AM	3 V/m @ (80 to 1 000) MHz 3 V/m @ (1 400 to 2 000) MHz 1 V/m @ (2 000 to 2 700) MHz	3 V/m @ (80 to 1 000) MHz 3 V/m @ (1 400 to 2 000) MHz 1 V/m @ (2 000 to 2 700) MHz	10 V/m @ (80 to 1 000) MHz 3 V/m @ (1 400 to 2 000) MHz 1 V/m @ (2 000 to 2 700) MHz
Conducted RF	3 V@ 150 kHz to 80 MHz	3 V@ 150 kHz to 80 MHz	10 V@ 150 kHz to 80 MHz
EFT/B (comms)	500 V	500 V	1 000 V
Surge (transient ground potential difference) – signal, line to earth	500 V	1 000 V	1 000 V
Magnetic field (50/60 Hz)	1 Am^{-1}	3 Am^{-1}	30 Am^{-1}
Magnetic field (60 Hz to 20 000 Hz)	ffs	ffs	ffs

[a] Bump: the repetitive nature of the shock experienced by the channel shall be taken into account.

[b] This aspect of environmental classification is installation-specific and should be considered in association with IEC 61918 and the appropriate component specification.

[c] A single dimensional characteristic, i.e. concentration × 10^{-6}, was chosen to unify limits from different standards.

6.3 Balanced cabling transmission performance

6.3.1 General

This document specifies the following Classes for balanced cabling:

a) Class A is specified up to 100 kHz,

b) Class B is specified up to 1 MHz,

c) Class C is specified up to 16 MHz,

d) Class D is specified up to 100 MHz,

e) Class E is specified up to 250 MHz,

f) Class E_A is specified up to 500 MHz,

g) Class F is specified up to 600 MHz,

h) Class F_A is specified up to 1 000 MHz.

A Class A channel is specified so that it will provide the minimum transmission performance to support Class A applications. Similarly, Class B, C, D, E, E_A, F and F_A channels provide the transmission performance to support Class B, C, D, E, E_A, F and F_A applications, respectively. Channels of a given Class will support all applications of a lower Class. Class A is regarded as the lowest Class.

This document specifies the following additional Classes for balanced cabling described in certain parts of the cabling design standards:

1) Class BCT-B: specified up to 1 000 MHz,
2) Class I and Class II: specified up to 2 000 MHz.

The insertion loss and other length related parameter performance of BCT-B cabling is further subdivided into two sub-Classes, L and M (see Table 5). These sub-Classes have identical performance requirements for all other transmission parameters.

Annex E lists known balanced cabling applications by Class. The requirements in 6.3 are given by limits computed to one decimal place, using the formula for a defined frequency range. The limits for the propagation delay and delay skew are computed to three decimal places. The additional tables are for information only and have limits derived from the relevant formula at key frequencies. Many specifications in 6.3 have a plateau in the specified requirement. These plateaus do not accurately depict the system performance. They have been added for measurement purposes.

6.3.2 Component choice

The parameters specified in 6.3 apply to channels with screened or unscreened cable elements, with or without an overall screen, unless explicitly stated otherwise.

The nominal differential mode impedance of channels is 100 Ω. This is achieved by suitable design and appropriate choice of cabling components (irrespective of their nominal impedance). In the case of cable sharing, additional crosstalk requirements specified in 9.3.2.5.1 should be taken into account.

6.3.3 Channel parameters

6.3.3.1 Return loss

The return loss requirements are only applicable to Classes C through F_A, BCT-B, I, and II.

The return loss (*RL*) of each pair of a channel shall meet the requirements in Table 3.

The *RL* of each pair of a channel at key frequencies is given in Table 4 for information only.

The return loss requirements shall be met at both ends of the cabling. Return loss (*RL*) values at frequencies where the insertion loss (*IL*) is below 3,0 dB are for information only.

Table 3 – Return loss for a channel

Class	Frequency MHz	Minimum return loss dB
C	$1 \le f \le 16$	15,0
D	$1 \le f < 20$	17,0
	$20 \le f \le 100$	$30 - 10\,\lg(f)$
E	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5\,\lg(f)$
	$40 \le f \le 250$	$32 - 10\,\lg(f)$
E_A	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5\,\lg(f)$
	$40 \le f < 398.1$	$32 - 10\,\lg(f)$
	$398,1 \le f \le 500$	6,0
F	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5\,\lg(f)$
	$40 \le f < 251,2$	$32 - 10\,\lg(f)$
	$251,2 \le f \le 600$	8,0
F_A	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5\,\lg(f)$
	$40 \le f < 251,2$	$32 - 10\,\lg(f)$
	$251,2 \le f < 631$	8,0
	$631 \le f \le 1\,000$	$36 - 10\,\lg(f)$
BCT-B	$1 \le f < 10$	19,0
	$10 \le f < 100$	$24 - 5\,\lg(f)$
	$100 \le f < 251,2$	$29 - 7,5\,\lg(f)$
	$251,2 \le f < 600$	$17,2 - 2,6\,\lg(f)$
	$600 \le f < 1\,000$	$35 - 9\,\lg(f)$
I	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5\,\lg(f)$
	$40 \le f < 130$	16,0
	$130 \le f < 1\,000$	$35 - 9\,\lg(f)$
	$1\,000 \le f < 1600$	8,0
	$1\,600 \le f < 2\,000$	$8 - 19\,\lg(\frac{f}{1600})$
II	$1 \le f < 10$	19,0
	$10 \le f < 40$	$24 - 5\,\lg(f)$
	$40 \le f < 130$	16,0
	$130 \le f < 1\,000$	$35 - 9\,\lg(f)$
	$1\,000 \le f < 1600$	8,0
	$1\,600 \le f < 2\,000$	$8 - 19\,\lg(\frac{f}{1600})$

Table 4 – Informative return loss values for a channel at key frequencies

Frequency MHz	Minimum return loss dB								
	Class								
	C	D	E	E_A	F	F_A	BCT-B	I	II
1	15,0	17,0	19,0	19,0	19,0	19,0	19,0	19,0	19,0
16	15,0	17,0	18,0	18,0	18,0	18,0	18,0	18,0	18,0
100	–	10,0	12,0	12,0	12,0	12,0	14,0	16,0	16,0
250	–	–	8,0	8,0	8,0	8,0	11,0	13,4	13,4
500	–	–	–	6,0	8,0	8,0	10,2	10,7	10,7
600	–	–	–	–	8,0	8,0	10,0	10,0	10,0
1 000	–	–	–	–	–	6,0	8,0	8,0	8,0
1 600	–	–	–	–	–	–	–	8,0	8,0
2 000	–	–	–	–	–	–	–	6,2	6,2

6.3.3.2 Insertion loss/attenuation

The term “attenuation” is still widely used in the cable industry; however, this characteristic is better described as “insertion loss”. In this document, the term “insertion loss” is adopted throughout to describe the signal attenuation over the length of channels, links and components. Unlike attenuation, insertion loss does not scale linearly with length.

The term “attenuation” is maintained for the following parameters:

a) attenuation to crosstalk ratio at the near end (*ACR-N*) – see 6.3.3.4,

b) attenuation to crosstalk ratio at the far end (*ACR-F*) – see 6.3.3.5,

c) unbalance attenuation and coupling attenuation – see 6.3.3.12,

d) power sum alien attenuation to crosstalk ratio at the far end (*PS AACR-F*) – see 6.3.3.13.4.

For the calculation of *ACR-N*, *PS ACR-N*, *ACR-F*, *PS ACR-F* and *PS AACR-F*, the corresponding value for insertion loss (*IL*) shall be used.

The insertion loss requirements are applicable to all cabling Classes.

The insertion loss (*IL*) of each pair of a channel shall meet the requirements in Table 5.

The *IL* of each pair of a channel at key frequencies is given in Table 6 for information only.

Table 5 – Insertion loss for a channel

Class	**Frequency** MHz	**Maximum insertion loss** dB
A	$f = 0{,}1$	16,0 [a]
B	$f = 0{,}1$	5,5 [a]
	$f = 1$	5,8 [a]
C	$1 \le f \le 16$	$1{,}05 \times \left(3{,}23\sqrt{f}\right) + 4 \times 0{,}2$ [a]
D	$1 \le f \le 100$	$1{,}05 \times \left(1{,}910\,8\sqrt{f} + 0{,}022\,2 \times f + 0{,}2/\sqrt{f}\right) + 4 \times 0{,}04 \times \sqrt{f}$ [a]
E	$1 \le f \le 250$	$1{,}05 \times \left(1{,}82\sqrt{f} + 0{,}016\,9 \times f + 0{,}25/\sqrt{f}\right) + 4 \times 0{,}02 \times \sqrt{f}$ [a]
E_A	$1 \le f \le 500$	$1{,}05 \times \left(1{,}82\sqrt{f} + 0{,}009\,1 \times f + 0{,}25/\sqrt{f}\right) + 4 \times 0{,}02 \times \sqrt{f}$ [a]
F	$1 \le f \le 600$	$1{,}05 \times \left(1{,}8\sqrt{f} + 0{,}01 \times f + 0{,}2/\sqrt{f}\right) + 4 \times 0{,}02 \times \sqrt{f}$ [a]
F_A	$1 \le f \le 1\,000$	$1{,}05 \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + 0{,}25/\sqrt{f}\right) + 4 \times 0{,}02 \times \sqrt{f}$ [a]
BCT-B-L	$1 \le f \le 1\,000$	$0{,}138 \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + 0{,}25/\sqrt{f}\right) + 2 \times 0{,}02 \times \sqrt{f}$ [b]
BCT-B-M	$1 \le f \le 1\,000$	$0{,}27 \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + 0{,}25/\sqrt{f}\right) + 2 \times 0{,}02 \times \sqrt{f}$ [b]
I	$1 < f \le 500$	$\left(0{,}634\sqrt{f} + 0{,}00156 \times f + \frac{0{,}078}{\sqrt{f}}\right)$ [d]
	$500 < f \le 2\,000$	$\left(0{,}60698\sqrt{f} + 0{,}00277 \times f + \frac{0{,}078}{\sqrt{f}}\right)$ [e]
II	$1 < f \le 2\,000$	$0{,}32 \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + 0{,}25/\sqrt{f}\right) + 2 \times 0{,}02 \times \sqrt{f}$ [c]

[a] Insertion loss (*IL*) at frequencies that correspond to calculated values of less than 4,0 dB shall revert to a maximum requirement of 4,0 dB.

[b] Insertion loss (*IL*) at frequencies that correspond to calculated values of less than 2,0 dB shall revert to a maximum requirement of 2,0 dB.

[c] Insertion loss (*IL*) at frequencies that correspond to calculated values of less than 3,0 dB shall revert to a maximum requirement of 3,0 dB.

[d] This formula is derived using $0{,}312 \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + \frac{0{,}25}{\sqrt{f}}\right) + 2 \times \left(0{,}02 \times \sqrt{f}\right) + 0{,}0324 \times \sqrt{f}$

[e] This formula is derived using

$$0{,}312 \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + \frac{0{,}25}{\sqrt{f}}\right) + 2 \times \left(0{,}00649 \times \sqrt{f} + 0{,}000605 \times f\right) + 0{,}0324 \times \sqrt{f}$$

Table 6 – Informative insertion loss values for a channel at key frequencies

Frequency MHz	**Maximum insertion loss** dB											
	Class											
	A	**B**	**C**	**D**	**E**	E_A	**F**	F_A	**BCT-B-L**[a]	**BCT-B-M**[a]	**I**[a]	**II**[a]
0,1	16,0	5,5	–	–	–	–	–	–	–	–	–	–
1	–	5,8	4,2	4,0	4,0	4,0	4,0	4,0	2,0	2,0	3,0	3,0
16	–	–	14,4	9,1	8,3	8,2	8,1	8,0	2,0	2,1	3,0	3,0
100	–	–	–	24,0	21,7	20,9	20,8	20,3	3,0	5,4	6,5	6,3
250	–	–	–	–	35,9	33,9	33,8	32,5	4,7	8,6	10,4	10,1
500	–	–	–	–	–	49,3	49,3	46,7	6,8	12,4	15,0	14,6
600	–	–	–	–	–	–	54,6	51,4	7,5	13,7	16,5	16,1
1 000	–	–	–	–	–	–	–	67,6	9,8	18,0	22,0	21,1
1 600	–	–	–	–	–	–	–	–	–	–	28,7	27,2
2 000	–	–	–	–	–	–	–	–	–	–	32,7	30,8

[a] Values reflect reduced channel lengths as compared to those of other Classes.

6.3.3.3 NEXT

6.3.3.3.1 Pair-to-pair NEXT

The *NEXT* requirements are applicable to all cabling Classes.

The *NEXT* between each pair combination of a channel shall meet the requirements in Table 7.

The *NEXT* of each pair of a channel, at maximum implementation, at key frequencies is given in Table 8 for information only.

The *NEXT* requirements shall be met at both ends of the cabling. *NEXT* values at frequencies where the insertion loss (*IL*) is below 4,0 dB are for information only.

Table 7 – NEXT for a channel

Class	Frequency MHz	Minimum NEXT [a] dB
A	$f = 0{,}1$	27,0
B	$0{,}1 \le f \le 1$	$25 - 15\lg(f)$
C	$1 \le f \le 16$	$39{,}1 - 16{,}4\lg(f)$
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{65{,}3-15\lg(f)}{-20}} + 2\times 10^{\frac{83-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{74{,}3-15\lg(f)}{-20}} + 2\times 10^{\frac{94-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{74{,}3-15\lg(f)}{-20}} + 2\times 10^{\frac{94-20\lg(f)}{-20}}\right)$ [b, d]
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}} + 2\times 10^{\frac{102{,}4-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{105{,}4-15\lg(f)}{-20}} + 2\times 10^{\frac{116{,}3-20\lg(f)}{-20}}\right)$ [c, d]
BCT-B	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{105{,}4-15\lg(f)}{-20}} + 2\times 10^{\frac{116{,}3-20\lg(f)}{-20}}\right)$ [c, d]
I	$1 \le f \le 500$	$-20\lg\left(10^{\frac{75{,}3-15\lg(f)}{-20}} + 2\times 10^{\frac{94-20\lg(f)}{-20}}\right)$
	$500 < f \le 2\,000$	$-20\lg\left(10^{\frac{75{,}3-15\lg(f)}{-20}} + 2\times 10^{\frac{40-38\lg(f/500)}{-20}}\right)$
II	$1 \le f \le 1000$	$-20\lg\left(10^{\frac{105{,}4-15\lg(f)}{-20}} + 2\times 10^{\frac{116{,}3-20\lg(f)}{-20}}\right)$
	$1000 < f \le 1600$	$-20\lg\left(10^{\frac{105{,}4-15\lg(f)}{-20}} + 2\times 10^{\frac{56{,}3-90\lg(f/1000)}{-20}}\right)$
	$1600 < f \le 2\,000$	$-20\lg\left(10^{\frac{105{,}4-15\lg(f)}{-20}} + 2\times 10^{\frac{37{,}93-40\lg(f/1600)}{-20}}\right)$

[a] *NEXT* at frequencies that correspond to calculated values of greater than 65,0 dB shall revert to a minimum requirement of 65,0 dB.

[b] Whenever the Class E_A channel insertion loss at 450 MHz is less than 12 dB, subtract the term $1{,}4((f-450)/50)$ from the formula stated above for the range of 450 MHz to 500 MHz.

[c] Whenever the Class F_A channel insertion loss at 900 MHz is less than 17 dB, subtract the term $2{,}8((f-900)/100)$ from the formula stated above for the range of 900 MHz to 1 000 MHz.

[d] The terms in the formulas are not intended to imply component performance.

Table 8 – Informative NEXT values for a channel at key frequencies

Minimum channel NEXT dB											
Frequency MHz	**Class**										
	A	**B**	**C**	**D**	**E**	**E_A**	**F**	**F_A**	**BCT-B**	**I**	**II**
0,1	27,0	40,0	–	–	–	–	–	–	–	–	–
1	–	25,0	39,1	63,3	65,0	65,0	65,0	65,0	65,0	65,0	65,0
16	–	–	19,4	43,6	53,2	53,2	65,0	65,0	65,0	53,9	65,0
100	–	–	–	30,1	39,9	39,9	62,9	65,0	65,0	40,5	65,0
250	–	–	–	–	33,1	33,1	56,9	59,1	59,1	33,6	59,1
500	–	–	–	–	–	27,9	52,4	53,6	53,6	28,4	53,6
600	–	–	–	–	–	–	51,2	52,1	52,1	26,2	52,1
1 000	–	–	–	–	–	–	–	47,9	47,9	19,6	47,9
1 600	–	–	–	–	–	–	–	–	–	12,9	31,5
2 000	–	–	–	–	–	–	–	–	–	9,6	27,7

6.3.3.3.2 Power sum NEXT

The *PS NEXT* requirements are only applicable to Classes D through F_A, BCT-B, I, and II.

The *PS NEXT* of each pair of a channel shall meet the requirements in Table 9.

The *PS NEXT* of each pair of a channel, at maximum implementation, at key frequencies is given in Table 10 for information only.

The *PS NEXT* requirements shall be met at both ends of the cabling. *PS NEXT* values at frequencies where the insertion loss (*IL*) is below 4,0 dB are for information only.

$PS\ NEXT_k$ of pair k is computed as follows:

$$PSNEXT_k = -10 \lg \sum_{i=1, i \neq k}^{n} 10^{\frac{-NEXT_{ik}}{10}} \quad (1)$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

n is the total number of pairs;

$NEXT_{ik}$ is the near-end crosstalk loss coupled from pair i into pair k.

Table 9 – PS NEXT for a channel

Class	Frequency MHz	Minimum PS NEXT[a] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{62{,}3-15\lg(f)}{-20}}+2\times 10^{\frac{80-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{72{,}3-15\lg(f)}{-20}}+2\times 10^{\frac{90-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{72{,}3-15\lg(f)}{-20}}+2\times 10^{\frac{90-20\lg(f)}{-20}}\right)$ [b, d]
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{99{,}4-15\lg(f)}{-20}}+2\times 10^{\frac{99{,}4-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}}+2\times 10^{\frac{113{,}3-20\lg(f)}{-20}}\right)$ [c, d]
BCT-B	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}}+2\times 10^{\frac{113{,}3-20\lg(f)}{-20}}\right)$ [c, d]
I	$1 \le f \le 500$	$-20\lg\left(10^{\frac{72{,}3-15\lg(f)}{-20}}+2\times 10^{\frac{91-20\lg(f)}{-20}}\right)$
	$500 < f \le 2\,000$	$-20\lg\left(10^{\frac{72{,}3-15\lg(f)}{-20}}+2\times 10^{\frac{37-38\lg(f/500)}{-20}}\right)$
II	$1 \le f \le 1000$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}}+2\times 10^{\frac{113{,}3-20\lg(f)}{-20}}\right)$
	$1000 < f \le 1600$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}}+2\times 10^{\frac{53{,}3-90\lg(f/1000)}{-20}}\right)$
	$1600 < f \le 2\,000$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}}+2\times 10^{\frac{34{,}93-40\lg(f/1600)}{-20}}\right)$

[a] *PS NEXT* at frequencies that correspond to calculated values of greater than 62,0 dB shall revert to a minimum requirement of 62,0 dB.

[b] Whenever the Class E_A channel insertion loss at 450 MHz is less than 12 dB, subtract the term $1{,}4((f-450)/50)$ from the formula stated above for the range of 450 MHz to 500 MHz.

[c] Whenever the Class F_A channel insertion loss at 900 MHz is less than 17 dB, subtract the term $2{,}8((f-900)/100)$ from the formula stated above for the range of 900 MHz to 1 000 MHz.

[d] The terms in the formulas are not intended to imply component performance.

Table 10 – Informative PS NEXT values for a channel at key frequencies

Minimum PS NEXT dB								
Frequency MHz	**Class**							
	D	**E**	**E_A**	**F**	**F_A**	**BCT-B**	**I**	**II**
1	60,3	62,0	62,0	62,0	62,0	62,0	62,0	62,0
16	40,6	50,6	50,6	62,0	62,0	62,0	50,9	62,0
100	27,1	37,1	37,1	59,9	62,0	62,0	37,5	62,0
250	–	30,2	30,2	53,9	56,1	56,1	30,6	56,1
500	–	–	24,8	49,4	50,6	50,6	25,4	50,6
600	–	–	–	48,2	49,1	49,1	23,2	49,1
1 000	–	–	–	–	44,9	44,9	16,6	44,9
1 600	–	–	–	–	–	–	9,9	28,5
2 000	–	–	–	–	–	–	6,6	24,7

6.3.3.4 Attenuation to crosstalk ratio at the near-end

6.3.3.4.1 General

ACR-N and *PS ACR-N* requirements are only applicable to Classes D through F_A, BCT-B, I, and II.

Except for the name, the definition and formulas for *ACR-N* and *PS ACR-N* are identical to those used for *ACR* and *PS ACR*, respectively, in prior editions of the ISO/IEC 11801 series documents.

6.3.3.4.2 Pair-to-pair ACR-N

Pair-to-pair *ACR-N* is the difference between the pair-to-pair *NEXT* and the insertion loss (*IL*) of the disturbed pair in decibels.

The *ACR-N* of each pair combination of a channel shall meet the difference of the *NEXT* requirement of Table 7 and the insertion loss (*IL*) requirement of Table 5 of the respective class.

The *ACR-N* of each pair of a channel, at maximum implementation, at key frequencies is given in Table 11 for information only.

The *ACR-N* requirements shall be met at both ends of the cabling.

$ACR\text{-}N_{ik}$ of pairs i and k is computed as follows:

$$ACR\text{-}N_{ik} = NEXT_{ik} - IL_k \quad (2)$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

$NEXT_{ik}$ is the near-end crosstalk loss coupled from pair i into pair k;

IL_k is the insertion loss of pair k.

Table 11 – Informative ACR-N values for a channel at key frequencies

Minimum ACR-N dB									
Frequency MHz	**Class**								
	D	**E**	**E_A**	**F**	**F_A**	**BCT-B-L**[a]	**BCT-B-M**[a]	**I**[a]	**II**[a]
1	59,3	61,0	61,0	61,0	61,0	63,0	63,0	62,0	62,0
16	34,5	44,9	45,0	56,9	57,0	63,0	62,9	51,3	62,0
100	6,1	18,2	19,0	42,1	44,7	60,0	59,6	34,0	58,7
250	–	−2,8	−0,8	23,1	26,7	54,4	50,5	23,2	49,0
500	–	–	−21,4	3,1	6,9	46,8	41,4	13,4	39,0
600	–	–	–	−3,4	0,7	44,6	39,4	9,7	36,0
1 000	–	–	–	–	−19,6	38,1	29,9	−2,4	26,8
1 600	–	–	–	–	–	–	–	−15,8	4,3
2 000	–	–	–	–	–	–	–	−23,1	−3,1

[a] Values reflect reduced channel lengths as compared to those of other Classes.

6.3.3.4.3 Power sum ACR-N

PS ACR-N is the difference between the *PS NEXT* and the insertion loss (*IL*) of the disturbed pair in decibels.

The *PS ACR-N* of each pair of a channel shall meet the difference of the *PS NEXT* requirement of Table 9 and the insertion loss (*IL*) requirement of Table 5 of the respective class.

The *PS ACR-N* of each pair of a channel, at maximum implementation, at key frequencies is given in Table 12 for information only.

The *PS ACR-N* requirements shall be met at both ends of the cabling.

$PS\ ACR\text{-}N_k$ of pair k is computed as follows:

$$PS\ ACR\text{-}N_k = PS\ NEXT_k - IL_k \qquad (3)$$

where

k is the number of the disturbed pair;

$PS\ NEXT_k$ is the power sum near-end crosstalk loss of pair k;

IL_k is the insertion loss of pair k.

Table 12 – Informative PS ACR-N values for a channel at key frequencies

Minimum PS ACR-N dB									
Frequency MHz	**Class**								
	D	**E**	**E_A**	**F**	**F_A**	**BCT-B-L**[a]	**BCT-B-M**[a]	**I**[a]	**II**[a]
1	56,3	58,0	58,0	58,0	58,0	60,0	60,0	59,0	59,0
16	31,5	42,3	42,4	53,9	54,0	60,0	59,9	48,3	59,5
100	3,1	15,4	16,2	39,1	41,7	57,0	56,6	31,0	55,7
250	–	−5,8	−3,7	20,1	23,7	51,4	47,5	20,2	46,0
500	–	–	−24,5	0,1	3,9	43,8	38,4	10,4	36,0
600	–	–	–	−6,4	−2,3	41,6	36,4	6,7	33,0
1 000	–	–	–	–	−22,6	35,1	26,9	−5,4	23,8
1 600	–	–	–	–	–	–	–	−18,8	1,3
2 000	–	–	–	–	–	–	–	−26,1	−6,1
[a] Values reflect reduced channel lengths as compared to those of other Classes.									

6.3.3.5 Attenuation to crosstalk ratio at the far-end

6.3.3.5.1 General

ACR-F and *PS ACR-F* requirements are only applicable to Classes D through F_A, BCT-B, I, and II.

NOTE *ACR-F* and *PS ACR-F* replace parameters *ELFEXT* and *PS ELFEXT*, respectively, which were specified in prior editions of ISO/IEC 11801. Whereas *ELFEXT* is computed using the insertion loss of the disturbing pair, *ACR-F* is computed using the insertion loss of the disturbed pair. Because both disturbing pairs and disturbed pairs are subject to the same insertion loss requirements (see Table 5), the specified requirements in Table 13 and Table 15 for Classes D, E and F have not been changed.

6.3.3.5.2 Pair-to-pair ACR-F

The *ACR-F* of each pair combination of a channel shall meet the requirements in Table 13.

The *ACR-F* of each pair of a channel, at maximum implementation, at key frequencies is given in Table 14 for information only.

$ACR\text{-}F_{ik}$ of pairs i and k is computed as follows:

$$ACR\text{-}F_{ik} = FEXT_{ik} - IL_k \quad (4)$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

$FEXT_{ik}$ is the far-end crosstalk loss coupled from pair i into pair k;

IL_k is the insertion loss of pair k.

Table 13 – ACR-F for a channel

Class	**Frequency** MHz	**Minimum ACR-F** [a, b] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{63{,}8-20\lg(f)}{-20}}+4\times10^{\frac{75{,}1-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{67{,}8-20\lg(f)}{-20}}+4\times10^{\frac{83{,}1-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{67{,}8-20\lg(f)}{-20}}+4\times10^{\frac{83{,}1-20\lg(f)}{-20}}\right)$
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{94-20\lg(f)}{-20}}+4\times10^{\frac{90-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{95{,}3-20\lg(f)}{-20}}+4\times10^{\frac{103{,}9-20\lg(f)}{-20}}\right)$
BCT-B-L	$1 \le f \le 1\,000$	$-20\lg\left(\sqrt{0{,}118}\times10^{\frac{91{,}0-20\lg(f)}{-20}}+2\times10^{\frac{103{,}9-20\lg(f)}{-20}}\right)$
BCT-B-M	$1 \le f \le 1\,000$	$-20\lg\left(\sqrt{0{,}25}\times10^{\frac{91{,}0-20\lg(f)}{-20}}+2\times10^{\frac{103{,}9-20\lg(f)}{-20}}\right)$
I	$1 \le f \le 2\,000$	$-20\lg\left(10^{\frac{79-20\lg(f)}{-20}}+2\times10^{\frac{83{,}1-20\lg(f)}{-20}}\right)$
II	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{100{,}6-20\lg(f)}{-20}}+2\times10^{\frac{103{,}9-20\lg(f)}{-20}}\right)$
	$1\,000 < f < 1\,600$	$-20\lg\left(10^{\frac{100{,}6-20\lg(f)}{-20}}+2\times10^{\frac{43{,}9-90\lg(f/1000)}{-20}}\right)$
	$1\,600 \le f \le 2\,000$	$-20\lg\left(10^{\frac{100{,}6-20\lg(f)}{-20}}+2\times10^{\frac{25{,}52-40\lg(f/1600)}{-20}}\right)$

[a] *ACR-F* at frequencies that correspond to measured *FEXT* values of greater than 70,0 dB are for information only.

[b] The *ACR-F* limit at frequencies that correspond to calculated values of greater than 65,0 dB shall revert to a minimum requirement of 65,0 dB.

Table 14 – Informative ACR-F values for a channel at key frequencies

Minimum ACR-F dB									
Frequency MHz	**Class**								
	D	**E**	**E_A**	**F**	**F_A**	**BCT-B-L**[a]	**BCT-B-M**[a]	**I**[a]	**II**[a]
1	57,4	63,3	63,3	65,0	65,0	65,0	65,0	65,0	65,0
16	33,3	39,2	39,2	57,5	63,3	65,0	65,0	47,9	65,0
100	17,4	23,3	23,3	44,4	47,4	53,0	51,4	32,0	53,1
250	–	15,3	15,3	37,8	39,4	45,0	43,5	24,0	45,2
500	–	–	9,3	32,6	33,4	39,0	37,4	18,0	39,1
600	–	–	–	31,3	31,8	37,4	35,9	16,4	37,6
1 000	–	–	–	–	27,4	33,0	31,4	12,0	33,1
1 600	–	–	–	–	–	–	–	7,9	18,4
2 000	–	–	–	–	–	–	–	6,0	14,7
[a] Values reflect reduced channel lengths as compared to those of other Classes.									

6.3.3.5.3 Power sum ACR-F

The *PS ACR-F* of each pair of a channel shall meet the requirements in Table 15.

The *PS ACR-F* of each pair of a channel, at maximum implementation, at key frequencies is given in Table 16 for information only.

$PS\ ACR\text{-}F_k$ of pair k is computed as follows:

$$PS\ ACR\text{-}F_k = \left(-10\lg \sum_{i=1, i \neq k}^{n} 10^{\frac{-FEXT_{ik}}{10}} \right) - IL_k \quad (5)$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

n is the number of disturbing pairs in the channel;

$FEXT_{ik}$ is the far-end crosstalk loss coupled from pair i into pair k;

IL_k is the insertion loss of pair k.

Table 15 – PS ACR-F for a channel

Class	**Frequency** MHz	**Minimum PS ACR-F** [a, b] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{60{,}8-20\lg(f)}{-20}}+4\times10^{\frac{72{,}1-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{64{,}8-20\lg(f)}{-20}}+4\times10^{\frac{80{,}1-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{64{,}8-20\lg(f)}{-20}}+4\times10^{\frac{80{,}1-20\lg(f)}{-20}}\right)$
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{91-20\lg(f)}{-20}}+4\times10^{\frac{87-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{92{,}3-20\lg(f)}{-20}}+4\times10^{\frac{100{,}9-20\lg(f)}{-20}}\right)$
BCT-B-L	$1 \le f \le 1\,000$	$-20\lg\left(\sqrt{0{,}118}\times10^{\frac{88{,}0-20\lg(f)}{-20}}+2\times10^{\frac{100{,}9-20\lg(f)}{-20}}\right)$
BCT-B-M	$1 \le f \le 1\,000$	$-20\lg\left(\sqrt{0{,}25}\times10^{\frac{88{,}0-20\lg(f)}{-20}}+2\times10^{\frac{100{,}9-20\lg(f)}{-20}}\right)$
I	$1 \le f \le 2\,000$	$-20\lg\left(10^{\frac{76-20\lg(f)}{-20}}+2\times10^{\frac{80{,}1-20\lg(f)}{-20}}\right)$
II	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{97{,}6-20\lg(f)}{-20}}+2\times10^{\frac{100{,}9-20\lg(f)}{-20}}\right)$
	$1\,000 < f < 1\,600$	$-20\lg\left(10^{\frac{97{,}6-20\lg(f)}{-20}}+2\times10^{\frac{40{,}9-90\lg(f/1000)}{-20}}\right)$
	$1\,600 \le f \le 2\,000$	$-20\lg\left(10^{\frac{97{,}6-20\lg(f)}{-20}}+2\times10^{\frac{22{,}52-40\lg(f/1600)}{-20}}\right)$

[a] *PS ACR-F* at frequencies that correspond to calculated *PS FEXT* values of greater than 67,0 dB are for information only.

[b] The *PS ACR-F* limit at frequencies that correspond to calculated values of greater than 62,0 dB shall revert to a minimum requirement of 62,0 dB.

Table 16 – Informative PS ACR-F values for a channel at key frequencies

Minimum PS ACR-F dB									
Frequency MHz	**Class**								
	D	**E**	**E_A**	**F**	**F_A**	**BCT-B-L**[a]	**BCT-B-M**[a]	**I**[a]	**II**[a]
1	54,4	60,3	60,3	62,0	62,0	65,0	65,0	62,0	62,0
16	30,3	36,2	36,2	54,5	60,3	65,0	64,3	44,9	62,0
100	14,4	20,3	20,3	41,4	44,4	50,0	48,4	29,0	50,1
250	–	12,3	12,3	34,8	36,4	42,0	40,5	21,0	42,2
500	–	–	6,3	29,6	30,4	36,0	34,4	15,0	36,1
600	–	–	–	28,3	28,8	34,4	32,9	13,4	34,6
1 000	–	–	–	–	24,4	30,0	28,4	9,0	30,1
1 600	–	–	–	–	–	–	–	4,9	15,4
2 000	–	–	–	–	–	–	–	3,0	11,7

[a] Values reflect reduced channel lengths as compared to those of other Classes.

6.3.3.6 Direct current loop resistance

The DC loop resistance requirements are applicable to all cabling Classes.

The DC loop resistance of each pair of a channel shall meet the requirements in Table 17.

Table 17 – DC loop resistance for a channel

Maximum DC loop resistance Ω						
Class A	**Class B**	**Class C**	**Class D, E, E_A, F, F_A**[a]	**Class BCT-B-L**	**Class BCT-B-M**	**Class I,II**[b]
560	170	40	25	4,0	6,9	6,4

[a] The maximum DC loop resistance at 20 °C of each pair of a cable (excluding connections) within a 2-connector link used in a channel shall be 0,19 Ω/m. This shall be achieved by an appropriate design.

[b] The maximum DC loop resistance at 20 °C of each pair of a cable (excluding connections) within a 2-connector link used in a channel shall be 0,14 Ω/m. This shall be achieved by an appropriate design.

For applications requiring remote power delivery, see ISO/IEC TS 29125 for the DC resistance and DC resistance unbalance (within, and between pairs) component specifications.

6.3.3.7 Direct current resistance unbalance

The DC resistance unbalance requirements are applicable to all cabling Classes.

The DC resistance unbalance between the two conductors within each pair of a channel shall not exceed 3 % or 0,200 Ω, whichever is greater. The maximum DC resistance unbalance between pairs within a channel shall not exceed 7 % or 100 mΩ, whichever is greater.

NOTE For the purposes of field measurements, calculations that provide values of less than 200 mΩ revert to 200 mΩ.

For applications requiring remote power delivery, see ISO/IEC TS 29125 for the DC resistance and DC resistance unbalance (within, and between pairs) component specifications.

6.3.3.8 DC current carrying capacity

The minimum DC current carrying capacity requirements are applicable to cabling Classes C through F_A, BCT-B, Class I and Class II.

Each conductor within a single channel shall have a minimum DC current carrying capacity under continuous operation of 0,75 A at operating temperatures up to 60 °C. This requirement shall be met by design.

The DC current carrying capacity is not a guide for application support since other factors including the number of conductors and cables carrying remote powering current and their installation environment may place further restrictions on the current per conductor.

For information on DC current carrying capacity with respect to installation conditions and applications using remote power supplied over these Classes of balanced cabling, see ISO/IEC TS 29125.

The design and operation of the channel shall take into account the impact of mating and de-mating under load (see Clause 10 and Annex B).

6.3.3.9 Dielectric withstand

The minimum dielectric withstand requirements are applicable to cabling Classes D through F_A, BCT-B, I and II.

Dielectric withstand of Classes D through F_A, BCT-B, I and II channels shall be a minimum of 1 000 V DC conductor-to-conductor and shall be a minimum of 1 000 V DC conductor-to-screen or conductor to earth, if a screen is not present, in accordance with IEC 61156-1 generic specification. This requirement shall be met by design.

6.3.3.10 Propagation delay

The propagation delay requirements are applicable to all cabling Classes.

The propagation delay of each pair of a channel shall meet the requirements in Table 18.

The propagation delay of each pair of a channel, at maximum implementation, at key frequencies is given in Table 19 for information only.

Table 18 – Propagation delay for a channel

Class	Frequency MHz	Maximum propagation delay µs
A	$f = 0,1$	20,000
B	$0,1 \le f \le 1$	5,000
C, D, E, E_A, F, F_A	$1 \le f \le f_u$ [a]	$0,534 + 0,036/\sqrt{f} + 4 \times 0,002\,5$
BCT-B-L	$1 \le f \le 1\,000$	$0,118 \times \left(0,534 + 0,036/\sqrt{f}\right) + 2 \times 0,002\,5$
BCT-B-M	$1 \le f \le 1\,000$	$0,25 \times \left(0,534 + 0,036/\sqrt{f}\right) + 2 \times 0,002\,5$
I	$1 \le f \le 2\,000$	$0,3 \times \left(0,534 + 0,036/\sqrt{f}\right) + 2 \times 0,002\,5$
II	$1 \le f \le 2\,000$	$0,3 \times \left(0,534 + 0,036/\sqrt{f}\right) + 2 \times 0,002\,5$

[a] f_u is the upper frequency of the Class.

Table 19 – Informative propagation delay values for a channel at key frequencies

Maximum propagation delay µs												
Frequency MHz	**Class**											
	A	**B**	**C**	**D**	**E**	**E_A**	**F**	**F_A**	**BCT-B-L**[a]	**BCT-B-M**[a]	**I**[a]	**II**[a]
0,1	20,000	5,000	–	–	–	–	–	–	–	–	–	–
1	–	5,000	0,580	0,580	0,580	0,580	0,580	0,580	0,072	0,148	0,176	0,176
16	–	–	0,553	0,553	0,553	0,553	0,553	0,553	0,069	0,141	0,168	0,168
100	–	–	–	0,548	0,548	0,548	0,548	0,548	0,068	0,139	0,166	0,166
250	–	–	–	–	0,546	0,546	0,546	0,546	0,068	0,139	0,166	0,166
500	–	–	–	–	–	0,546	0,546	0,546	0,068	0,139	0,166	0,166
600	–	–	–	–	–	–	0,545	0,545	0,068	0,139	0,166	0,166
1 000	–	–	–	–	–	–	–	0,545	0,068	0,139	0,166	0,166
1 600	–	–	–	–	–	–	–	–	–	–	0,165	0,165
2 000	–	–	–	–	–	–	–	–	–	–	0,165	0,165

[a] Values reflect reduced channel lengths as compared to those of other Classes.

6.3.3.11 Delay skew

The delay skew requirements are applicable to all cabling Classes.

The delay skew between all pairs of a channel shall meet the requirements in Table 20.

Table 20 – Delay skew for a channel

Class	Frequency MHz	Maximum delay skew µs
A	f = 0,1	N/A
B	0,1 ≤ f ≤ 1	N/A
C	1 ≤ f ≤ 16	0,050 [a]
D	1 ≤ f ≤ 100	0,050 [a, e]
E	1 ≤ f ≤ 250	0,050 [a, e]
E_A	1 ≤ f ≤ 500	0,050 [a, e]
F	1 ≤ f ≤ 600	0,030 [b, e]
F_A	1 ≤ f ≤ 1 000	0,030 [b, e]
BCT-B-L	1 ≤ f ≤ 1 000	0,006 [c, e]
BCT-B-M	1 ≤ f ≤ 1 000	0,009 [d, e]
I	1 ≤ f ≤ 2 000	0,016 [f, h]
II	1 ≤ f ≤ 2 000	0,010 [g, h]

[a] This is the result of the calculation 0,045 + 4 × 0,001 25.

[b] This is the result of the calculation 0,025 + 4 × 0,001 25.

[c] This is the result of the calculation 0,118 × 0,025 + 2 × 0,001 25.

[d] This is the result of the calculation 0,25 × 0,025 + 2 × 0,001 25.

[e] Delay skew of any given installed cabling channel shall not vary by more than 0,010 µs within this requirement, due to effects such as the daily temperature variation.

[f] This is the result of the calculation 0,045 × 0,3 + 2 × 0,001 25.

[g] This is the result of the calculation 0,025 × 0,3 + 2 × 0,001 25.

[h] Delay skew between any two channel pairs due to environmental conditions shall not vary by more than 3 ns within the channel delay skew requirement (this is met by design).

6.3.3.12 Unbalance attenuation and coupling attenuation

6.3.3.12.1 General

Unbalance attenuation (*TCL* and *ELTCTL*) is specified for unscreened systems, and for Class I and Class II screened systems. Coupling attenuation is specified for screened systems.

Annex C provides additional information regarding unbalance attenuation and coupling attenuation.

6.3.3.12.2 Unbalance attenuation, near-end

The unbalance attenuation near-end is measured as transverse conversion loss (*TCL*).

Minimum *TCL* requirements are applicable to unscreened channels and Class I and II screened channels. The *TCL* of a channel that is intended to be subjected to an environmental classification E_x shall meet the requirements in Table 21. The *TCL* of a Class I or II channel shall meet the requirements of Table 23.

The *TCL* of each pair of a channel, at maximum implementation, at key frequencies is given in Table 22 and Table 24 for information only.

The *TCL* requirements shall be met at both ends of the cabling.

Table 21 – TCL for channel for unscreened channels

Class	Frequency MHz	Environmental classification		
		E_1	E_2 [c]	E_3 [c]
		Minimum TCL[a] dB		
A	0,1	30	30	30
B	f = 0,1	40	40	40
	f = 1	20	20	20
C	$1 \le f \le 16$	$30 - 5\lg(f)$	$30 - 5\lg(f)$	$30 - 5\lg(f)$
D, E, E_A	$1 \le f < 30$	$53 - 15\lg(f)$	$63 - 15\lg(f)$	$73 - 15\lg(f)$
	$30 \le f \le f_u$ [b]	$60{,}3 - 20\lg(f)$	$70{,}3 - 20\lg(f)$	$80{,}3 - 20\lg(f)$

[a] Calculated values of greater than 40 dB shall revert to a minimum requirement of 40 dB.

[b] *TCL* at frequencies above 250 MHz are for information only. f_u is the upper frequency of the Class.

[c] The reference implementations of this and other standards of the ISO/IEC 11801 series do not ensure conformance with this requirement for E_2 or E_3.

Table 22 – Informative TCL values for unscreened channels at key frequencies

Frequency MHz	Minimum TCL dB											
	Class											
	A			B			C			D, E, E_A		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
0,1	30,0	30,0	30,0	40,0	40,0	40,0	–	–	–	–	–	–
1	–	–	–	20,0	20,0	20,0	30,0	30,0	30,0	40,0	40,0	40,0
16	–	–	–	–	–	–	24,0	24,0	24,0	34,9	34,9	34,9
30	–	–	–	–	–	–	–	–	–	30,8	30,8	30,8
100	–	–	–	–	–	–	–	–	–	23,0	23,0	23,0
250	–	–	–	–	–	–	–	–	–	17,0	17,0	17,0

Table 23 – TCL for Class I and II screened channels

Class	Frequency MHz	Cable pair screening	Environmental classification		
			E_1	E_2	E_3
			Minimum TCL dB		
I	$1 \le f \le 2\,000$	unscreened pairs	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]
I	$1 \le f \le 2\,000$	screened pairs	$50{,}0 - 17\lg(f)$ [b, c]	$50{,}0 - 17\lg(f)$ [b, c]	$50{,}0 - 17\lg(f)$ [b, c]
II	$1 \le f \le 2\,000$	unscreened pairs	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]
II	$1 \le f \le 2\,000$	screened pairs	$50{,}0 - 17\lg(f)$ [b, c]	$50{,}0 - 17\lg(f)$ [b, c]	$50{,}0 - 17\lg(f)$ [b, c]

[a] Calculated values of greater than 40 dB shall revert to a minimum requirement of 40 dB.

[b] Calculated values of greater than 30 dB shall revert to a minimum requirement of 30 dB.

[c] Calculated values of less than 3 dB shall revert to a requirement of 3 dB.

Table 24 – Informative TCL values for Class I and II screened channels at key frequencies

Minimum TCL dB												
Frequency MHz	**Class**											
	I (unscreened pairs)			**I (screened pairs)**			**II (unscreened pairs)**			**II (screened pairs)**		
	E_1	**E_2**	**E_3**	**E_1**	**E_2**	**E_3**	**E_1**	**E_2**	**E_3**	**E_1**	**E_2**	**E_3**
1	40,0	40,0	40,0	30,0	30,0	30,0	40,0	40,0	40,0	30,0	30,0	30,0
100	26,0	26,0	26,0	16,0	16,0	16,0	26,0	26,0	26,0	16,0	16,0	16,0
250	19,2	19,2	19,2	9,2	9,2	9,2	19,2	19,2	19,2	9,2	9,2	9,2
500	14,1	14,1	14,1	4,1	4,1	4,1	14,1	14,1	14,1	4,1	4,1	4,1
1 000	9,0	9,0	9,0	3,0	3,0	3,0	9,0	9,0	9,0	3,0	3,0	3,0
1 600	5,5	5,5	5,5	3,0	3,0	3,0	5,5	5,5	5,5	3,0	3,0	3,0
2 000	3,9	3,9	3,9	3,0	3,0	3,0	3,9	3,9	3,9	3,0	3,0	3,0

6.3.3.12.3 Unbalance attenuation, far-end

The unbalance attenuation far-end is measured as equal level transverse conversion transfer loss (*ELTCTL*).

Minimum *ELTCTL* requirements are only applicable to channel Classes D through E_A, I and II.

The *ELTCTL* of a channel that is intended to be subjected to an environmental classification E_x shall meet the requirements in Table 25. The *ELTCTL* of a Class I or II channel shall meet the requirements of Table 27.

The *ELTCTL* of each pair of a channel, at maximum implementation, at key frequencies is given in Table 26 and Table 28 for information only.

The *ELTCTL* requirements shall be met at both ends of the cabling and shall be achieved by design and installation in accordance with manufacturer's instructions.

Table 25 – ELTCTL for channel for unscreened channels

Class	**Frequency** MHz	**Environmental classification**		
		E_1	**E_2**	**E_3**
		Minimum ELTCTL[a] dB		
D, E, E_A,	$1 \le f < 30$	$30 - 20\lg(f)$	$40 - 20\lg(f)$	$50 - 20\lg(f)$
[a] Calculated values of greater than 40 dB shall revert to a minimum requirement of 40 dB.				

Table 26 – Informative ELTCTL values for unscreened channels at key frequencies

Minimum ELTCTL dB			
Frequency MHz	**Class**		
	D, E, E_A		
	E_1	**E_2**	**E_3**
1	30,0	40,0	40,0
16	5,9	15,9	25,9
30	0,5	10,5	20,5

Table 27 – ELTCTL for Class I and II channels

Class	**Frequency** MHz	**Cable pair screening**	**Environmental classification**		
			E_1	**E_2**	**E_3**
			Minimum ELTCTL dB		
I	$1 \leq f \leq 2\,000$	unscreened pairs	$44,6 - 20\lg(f)$ [a, c]	$44,6 - 20\lg(f)$ [a, c]	$44,6 - 20\lg(f)$ [a, c]
I	$1 \leq f \leq 2\,000$	screened pairs	$34,6 - 20\lg(f)$ [b, c]	$34,6 - 20\lg(f)$ [b, c]	$34,6 - 20\lg(f)$ [b, c]
II	$1 \leq f \leq 2\,000$	unscreened pairs	$44,6 - 20\lg(f)$ [a, c]	$44,6 - 20\lg(f)$ [a, c]	$44,6 - 20\lg(f)$ [a, c]
II	$1 \leq f \leq 2\,000$	screened pairs	$34,6 - 20\lg(f)$ [b, c]	$34,6 - 20\lg(f)$ [b, c]	$34,6 - 20\lg(f)$ [b, c]

[a] Calculated values of greater than 40 dB shall revert to a minimum requirement of 40 dB.
[b] Calculated values of greater than 30 dB shall revert to a minimum requirement of 30 dB.
[c] Calculated values of less than 3 dB shall revert to a requirement of 3 dB.

Table 28 – Informative ELTCTL values for Class I and II channels at key frequencies

Minimum ELTCTL dB												
Frequency MHz	**Class**											
	I (unscreened pairs)			**I (screened pairs)**			**II (unscreened pairs)**			**II (screened pairs)**		
	E_1	**E_2**	**E_3**	**E_1**	**E_2**	**E_3**	**E_1**	**E_2**	**E_3**	**E_1**	**E_2**	**E_3**
1	40,0	40,0	40,0	30,0	30,0	30,0	40,0	40,0	40,0	30,0	30,0	30,0
100	4,6	4,6	4,6	3,0	3,0	3,0	4,6	4,6	4,6	3,0	3,0	3,0
250	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
500	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
1 000	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
1 600	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
2 000	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0

6.3.3.12.4 Coupling attenuation

Minimum coupling attenuation requirements are only applicable to channel Classes D through F_A, BCT-B, I and II.

The coupling attenuation of a channel that is intended to be subjected to an environmental classification E_x shall meet the requirements in Table 29. The coupling attenuation requirements shall be met at both ends of the cabling and shall be achieved by design and installation in accordance with manufacturer's instructions.

Table 29 – Coupling attenuation for a channel for screened channels

Class	Frequency MHz	Environmental classification		
		E_1	E_2	E_3
		Minimum coupling attenuation dB		
D, E, E_A, F, F_A	$30 \leq f \leq 100$	40	50	60
	$100 \leq f \leq f_u$ [a]	$80 - 20\lg(f)$	$90 - 20\lg(f)$	$100 - 20\lg(f)$
BCT-B	$30 \leq f < 300$	85	85	85
	$300 \leq f < 470$	80	80	80
	$470 \leq f \leq 1\,000$	75	75	75
I, II	$30 \leq f \leq 100$	50	50	60
	$100 \leq f \leq 2\,000$	$90 - 20\lg(f)$	$90 - 20\lg(f)$	$100 - 20\lg(f)$

[a] f_u is the upper frequency of the Class.

6.3.3.13 Alien crosstalk

6.3.3.13.1 General

The following alien crosstalk requirements are applicable to Classes E_A, F_A, I, and II. Alien crosstalk of Class F is considered to be as good as the alien crosstalk performance specified for Class E_A. For qualification of alien crosstalk using coupling attenuation see 6.3.3.13.6.

6.3.3.13.2 Power sum alien NEXT

The *PS ANEXT* of each pair of a channel shall meet the requirements derived by the formula in Table 30.

The *PS ANEXT* of each pair of a channel at key frequencies is given in Table 31 for information only.

The *PS ANEXT* requirements shall be met at both ends of the channel.

$PS\ ANEXT_k$ of pair k is computed as follows:

$$PS\ ANEXT_k = -10\lg\left[\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{\frac{-ANEXT_{l,i,k}}{10}}\right] \qquad (6)$$

where

k is the number of the disturbed pair in the disturbed channel;

i is the number of the disturbing pair in a disturbing channel l;

l is the number of the disturbing channel;

N is the number of disturbing channels;

n is the number of disturbing pairs in disturbing channel l;

$ANEXT_{l,i,k}$ is the alien near-end crosstalk loss coupled from pair i of disturbing channel (l) to the pair k of the disturbed channel.

Table 30 – PS ANEXT for a channel

Class	Frequency MHz	Minimum PS ANEXT dB
E_A [a, b]	$1 \leq f < 100$	$80 - 10\lg(f)$
	$100 \leq f \leq 500$	$90 - 15\lg(f)$
F_A [a, b]	$1 \leq f < 100$	$95 - 10\lg(f)$
	$100 \leq f \leq 1\,000$	$105 - 15\lg(f)$
I [c]	$1 \leq f < 100$	$105 - 10\lg(f)$
	$100 \leq f \leq 2\,000$	$115 - 15\lg(f)$
II [c]	$1 \leq f < 100$	$105 - 10\lg(f)$
	$100 \leq f \leq 2\,000$	$115 - 15\lg(f)$

[a] PS ANEXT at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[b] If the average insertion loss of all disturbed pairs at 100 MHz, $IL_{100\text{ MHz,avg}}$, is less than 7 dB, then subtract the following for $f \geq 100$ MHz:

$$\text{minimum}\left\{7 \cdot \frac{f-100}{400} \cdot \frac{7-IL_{100\text{MHz,avg}}}{IL_{100\text{MHz,avg}}},\ 6 \cdot \frac{f-100}{400}\right\}$$

where

f is the frequency in MHz;

$$IL_{100\text{MHz, avg}} = \frac{1}{4}\sum_{i=1}^{4} IL_{100\text{ MHz},i}\,;$$

$IL_{100\text{MHz},i}$ is the insertion loss of a pair i at 100 MHz.

[c] PS ANEXT at frequencies that correspond to calculated values of greater than 75,0 dB shall revert to a minimum requirement of 75,0 dB.

Table 31 – Informative PS ANEXT values for a channel at key frequencies

Frequency MHz	Minimum PS ANEXT dB Class E_A	F_A	I	II
1	67,0	67,0	75,0	75,0
100	60,0	67,0	75,0	75,0
250	54,0	67,0	75,0	75,0
500	49,5	64,5	74,5	74,5
1 000	–	60,0	70,0	70,0
1 600	–	–	66,9	66,9
2 000	–	–	65,5	65,5

6.3.3.13.3 PS $ANEXT_{avg}$

The *PS* $ANEXT_{avg}$ of a channel shall meet the requirements derived by the formulas in Table 32.

The *PS* $ANEXT_{avg}$ of each pair of a channel, at maximum implementation, at key frequencies is given in Table 33 for information only.

The *PS* $ANEXT_{avg}$ requirements shall be met at both ends of the channel.

PS ANEXT$_{avg}$ is computed as follows:

$$PS\ ANEXT_{avg} = \frac{1}{n}\left[\sum_{k=1}^{n} PS\ ANEXT_k\right] \quad (7)$$

where

k is the number of the disturbed pair in the disturbed channel;

n is the number of disturbed pairs in the disturbed channel;

$PS\ ANEXT_k$ is the power sum alien near-end crosstalk loss coupled to pair k of the disturbed channel.

Table 32 – PS ANEXT$_{avg}$ for a channel

Class	**Frequency** MHz	**Minimum PS ANEXT$_{avg}$** [a, b] dB
E_A	$1 \le f < 100$	$82{,}25 - 10\lg(f)$
	$100 \le f \le 500$	$92{,}25 - 15\lg(f)$

[a] *PS ANEXT*$_{avg}$ at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[b] If the average insertion loss of all disturbed pairs at 100 MHz, $IL_{100\text{MHz,avg}}$, is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

$$\text{minimum}\left\{7 \cdot \frac{f-100}{400} \cdot \frac{7 - IL_{100\text{MHz,avg}}}{IL_{100\text{MHz,avg}}},\ 6 \cdot \frac{f-100}{400}\right\}$$

where

f is the frequency in MHz;

$IL_{100\text{MHz,avg}} = \frac{1}{4}\sum_{i=1}^{4} IL_{100\text{MHz},i}$;

$IL_{100\text{MHz},i}$ is the insertion loss of a pair i at 100 MHz.

Table 33 – Informative PS ANEXT$_{avg}$ values for a channel at key frequencies

Frequency MHz	**Minimum Class E_A PS ANEXT$_{avg}$** dB
1	67,0
100	62,3
250	56,3
500	51,8

6.3.3.13.4 Power sum alien ACR-F

The *PS AACR-F* of each pair of a channel shall meet the requirements in Table 34.

The *PS AACR-F* of each pair of a channel, at maximum implementation, at key frequencies is given in Table 35 for information only.

The *PS AACR-F* shall be met at both ends of the channel.

The *PS AACR-F* is computed based on *PS AFEXT*, and insertion losses of disturbing and disturbed channels.

The $PS\ AACR\text{-}F_k$ of disturbed pair k is determined according to Equation (8).

$$PS\ AACR\text{-}F_k = PS\ AFEXT_k - IL_k \quad (8)$$

where

IL_k is the measured insertion loss of pair k in the disturbed channel;

$PS\ AFEXT_k$ is the power sum alien far-end crosstalk loss coupled to pair k.

with

$$PS\ AFEXT_k = -10\lg\left[\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{\frac{-AFEXT_{l,i,k}}{10}}\right] \quad (9)$$

where

k is the number of the disturbed pair in the disturbed channel;

i is the number of the disturbing pair in a disturbing channel l;

l is the number of the disturbing channel;

N is the number of disturbing channels;

n is the number of disturbing pairs in disturbing channel l;

$AFEXT_{l,i,k}$ is the alien far-end crosstalk loss coupled from pair i of disturbing channel (l) to the pair k of the disturbed channel.

Table 34 – PS AACR-F for a channel

Class	**Frequency** MHz	**Minimum PS AACR-F** dB
E_A [a, c]	$1 \le f \le 500$	$77 - 20\lg(f)$
F_A [a, c]	$1 \le f \le 1\,000$	$92 - 20\lg(f)$
I [b, d]	$1 \le f \le 2\,000$	$101 - 20\lg(f)$
II [b, d]	$1 \le f \le 2\,000$	$101 - 20\lg(f)$

[a] *PS AACR-F* at frequencies that correspond to calculated *PS AFEXT* values of greater than 67,0 dB or 102 − 15lg(f) dB shall be for information only.

[b] *PS AACR-F* at frequencies that correspond to calculated values of greater than 75,0 dB shall revert to a minimum requirement of 75,0 dB.

[c] The reference lengths are 100 m.

[d] The reference lengths are 30 m.

Table 35 – Informative PS AACR-F values for a channel at key frequencies

Minimum PS AACR-F dB				
Frequency MHz	**Class**			
	E_A	F_A	I[b]	II[b]
1[a]	64,7	64,8	75,0	75,0
100	37,0	52,0	61,0	61,0
250	29,0	44,0	53,0	53,0
500	23,0	38,0	47,0	47,0
1 000	–	32,0	41,0	41,0
1 600	–	–	36,9	36,9
2 000	–	–	35,0	35,0

[a] *PS AACR-F* values at 1 MHz are affected by the computed insertion loss.

[b] Values reflect reduced channel lengths as compared to those of other Classes.

6.3.3.13.5 PS AACR-F_{avg}

The *PS AACR-*F_{avg} of a channel shall meet the requirements in Table 36.

The *PS AACR-*F_{avg} of each pair of a channel, at maximum implementation, at key frequencies is given in Table 37 for information only.

The *PS AACR-*F_{avg} requirements shall be met at both ends of the channel.

PS AACR-F_{avg} is computed as follows:

$$PSAACR\text{-}F_{avg} = \frac{1}{n}\left[\sum_{k=1}^{n} PSAACR\text{-}F_k\right] \tag{10}$$

where

k is the number of the disturbed pair in the disturbed channel;

n is the number of disturbed pairs in the disturbed channel;

$PS\ AACR\text{-}F_k$ is the power sum alien far-end crosstalk loss coupled to pair k of the disturbed channel relative to insertion loss of pair k of the disturbed channel.

Table 36 – PS AACR-F_{avg} for a channel

Class	**Frequency** MHz	**Minimum PS AACR-F_{avg}** [a] dB
E_A	$1 \le f \le 500$	$81 - 20\lg(f)$

[a] *PS AACR-*F_{avg} at frequencies that correspond to *PS AFEXT* values of greater than 67,0 dB or $102 - 15\lg(f)$ dB shall be for information only.

Table 37 – Informative PS AACR-F$_{avg}$ values for a channel at key frequencies

Frequency MHz	**Minimum Class E$_A$ PS AACR-F$_{avg}$** dB
1[a]	64,7
100	41,0
250	33,0
500	27,0

[a] *PS AACR-F$_{avg}$* values at 1 MHz are affected by the computed insertion loss.

6.3.3.13.6 Alien crosstalk and coupling attenuation for screened channels

When coupling attenuation for a channel meets or exceeds the values of Table 38, the PS ANEXT limits are met by design.

When coupling attenuation for a channel meets or exceeds the values of Table 38, the *PS AACR-F* limits are met by design.

Table 38 – Alien crosstalk and coupling attenuation for screened channels

Class	**Frequency** MHz	**Minimum coupling attenuation to meet PS ANEXT limits** dB	**Minimum coupling attenuation to meet PS AACR-F limits** dB
E$_A$	$30 \le f \le 100$	50	50
	$100 \le f \le 500$	$90 - 20\lg(f)$	$90 - 20\lg(f)$
F	$30 \le f \le 100$	50	50
	$100 \le f \le 600$	$90 - 20\lg(f)$	$90 - 20\lg(f)$
F$_A$	$30 \le f \le 100$	65	65
	$100 \le f \le 1000$	$105 - 20\lg(f)$	$105 - 20\lg(f)$
I	$30 \le f \le 100$	50	65
	$100 \le f \le 2\,000$	$90 - 20\lg(f)$	$105 - 20\lg(f)$
II	$30 \le f \le 100$	50	65
	$100 \le f \le 2\,000$	$90 - 20\lg(f)$	$105 - 20\lg(f)$

6.4 Coaxial cabling transmission performance

6.4.1 General

This document specifies Class BCT-C up to 3 000 MHz. The insertion loss performance of BCT-C cabling is further subdivided into two sub-Classes, L and M. These sub-Classes have identical performance requirements for all other transmission parameters.

Annex E lists known applications by Classes.

The performance limits for coaxial cabling channels are given in 6.4.3. These limits are derived from the component performance limits of Clauses 9 and 10 using the reference implementations of the cabling design documents. The performance limits for coaxial cabling links are given in Clause 7.

The requirements in 6.4 are given by limits computed to one decimal place, using the formula for a defined frequency range. The limits for propagation delay are computed to three decimal places. The additional tables are for information only and have limits derived from the relevant formula at key frequencies.

6.4.2 Component choice

The nominal impedance of channels is 75 Ω. This is achieved by suitable design and appropriate choice of cabling components. For the purposes of this document, insertion loss is measured with source and load impedances of 75 Ω.

6.4.3 Channel parameters

6.4.3.1 Return loss

The return loss (*RL*) of a channel shall meet the requirements in Table 39.

The return loss requirements shall be met at both ends of the cabling.

Table 39 – Return loss for a channel

Class	Frequency MHz	Minimum return loss dB
BCT-C	$5 \le f < 470$	18,0
	$470 \le f < 1\,000$	16,0
	$1\,000 \le f \le 3\,000$	10,0

6.4.3.2 Insertion loss

The insertion loss (*IL*) of a channel shall meet the requirements in Table 40.

The *IL* at maximum implementation, at key frequencies is given in Table 41 for information only.

Table 40 – Insertion loss for a channel

Class	Frequency MHz	Maximum insertion loss [a] dB
BCT-C-L	$1 \le f \le 100$	$(0{,}3 + 0.05) \times \left(0{,}625\sqrt{f} + 0{,}0001 f\right) + 2 \times 0{,}0001\, f$
	$100 \le f \le 3000$	$(0{,}3 + 0.05) \times \left(0{,}597\sqrt{f} + 0{,}0026 f\right) + 2 \times 0{,}0001\, f$
BCT-C-M	$1 \le f \le 100$	$(0{,}69 + 0.05) \times \left(0{,}625\sqrt{f} + 0{,}0001 f\right) + 2 \times 0{,}0001\, f$
	$100 \le f \le 3000$	$(0{,}69 + 0.05) \times \left(0{,}597\sqrt{f} + 0{,}0026 f\right) + 2 \times 0{,}0001\, f$

[a] Insertion loss (*IL*) at frequencies that correspond to calculated values of less than 2,0 dB shall revert to a maximum requirement of 2,0 dB.

Table 41 – Informative insertion loss values for a channel at key frequencies

Frequency MHz	Maximum insertion loss dB	
	Class BCT-C-L	Class BCT-C-M
1	2,0	2,0
10	2,0	2,0
100	2,2	4,7
200	3,2	6,7
600	5,8	12,1
1 000	7,7	16,1
2 400	12,9	26,7
3 000	14,8	30,6

6.4.3.3 Direct current loop resistance

The DC loop resistance of a channel shall meet the requirements in Table 42.

Table 42 – DC loop resistance for a channel

Maximum DC loop resistance Ω	
Class BCT-C-L	Class BCT-C-M
3,2	6,7

6.4.3.4 DC current carrying capacity

The minimum DC current carrying capacity of a channel shall meet the requirements in Table 43. This shall be achieved by an appropriate design.

Table 43 – DC current carrying capacity for a channel

Minimum DC current carrying capacity mA
Class BCT-C
500,0

6.4.3.5 Operating voltage

The minimum operating voltage of a channel shall meet the requirements in Table 44. This shall be achieved by an appropriate design.

Table 44 – Operating voltage for a channel

Minimum operating voltage V DC
Class BCT-C
72,0

6.4.3.6 Screening attenuation

The minimum screening attenuation of a channel shall meet the requirements in Table 45. This shall be achieved by an appropriate design.

Table 45 – Screening attenuation for a channel

Class	**Frequency** MHz	**Minimum screening attenuation** dB
BCT-C	$30 \leq f < 300$	85,0
	$300 \leq f < 470$	80,0
	$470 \leq f < 1\ 000$	75,0
	$1\ 000 \leq f \leq 3\ 000$	55,0

6.5 Optical fibre cabling transmission performance

6.5.1 Component choice

Optical fibre components are referenced in Clauses 9, 10 and 11. The optical fibres are defined in terms of physical construction (core/cladding diameter) and their transmission performance Category within a cable. The selection of an optical fibre cabling channel design for use within a generic cabling system should be made with reference to Annex E.

6.5.2 Channel parameters

6.5.2.1 Channel attenuation

For the purpose of defining channel limits, the cable requirements of Table 93 and the connecting hardware requirements of Table 136 shall be used.

The attenuation of a channel shall be measured according to ISO/IEC 14763-3.

The attenuation of channels at a specified wavelength shall not exceed the sum of the specified attenuation values for the components at that wavelength (where the attenuation of a length of cabled optical fibre is calculated from its attenuation coefficient multiplied by its length).

6.5.2.2 Propagation delay

Propagation delay of a channel can be approximated by the application of a conservative value per unit length described in 9.5.2.4. The channel length shall comply with the application length requirements (see Annex E for information for supported applications).

7 Link performance requirements

7.1 General

The 2-connection link cabling under test in Figure 7 may be either in the backbone or in the premises-specific cabling subsystems (the permanent link (*PL*)) defined in the cabling design standards. The designation of the TE is dependent upon the applicable cabling subsystem.

The 3-connection link cabling under test in Figure 7 may be found in the premises-specific cabling subsystems defined in the cabling design standards and is also termed the permanent link. It comprises a fixed cabling element from Distributor 1 to the Consolidation point and a Consolidation point cord to the TE outlet. The designation of the Consolidation point and the TE is dependent upon the applicable cabling subsystem. Measurements made for this configuration are invalid if the Consolidation point cord is changed.

The consolidation point link shall be tested according to the requirements of a 2-connection link. The name applied to this link is defined in the premises-specific cabling subsystems defined in other parts of the ISO/IEC 11801 series.

In all configurations the test reference plane of a link is within the test cord. The test cord connector which mates with the termination point of the link under test is part of the link under test.

Consideration should be given to calculating worst case performance at the worst case temperatures, when measuring performance at other temperatures.

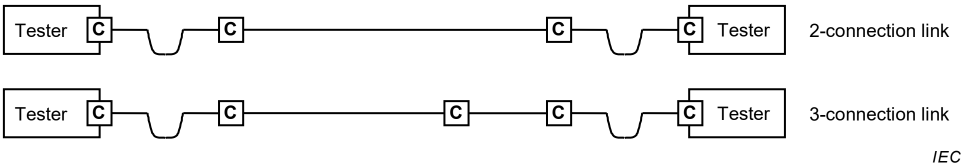
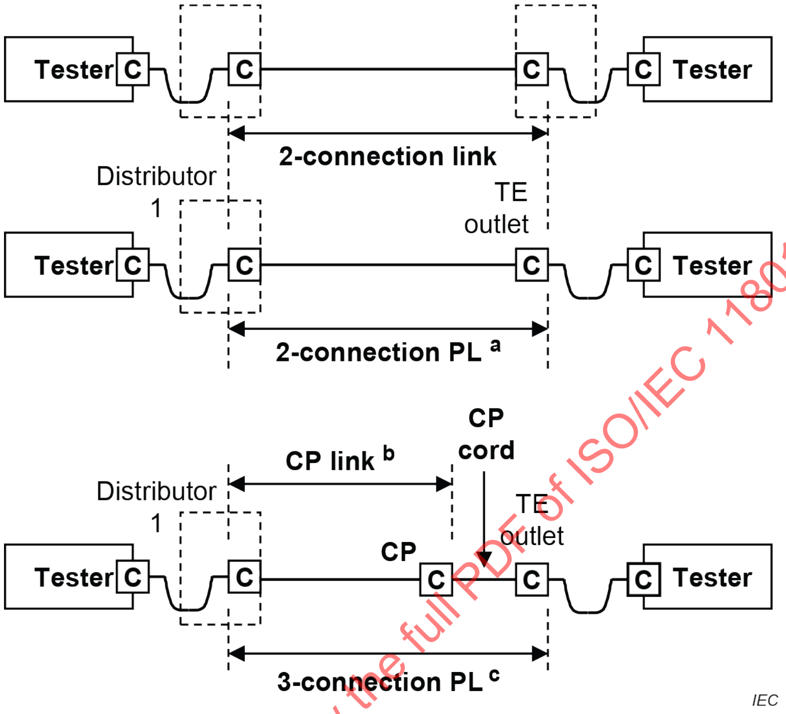


Figure 6 – Link options



[a] The limits for the 2-connection PL are those of a 2-connection link.

[b] The limits for the CP link are those of a 2-connection link.

[c] The limits for the 3-connection PL are those of a 3-connection link.

Figure 7 – Link designations

7.2 Balanced cabling

7.2.1 General

Subclause 7.2 contains requirements for balanced links of Classes A through F_A, BCT-B, Class I and II.

Two- and three-connection links of Figure 6 and Figure 7 are supported by Classes A through F_A link models.

Three-connection links of Figure 7 are not supported by Class BCT-B, Class I or II link models.

The parameters specified in 7.2 apply to balanced links with screened or unscreened cable elements, with or without an overall screen, unless explicitly stated otherwise. When required, link measurements (including those required for link calculations) shall be measured according to IEC 61935-1, unless otherwise specified in 7.2.

The nominal impedance of balanced links is 100 Ω. This impedance is achieved by suitable design, and an appropriate choice of cabling components.

The requirements in 7.2 are given by limits computed, to one decimal place, using the formula for a defined frequency range. The limits for the propagation delay and delay skew are computed to three decimal places. Where relevant, in the informative tables for maximum implementation at key frequencies, the values of L, Y and n are: Y = 1 for all Classes, L = 90, and n = 3 for Classes A to F_A, L = 7,8 and n = 2 for Class BCT-B-L, L = 21,0 and n = 2 for Class BCT-B-M, and L = 26,0 and n = 2 for Classes I and II. Many specifications in 7.2 have a plateau in the specified requirement. These plateaus do not accurately depict the system performance. They have been added for measurement purposes.

7.2.2 Return loss

The *RL* of each pair of a 2-connection or 3-connection link shall meet the requirements derived by the formula in Table 46.

The *RL* of each pair of a link at key frequencies is given in Table 47 for information only.

The *RL* requirements shall be met at both ends of the cabling.

Table 46 – Return loss for 2-connection or 3-connection link

Class	**Frequency** MHz	**Minimum return loss** [a] dB
C	$1 \leq f \leq 16$	15,0
D	$1 \leq f \leq 20$	19,0
	$20 < f \leq 100$	$32 - 10\ \lg(f)$
E	$1 \leq f \leq 10$	21,0
	$10 < f \leq 40$	$26 - 5\ \lg(f)$
	$40 < f \leq 250$	$34 - 10\ \lg(f)$
E_A	$1 \leq f \leq 10$	21,0
	$10 < f \leq 40$	$26 - 5\ \lg(f)$
	$40 < f \leq 398,1$	$34 - 10\ \lg(f)$
	$398,1 < f \leq 500$	8,0
F	$1 \leq f \leq 10$	21,0
	$10 < f \leq 40$	$26 - 5\ \lg(f)$
	$40 < f \leq 251,2$	$34 - 10\ \lg(f)$
	$251,2 < f \leq 600$	10,0
F_A	$1 \leq f \leq 10$	21,0
	$10 < f \leq 40$	$26 - 5\ \lg(f)$
	$40 < f \leq 251,2$	$34 - 10\ \lg(f)$
	$251,2 < f \leq 631$	10,0
	$631 < f \leq 1\ 000$	$38 - 10\ \lg(f)$
BCT-B	$1 \leq f < 10$	21,0
	$10 \leq f < 100$	$27,6 - 6,3\ \lg(f)$
	$100 \leq f < 251,2$	$25 - 5\ \lg(f)$
	$251,2 \leq f < 600$	$25,7 - 5,3\ \lg(f)$
	$600 \leq f < 1000$	$36 - 9\ \lg(f)$
I	$1 \leq f < 3$	$21 + 4\lg(\frac{f}{3})$
	$3 \leq f < 10$	21,0
	$10 \leq f < 40$	$26 - 5\lg(f)$
	$40 \leq f < 100$	18,0
	$100 \leq f < 464.2$	$42 - 12\lg(f)$
	$464,2 \leq f < 631$	10,0
	$631 \leq f < 1000$	$38 - 10\lg(f)$
	$1000 \leq f < 1600$	8,0
	$1600 \leq f < 2\,000$	$8 - 19\lg(\frac{f}{1600})$
II	$1 \leq f < 3$	$21 + 4\lg(\frac{f}{3})$
	$3 \leq f < 10$	21,0

Class	Frequency MHz	Minimum return loss [a] dB
	$10 \le f < 40$	$26 - 5\lg(f)$
	$40 \le f < 100$	18,0
	$100 \le f < 464.2$	$42 - 12\lg(f)$
	$464{,}2 \le f < 631$	10,0
	$631 \le f < 1000$	$38 - 10\lg(f)$
	$1000 \le f < 1600$	8,0
	$1600 \le f < 2\,000$	$8 - 19\lg(\frac{f}{1600})$

[a] *RL* values at frequencies where the insertion loss is below 3,0 dB are for information only.

Table 47 – Informative return loss values for links at key frequencies

Frequency MHz	Minimum return loss dB								
	Class								
	C	D	E	E_A	F	F_A	BCT-B	I	II
1	15,0	19,0	21,0	21,0	21,0	21,0	21,0	19,1	19,1
16	15,0	19,0	20,0	20,0	20,0	20,0	20,0	20,0	20,0
100	–	12,0	14,0	14,0	14,0	14,0	15,0	18,0	18,0
250	–	–	10,0	10,0	10,0	10,0	13,0	13,2	13,2
500	–	–	–	8,0	10,0	10,0	11,4	10,0	10,0
600	–	–	–	–	10,0	10,0	11,0	10,0	10,0
1 000	–	–	–	–	–	8,0	9,0	8,0	8,0
1 600	–	–	–	–	–	–	–	8,0	8,0
2 000	–	–	–	–	–	–	–	6,2	6,2

7.2.3 Insertion loss/attenuation

The insertion loss of each pair of a 2-connection or 3-connection link shall meet the requirements derived by the formula in Table 48.

A method of establishing conformant link performance is to demonstrate that the margin between the measured value and the channel limits of Table 5 are adequate to accommodate any additional cabling components used to create a channel.

The insertion loss of each pair of a link, with maximum implementation, at key frequencies is given in Table 49 for information only.

Table 48 – Insertion loss for 2-connection or 3-connection link

Class	Frequency MHz	Maximum insertion loss [a] dB
A	f = 0,1	16,0
B	f = 0,1	5,5
	f = 1	5,8
C	$1 \le f \le 16$	$0{,}9 \times \left(3{,}23\sqrt{f}\right) + 3 \times 0{,}2$
D	$1 \le f \le 100$	$(L/100) \times \left(1{,}910\ 8\sqrt{f} + 0{,}022\ 2 \times f + 0{,}2/\sqrt{f}\right) + n \times 0{,}04 \times \sqrt{f}$
E	$1 \le f \le 250$	$(L/100) \times \left(1{,}82\sqrt{f} + 0{,}016\ 9 \times f + 0{,}25/\sqrt{f}\right) + n \times 0{,}02 \times \sqrt{f}$
E_A	$1 \le f \le 500$	$(L/100) \times \left(1{,}82\sqrt{f} + 0{,}009\ 1 \times f + 0{,}25/\sqrt{f}\right) + n \times 0{,}02 \times \sqrt{f}$
F	$1 \le f \le 600$	$(L/100) \times \left(1{,}8\sqrt{f} + 0{,}01 \times f + 0{,}2/\sqrt{f}\right) + n \times 0{,}02 \times \sqrt{f}$
F_A	$1 \le f \le 1\ 000$	$(L/100) \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + 0{,}25/\sqrt{f}\right) + n \times 0{,}02 \times \sqrt{f}$
BCT-B	$1 \le f \le 1\ 000$	$(L/100) \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + 0{,}25/\sqrt{f}\right) + 2 \times 0{,}02 \times \sqrt{f}$ [b]
I	$1 \le f \le 500$	$(L/100) \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + \frac{0{,}25}{\sqrt{f}}\right) + 2 \times \left(0{,}02 \times \sqrt{f}\right)$ [c]
	$500 \le f \le 2\ 000$	$(L/100) \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + \frac{0{,}25}{\sqrt{f}}\right) + 2 \times \left(0{,}006\ 49 \times \sqrt{f} + 0{,}000\ 605 \times f\right)$ [c]
II	$1 \le f \le 2\ 000$	$(L/100) \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + 0{,}25/\sqrt{f}\right) + 2 \times 0{,}02 \times \sqrt{f}$ [c]

$L = L_{FC} + L_{CP} \times Y$

where

L_{FC} is the length of fixed cable (m);

L_{CP} is the length of link extension, where present (m);

Y is the ratio of link extension cable insertion loss (dB/m) to fixed cable insertion loss (dB/m) (see 9.3.2.6).

n = 2 for 2-connection link configurations (see Figure 6)

n = 3 for 3-connection link configurations (see Figure 6)

[a] Insertion loss (*IL*) at frequencies that correspond to calculated values of less than 4,0 dB shall revert to a maximum requirement of 4,0 dB.

[b] Insertion loss (*IL*) at frequencies that correspond to calculated values of less than 2,0 dB shall revert to a maximum requirement of 2,0 dB.

[c] Insertion loss (*IL*) at frequencies that correspond to calculated values of less than 3,0 dB shall revert to a maximum requirement of 3,0 dB.

Table 49 – Informative insertion loss values for links with maximum implementation at key frequencies

Frequency MHz	Maximum insertion loss dB											
	Class											
	A	B	C	D	E	E_A	F	F_A	BCT-B-L	BCT-B-M	I	II
0,1	16,0	5,5	–	–	–	–	–	–	–		–	–
1	–	5,8	4,0	4,0	4,0	4,0	4,0	4,0	2,0	2,0	3,0	3,0
16	–	–	12,2	7,7	7,1	7,0	6,9	6,8	2,0	2,0	3,0	3,0
100	–	–	–	20,4	18,5	17,8	17,7	17,3	2,0	4,3	5,2	5,2
250	–	–	–	–	30,7	28,9	28,8	27,7	3,0	6,9	8,4	8,4
500	–	–	–	–	–	42,1	42,1	39,8	4,2	9,9	12,0	12,0
600	–	–	–	–	–	–	46,6	43,9	4,6	10,9	13,3	13,2
1 000	–	–	–	–	–	–	–	57,6	6,1	14,3	17,7	17,4
1 600	–	–	–	–	–	–	–	–	–	–	23,3	22,4
2 000	–	–	–	–	–	–	–	–	–	–	26,5	25,3

7.2.4 NEXT

7.2.4.1 Pair-to-pair NEXT

The *NEXT* of each pair combination of a 2-connection or 3-connection link shall meet the requirements derived by the formula in Table 50.

The *NEXT* of each pair combination of a link, with maximum implementation, at key frequencies is given in Table 51 for information only.

The *NEXT* requirements shall be met at both ends of the cabling.

Table 50 – NEXT for 2-connection or 3-connection link

Class	Frequency MHz	Minimum NEXT [a, b, h] dB
A	$f = 0,1$	27,0
B	$0,1 \leq f \leq 1$	$25 - 5\lg(f)$
C	$1 \leq f \leq 16$	$40,1 - 15,8\lg(f)$
D	$1 \leq f \leq 100$	$-20\lg\left(10^{\frac{65,3-15\lg(f)}{-20}} + 10^{\frac{83-20\lg(f)}{-20}}\right)$
E	$1 \leq f \leq 250$	$-20\lg\left(10^{\frac{74,3-15\lg(f)}{-20}} + 10^{\frac{94-20\lg(f)}{-20}}\right)$
E_A [h]	$1 \leq f \leq 300$	$-20\lg\left(10^{\frac{74,3-15\lg(f)}{-20}} + 10^{\frac{94-20\lg(f)}{-20}}\right)$
	$300 < f \leq 500$	$87,46 - 21,57\lg(f)$ [c, d]

Class	Frequency MHz	Minimum NEXT [a, b, h] dB
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{102,4-15\lg(f)}{-20}}+10^{\frac{102,4-15\lg(f)}{-20}}\right)$
F_A [g]	$1 \le f \le 600$	$106,1 - 18,5\lg(f)$
	$600 < f \le 1\,000$	$124,85 - 25,25\lg(f)$ [e, f]
BCT-B	$1 \le f \le 600$	$106,1 - 18,5\lg(f)$
	$600 < f \le 1\,000$	$124,85 - 25,25\lg(f)$
I	$1 \le f \le 500$	$-20\lg\left(10^{\frac{75,3-15\lg(f)}{-20}}+2\times 10^{\frac{94-20\lg(f)}{-20}}\right)$
	$500 < f \le 2\,000$	$-20\lg\left(10^{\frac{75,3-15\lg(f)}{-20}}+2\times 10^{\frac{40-38\lg(f/500)}{-20}}\right)$
II	$1 \le f \le 1000$	$-20\lg\left(10^{\frac{105,4-15\lg(f)}{-20}}+2\times 10^{\frac{116,3-20\lg(f)}{-20}}\right)$
	$1000 < f \le 1600$	$-20\lg\left(10^{\frac{105,4-15\lg(f)}{-20}}+2\times 10^{\frac{56,3-90\lg(f/1000)}{-20}}\right)$
	$1600 < f \le 2\,000$	$-20\lg\left(10^{\frac{105,4-15\lg(f)}{-20}}+2\times 10^{\frac{37,93-40\lg(f/1600)}{-20}}\right)$

[a] *NEXT* at frequencies that correspond to calculated values of greater than 65,0 dB shall revert to a minimum requirement of 65,0 dB.

[b] *NEXT* values at frequencies where the insertion loss (*IL*) is below 4,0 dB are for information only.

[c] For 3-connection link configurations (see Figure 7), this formula is $102,22 – 27,54\lg(f)$.

[d] For 2-connection links, whenever the class E_A link insertion loss at 450 MHz is less than 12 dB, subtract the term $1,4((f – 450)/50)$ from the formula stated above for the range of 450 MHz to 500 MHz.

[e] For 3-connection link configuration (see Figure 7), this formula is $139,7 – 30,6\lg(f)$.

[f] For 2-connection links, whenever the class F_A link insertion loss at 900 MHz is less than 17 dB, subtract the term $2,8((f – 900)/100)$ from the formula stated above for the range of 900 MHz to 1 000 MHz.

[g] When using connecting hardware with enhanced performance at the connection B (see 10.2.5.1), the consolidation point link limits do not represent appropriate minimum performance requirements, and therefore do not apply. In this case, the 3-connection link shall be tested for compliance instead.

[h] The terms in the formulas are not intended to imply component performance.

Table 51 – Informative NEXT values for links with maximum implementation at key frequencies

Minimum NEXT dB											
Frequency MHz	**Class**										
	A	**B**	**C**	**D**	**E**	**E_A**	**F**	**F_A**	**BCT-B**	**I**	**II**
0,1	27,0	40,0	–	–	–	–	–	–	–	–	–
1	–	25,0	40,1	64,2	65,0	65,0	65,0	65,0	65,0	65,0	65,0
16	–	–	21,1	45,2	54,6	54,6	65,0	65,0	65,0	53,9	65,0
100	–	–	–	32,3	41,8	41,8	65,0	65,0	65,0	40,5	65,0
250	–	–	–	–	35,3	35,3	60,4	61,7	61,7	33,6	59,1
500	–	–	–	–	–	29,2 (27,9)[a]	55,9	56,1	56,1	28,4	53,6
600	–	–	–	–	–	–	54,7	54,7	54,7	26,2	52,1
1 000	–	–	–	–	–	–	–	49,1 (47,9)[a]	49,1	19,6	47,9
1 600	–	–	–	–	–	–	–	–	–	12,9	31,5
2 000	–	–	–	–	–	–	–	–	–	9,6	27,7

[a] Value applicable to 3-connection link configuration (see Figure 7).

7.2.4.2 Power sum NEXT

The *PS NEXT* requirements are applicable to Classes D through F_A, BCT-B, I and II.

The *PS NEXT* of each pair of a 2-connection or 3-connection link shall meet the requirements derived by the formula in Table 52.

The *PS NEXT* of each pair of a link, with maximum implementation, at key frequencies is given in Table 53 for information only.

The *PS NEXT* requirements shall be met at both ends of the cabling.

$PS\ NEXT_k$ of pair k is computed as follows:

$$PSNEXT_k = -10\lg \sum_{i=1,i\neq k}^{n} 10^{\frac{-NEXT_{ik}}{10}} \quad (11)$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

n is the total number of pairs;

$NEXT_{ik}$ is the near-end crosstalk loss coupled from pair i into pair k.

Table 52 – PS NEXT for 2-connection or 3-connection link

Class	Frequency MHz	Minimum PS NEXT [a, b, h] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{62,3-15\lg(f)}{-20}}+10^{\frac{80-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}}+10^{\frac{90-20\lg(f)}{-20}}\right)$
E_A [h]	$1 \le f \le 300$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}}+10^{\frac{90-20\lg(f)}{-20}}\right)$
	$300 < f \le 500$	$87,56 - 22,67\lg(f)$ [c, d]
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{99,4-15\lg(f)}{-20}}+10^{\frac{99,4-15\lg(f)}{-20}}\right)$
F_A [g]	$1 \le f \le 600$	$103,1 - 18,5\lg(f)$
	$600 < f \le 1\,000$	$121,85 - 25,25\lg(f)$ [e, f]
BCT-B	$1 \le f \le 600$	$103,1 - 18,5\lg(f)$
	$600 < f \le 1\,000$	$121,85 - 25,25\lg(f)$
I	$1 \le f \le 500$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}}+2\times10^{\frac{91-20\lg(f)}{-20}}\right)$
	$500 < f \le 2\,000$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}}+2\times10^{\frac{37-38\lg(f/500)}{-20}}\right)$
II	$1 \le f \le 1000$	$-20\lg\left(10^{\frac{102,4-15\lg(f)}{-20}}+2\times10^{\frac{113,3-20\lg(f)}{-20}}\right)$
	$1000 < f \le 1600$	$-20\lg\left(10^{\frac{102,4-15\lg(f)}{-20}}+2\times10^{\frac{53,3-90\lg(f/1000)}{-20}}\right)$
	$1600 < f \le 2\,000$	$-20\lg\left(10^{\frac{102,4-15\lg(f)}{-20}}+2\times10^{\frac{34,93-40\lg(f/1600)}{-20}}\right)$

[a] *PS NEXT* at frequencies that correspond to calculated values of greater than 62,0 dB shall revert to a minimum requirement of 62,0 dB.

[b] *PS NEXT* values at frequencies where the insertion loss *(IL)* is below 4,0 dB are for information only.

[c] For 3-connection link configurations (see Figure 7) this formula is $104,65 - 29,57\lg(f)$.

[d] For 2-connection links, whenever the class E_A link insertion loss at 450 MHz is less than 12 dB, subtract the term $1,4((f-450)/50)$ from the formula stated above for the range of 450 MHz to 500 MHz.

[e] For 3-connection link configurations (see Figure 7) this formula is $136,7 - 30,6\lg(f)$.

[f] For 2-connection links, whenever the class F_A link insertion loss at 900 MHz is less than 17 dB, subtract the term $2,8((f-900)/100)$ from the formula stated above for the range of 900 MHz to 1 000 MHz.

[g] When using connecting hardware with enhanced performance at connection B (see 10.2.5.1), the consolidation point link limits do not represent appropriate minimum performance requirements, and therefore do not apply. In this case, the 3-connection link shall be tested for compliance instead.

[h] The terms in the formulas are not intended to imply component performance.

Table 53 – Informative PS NEXT values for links with maximum implementation at key frequencies

Minimum PS NEXT dB								
Frequency MHz	**Class**							
	D	**E**	E_A	**F**	F_A	**BCT-B**	**I**	**II**
1	57,0	62,0	62,0	62,0	62,0	62,0	62,0	62,0
16	42,2	52,2	52,2	62,0	62,0	62,0	50,9	62,0
100	29,3	39,3	39,3	62,0	62,0	62,0	37,5	62,0
250	–	32,7	32,7	57,4	58,7	58,7	30,6	56,1
500	–	–	26,4 (24,8)[a]	52,9	53,1	53,1	25,4	50,6
600	–	–	–	51,7	51,7	51,7	23,2	49,1
1 000	–	–	–	–	46,1 (44,9)[a]	46,1	16,6	44,9
1 600	–	–	–	–	–	–	9,9	28,5
2 000	–	–	–	–	–	–	6,6	24,7

[a] Value applicable to 3-connection link configurations (see Figure 7).

7.2.5 Attenuation to crosstalk ratio at the near-end

7.2.5.1 General

The *ACR-N* requirements are applicable only to Classes D through F_A, BCT-B, I and II.

7.2.5.2 Pair-to-pair ACR-N

Pair-to-pair *ACR-N* is the difference between the pair-to-pair *NEXT* and the insertion loss of the cabling in decibels.

The *ACR-N* of each pair combination of a 2-connection or 3-connection link shall meet the difference of the *NEXT* requirement of Table 50 and the insertion loss requirement of Table 48 of the respective class.

The *ACR-N* of each pair combination of a link, with maximum implementation, at key frequencies is given in Table 54 for information only.

The *ACR-N* requirements shall be met where the *NEXT* requirements apply, and at both ends of the cabling.

$ACR\text{-}N_{ik}$ of pairs i and k is computed as follows:

$$ACR\text{-}N_{ik} = NEXT_{ik} - IL_k \qquad (12)$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

$NEXT_{ik}$ is the near-end crosstalk loss coupled from pair i into pair k;

IL_k is the insertion loss of pair k.

Table 54 – Informative ACR-N values for links with maximum implementation at key frequencies

Minimum ACR-N dB									
Frequency MHz	**Class**								
	D	**E**	**E_A**	**F**	**F_A**	**BCT-B-L**	**BCT-B-M**	**I**	**II**
1	60,2	61,0	61,0	61,0	61,0	63,0	63,0	62,0	62,0
16	37,5	47,5	47,6	58,1	58,2	63,0	63,0	50,9	62,0
100	11,9	23,3	24,0	47,3	47,7	63,0	60,7	35,3	59,8
250	–	4,7	6,4	31,6	34,0	58,7	54,8	25,2	50,7
500	–	–	−12,9 (−14,2)[a]	13,8	16,4	51,9	46,2	16,4	41,6
600	–	–	–	8,1	10,8	50,1	43,8	12,9	38,9
1 000	–	–	–	–	−8,5 (−9,7)[a]	43,0	34,8	1,9	30,5
1 600	–	–	–	–	–	–	–	−10,4	9,1
2 000	–	–	–	–	–	–	–	−16,9	2,4

[a] Value applicable to 3-connection link configurations (see Figure 7).

7.2.5.3 Power sum ACR-N

The *PS ACR-N* of each pair of a 2-connection or 3-connection link shall meet the difference of the *PS NEXT* requirement of Table 52 and the insertion loss requirement of Table 48 of the respective class.

The *PS ACR-N* of each pair of a link, with maximum implementation, at key frequencies is given in Table 55 for information only.

The *PS ACR-N* requirements shall be met where the *PS NEXT* requirements apply, and at both ends of the cabling.

$PS\ ACR\text{-}N_k$ of pair k is computed as follows:

$$PS\ ACR\text{-}N_k = PS\ NEXT_k - IL_k \quad (13)$$

where

k is the number of the disturbed pair;

$PS\ NEXT_k$ is the power sum near-end crosstalk loss of pair k;

IL_k is the insertion loss of pair k.

Table 55 – Informative PS ACR-N values for links with maximum implementation at key frequencies

Minimum PS ACR-N dB									
Frequency MHz	**Class**								
	D	**E**	**E_A**	**F**	**F_A**	**BCT-B-L**	**BCT-B-M**	**I**	**II**
1	53,0	58,0	58,0	58,0	58,0	61,0	61,0	59,0	59,0
16	34,5	45,1	45,2	55,1	55,2	61,0	61,0	47,9	59,0
100	8,9	20,8	21,5	44,3	44,7	61,0	58,7	32,3	56,8
250	–	2,0	3,8	28,6	31,0	56,7	52,8	22,2	47,7
500	–	–	−15,7 (−16,3)[a]	10,8	13,4	49,9	44,2	13,4	38,6
600	–	–	–	5,1	7,8	48,1	41,8	9,9	35,9
1 000	–	–	–	–	−11,5 (−12,7)[a]	41,0	32,8	−1,1	27,5
1 600	–	–	–	–	–	–	–	−13,4	6,1
2 000	–	–	–	–	–	–	–	−19,9	−0,6

[a] Value applicable to 3-connection link configurations (see Figure 7).

7.2.6 Attenuation to crosstalk ratio at the far-end

7.2.6.1 General

The *ACR-F* requirements are applicable only to Classes D through F_A, BCT-B, I and II.

7.2.6.2 Pair-to-pair ACR-F

The *ACR-F* of each pair combination of a 2-connection or 3-connection link shall meet the requirements in Table 56.

The *ACR-F* of each pair combination of a link, with maximum implementation, at key frequencies is given in Table 57 for information only.

$ACR\text{-}F_{ik}$ of pairs i and k is computed as follows:

$$ACR\text{-}F_{ik} = FEXT_{ik} - IL_k \tag{14}$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

$FEXT_{ik}$ is the far-end crosstalk loss coupled from pair i into pair k;

IL_k is the insertion loss of pair k.

NOTE The difference of input-to-output *FEXT* and the insertion loss of the disturbed pair is relevant to the signal-to-noise consideration. The results computed to the formal definition above cover all possible combinations of insertion loss of pairs and corresponding input-to-output *FEXT*.

Table 56 – ACR-F for 2-connection or 3-connection link

Class	Frequency MHz	Minimum ACR-F [a, b] dB
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{63{,}8-20\lg(f)}{-20}}+n\times 10^{\frac{75{,}1-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{67{,}8-20\lg(f)}{-20}}+n\times 10^{\frac{83{,}1-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{67{,}8-20\lg(f)}{-20}}+n\times 10^{\frac{83{,}1-20\lg(f)}{-20}}\right)$
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{94-20\lg(f)}{-20}}+n\times 10^{\frac{90-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{95{,}3-20\lg(f)}{-20}}+n\times 10^{\frac{103{,}9-20\lg(f)}{-20}}\right)$
BCT-B-L	$1 \le f \le 1\,000$	$-20\lg\left(\sqrt{0{,}078}\left(10^{\frac{91-20\lg(f)}{-20}}\right)+2\times 10^{\frac{103{,}9-20\lg(f)}{-20}}\right)$
BCT-B-M	$1 \le f \le 1\,000$	$-20\lg\left(\sqrt{0{,}21}\left(10^{\frac{91-20\lg(f)}{-20}}\right)+2\times 10^{\frac{103{,}9-20\lg(f)}{-20}}\right)$
I	$1 \le f \le 2\,000$	$-20\lg\left(10^{\frac{80-20\lg(f)}{-20}}+2\times 10^{\frac{83{,}1-20\lg(f)}{-20}}\right)$
II	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{101{,}6-20\lg(f)}{-20}}+2\times 10^{\frac{103{,}9-20\lg(f)}{-20}}\right)$
	$1\,000 < f < 1\,600$	$-20\lg\left(10^{\frac{101{,}6-20\lg(f)}{-20}}+2\times 10^{\frac{43{,}9-90\lg(f/1000)}{-20}}\right)$
	$1\,600 \le f \le 2\,000$	$-20\lg\left(10^{\frac{101{,}6-20\lg(f)}{-20}}+2\times 10^{\frac{25{,}52-40\lg(f/1600)}{-20}}\right)$

n = 2 for 2-connection link configurations (see Figure 6).
n = 3 for 3-connection link configurations (see Figure 6).

[a] *ACR-F* at frequencies that correspond to measured FEXT values of greater than 70,0 dB are for information only.

[b] *ACR-F* at frequencies that correspond to calculated values of greater than 65,0 dB shall revert to a minimum requirement of 65,0 dB.

Table 57 – Informative ACR-F values for links with maximum implementation at key frequencies

Minimum ACR-F dB									
Frequency MHz	**Class**								
	D	**E**	**E_A**	**F**	**F_A**	**BCT-B-L**	**BCT-B-M**	**I**	**II**
1	58,6	64,2	64,2	65,0	65,0	65,0	65,0	65,0	65,0
16	34,5	40,1	40,1	59,3	64,7	65,0	65,0	48,3	65,0
100	18,6	24,2	24,2	46,0	48,8	53,7	51,8	32,4	53,5
250	–	16,2	16,2	39,2	40,8	45,7	43,8	24,4	45,6
500	–	–	10,2	34,0	34,8	39,7	37,8	18,4	39,5
600	–	–	–	32,6	33,2	38,1	36,2	16,8	38,0
1 000	–	–	–	–	28,8	33,7	31,8	12,4	33,5
1 600	–	–	–	–	–	–	–	8,3	18,5
2 000	–	–	–	–	–	–	–	6,4	14,8

7.2.6.3 Power sum ACR-F

The *PS ACR-F* of each pair of a 2-connection or 3-connection link shall meet the requirements derived by the formulas in Table 58.

The *PS ACR-F* of each pair of a link, with maximum implementation, at key frequencies is given in Table 59 for information only.

$PS\ ACR\text{-}F_k$ of pair k is computed as follows:

$$PSACR\text{-}F_k = (-10\lg \sum_{i=1, i \neq k}^{n} 10^{\frac{-FEXT_{ik}}{10}}) - IL_k \qquad (15)$$

where

i is the number of the disturbing pair;

k is the number of the disturbed pair;

n is the total number of pairs;

$FEXT_{ik}$ is the far-end crosstalk loss coupled from pair i into pair k;

IL_k is the insertion loss of pair k.

Table 58 – PS ACR-F for 2-connection or 3-connection link

Class	Frequency MHz	Minimum PS ACR-F [a, b, c] dB
D	$1 \leq f \leq 100$	$-20\lg\left(10^{\frac{60,8-20\lg(f)}{-20}} + n\times 10^{\frac{72,1-20\lg(f)}{-20}}\right)$
E	$1 \leq f \leq 250$	$-20\lg\left(10^{\frac{64,8-20\lg(f)}{-20}} + n\times 10^{\frac{80,1-20\lg(f)}{-20}}\right)$
E_A	$1 \leq f \leq 500$	$-20\lg\left(10^{\frac{64,8-20\lg(f)}{-20}} + n\times 10^{\frac{80,1-20\lg(f)}{-20}}\right)$
F	$1 \leq f \leq 600$	$-20\lg\left(10^{\frac{91-20\lg(f)}{-20}} + n\times 10^{\frac{87-15\lg(f)}{-20}}\right)$
F_A	$1 \leq f \leq 1\,000$	$-20\lg\left(10^{\frac{92,3-20\lg(f)}{-20}} + n\times 10^{\frac{100,9-20\lg(f)}{-20}}\right)$
BCT-B-L	$1 \leq f \leq 1\,000$	$-20\lg\left(\sqrt{0,078}\left(10^{\frac{88-20\lg(f)}{-20}}\right) + 2\times 10^{\frac{100,9-20\lg(f)}{-20}}\right)$
BCT-B-M	$1 \leq f \leq 1\,000$	$-20\lg\left(\sqrt{0,21}\left(10^{\frac{88-20\lg(f)}{-20}}\right) + 2\times 10^{\frac{100,9-20\lg(f)}{-20}}\right)$
I	$1 \leq f \leq 2\,000$	$-20\lg\left(10^{\frac{77-20\lg(f)}{-20}} + 2\times 10^{\frac{80,1-20\lg(f)}{-20}}\right)$
II	$1 \leq f \leq 1\,000$	$-20\lg\left(10^{\frac{98,6-20\lg(f)}{-20}} + 2\times 10^{\frac{100,9-20\lg(f)}{-20}}\right)$
	$1\,000 < f < 1\,600$	$-20\lg\left(10^{\frac{98,6-20\lg(f)}{-20}} + 2\times 10^{\frac{40,9-90\lg(f/1000)}{-20}}\right)$
	$1\,600 \leq f \leq 2\,000$	$-20\lg\left(10^{\frac{98,6-20\lg(f)}{-20}} + 2\times 10^{\frac{22,52-40\lg(f/1600)}{-20}}\right)$

n = 2 for 2-connection link configurations (see Figure 6).
n = 3 for 3-connection link configurations (see Figure 6).

[a] *PS ACR-F* at frequencies that correspond to measured *PS FEXT* values of greater than 70,0 dB are for information only.

[b] *PS ACR-F* at frequencies that correspond to calculated values of greater than 62,0 dB shall revert to a minimum requirement of 62,0 dB.

[c] The terms in the formulas are not intended to imply component performance.

Table 59 – Informative PS ACR-F values for links with maximum implementation at key frequencies

Frequency MHz	Minimum PS ACR-F dB								
	Class								
	D	E	E_A	F	F_A	BCT-B-L	BCT-B-M	I	II
1	55,6	61,2	61,2	62,0	62,0	62,0	62,0	62,0	62,0
16	31,5	37,1	37,1	56,3	61,7	62,0	62,0	45,3	62,0
100	15,6	21,2	21,2	43,0	45,8	50,7	48,8	29,4	50,5
250	–	13,2	13,2	36,2	37,8	42,7	40,8	21,4	42,6
500	–	–	7,2	31,0	31,8	36,7	34,8	15,4	36,5
600	–	–	–	29,6	30,2	35,1	33,2	13,8	35,0
1 000	–	–	–	–	25,8	30,7	28,8	9,4	30,5
1 600	–	–	–	–	–	–	–	5,3	15,5
2 000	–	–	–	–	–	–	–	3,4	11,8

7.2.7 Direct current loop resistance

The DC loop resistance of each pair of a 2-connection or 3-connection link shall meet the requirements derived by the formula in Table 60 when measured at or corrected to 20 °C.

The DC loop resistance of each pair of a link, with maximum implementation, at key frequencies is given in Table 61 for information only.

Table 60 – DC loop resistance for 2-connection or 3-connection link

Class	Maximum DC loop resistance Ω
A	530
B	140
C	34
D	$(L/100) \times 19 + n \times 0{,}4$
E	$(L/100) \times 19 + n \times 0{,}4$
E_A	$(L/100) \times 19 + n \times 0{,}4$
F	$(L/100) \times 19 + n \times 0{,}4$
F_A	$(L/100) \times 19 + n \times 0{,}4$
BCT-B	$(L/100) \times 19 + 2 \times 0{,}4$
I	$(L/100) \times 14{,}0 + 2 \times 0{,}4$
II	$(L/100) \times 14{,}0 + 2 \times 0{,}4$

$L = L_{FC} + L_{CP} \times Y$

where

L_{FC} is the length of fixed cable (m);

L_{CP} is the length of consolidation point cord, where present (m);

Y is the ratio of consolidation point cord cable insertion loss (dB/m) to fixed cable insertion loss (dB/m) (see 9.3.2.6).

n = 2 for 2-connection link configurations (see Figure 6)

n = 3 for 3-connection link configurations (see Figure 6)

Table 61 – Informative DC loop resistance for links with maximum implementation

Maximum DC loop resistance Ω											
Class											
A	B	C	D	E	E_A	F	F_A	BCT-B-L	BCT-B-M	I	II
530	140	34	18,3	18,3	18,3	18,3	18,3	2,3	4,8	4,4	4,4

7.2.8 Direct current resistance unbalance

The DC resistance unbalance between the two conductors within each pair of a 2-connection or 3-connection link shall not exceed the greater of 3 % or 0,150 Ω for all Classes.

The maximum DC resistance unbalance between pairs within a link shall not exceed 7 % or 100 mΩ, whichever is greater.

NOTE For the purposes of field measurements, calculations that provide values of less than 200 mΩ revert to 200 mΩ.

7.2.9 Propagation delay

The propagation delay of each pair of a 2-connection or 3-connection link shall meet the requirements derived by the formulas in Table 62.

A method of establishing conformant link performance is to demonstrate that the margin between the measured value and the channel limits of Table 17 are adequate to accommodate any additional cabling components used to create a channel. This is fulfilled if the insertion loss requirement and the delay skew requirement for the 2-connection or 3-connection link are met.

The propagation delay of each pair of a link, with maximum implementation, at key frequencies is given in Table 63 for information only.

Table 62 – Propagation delay for 2-connection or 3-connection link

Class	Frequency MHz	Maximum propagation delay µs
A	$f = 0,1$	19,400
B	$0,1 \leq f \leq 1$	4,400
C	$1 \leq f \leq 16$	$(L/100) \times \left(0,534 + 0,036/\sqrt{f}\right) + n \times 0,002\,5$
D	$1 \leq f \leq 100$	$(L/100) \times \left(0,534 + 0,036/\sqrt{f}\right) + n \times 0,002\,5$
E	$1 \leq f \leq 250$	$(L/100) \times \left(0,534 + 0,036/\sqrt{f}\right) + n \times 0,002\,5$
E_A	$1 \leq f \leq 500$	$(L/100) \times \left(0,534 + 0,036/\sqrt{f}\right) + n \times 0,002\,5$
F	$1 \leq f \leq 600$	$(L/100) \times \left(0,534 + 0,036/\sqrt{f}\right) + n \times 0,002\,5$
F_A	$1 \leq f \leq 1\,000$	$(L/100) \times \left(0,534 + 0,036/\sqrt{f}\right) + n \times 0,002\,5$
BCT-B	$1 \leq f \leq 1\,000$	$(L/100) \times \left(0,534 + 0,036/\sqrt{f}\right) + 2 \times 0,002\,5$
I	$1 \leq f \leq 2\,000$	$(L/100) \times \left(0,534 + 0,036/\sqrt{f}\right) + 2 \times 0,002\,5$
II	$1 \leq f \leq 2\,000$	$(L/100) \times \left(0,534 + 0,036/\sqrt{f}\right) + 2 \times 0,002\,5$

$L = L_{FC} + L_{CP}$

where

L_{FC} is the length of fixed cable (m);

L_{CP} is the length of consolidation point cord, where present (m).

n = 2 for 2-connection link configurations (see Figure 6)

n = 3 for 3-connection link configurations (see Figure 6)

Table 63 – Informative propagation delay values for links with maximum implementation at key frequencies

Frequency MHz	Maximum propagation delay µs										
	Class										
	A	B	C	D	E	E_A	F	F_A	BCT-B-L	BCT-B-M	I	II
0,1	19,400	4,400	–	–	–	–	–	–	–	–	–	–
1	–	4,400	0,521	0,521	0,521	0,521	0,521	0,521	0,049	0,125	0,150	0,150
16	–	–	0,496	0,496	0,496	0,496	0,496	0,496	0,047	0,119	0,142	0,142
100	–	–	–	0,491	0,491	0,491	0,491	0,491	0,047	0,118	0,141	0,141
250	–	–	–	–	0,490	0,490	0,490	0,490	0,047	0,118	0,141	0,141
500	–	–	–	–	–	0,490	0,490	0,490	0,047	0,117	0,141	0,141
600	–	–	–	–	–	–	0,489	0,489	0,047	0,117	0,141	0,141
1 000	–	–	–	–	–	–	–	0,489	0,047	0,117	0,140	0,140
1 600	–	–	–	–	–	–	–	–	–	–	0,140	0,140
2 000	–	–	–	–	–	–	–	–	–	–	0,140	0,140

7.2.10 Delay skew

The delay skew between all pairs of a 2-connection or 3-connection link shall meet the requirements derived by the formulas in Table 64.

A method of establishing a conformant link performance is to demonstrate that the margin between the measured value and the channel limits of Table 19 are adequate to accommodate any additional cabling components used to create a channel. This is fulfilled if the insertion loss requirement and the propagation delay requirement for the 2-connection or 3-connection link are met.

The delay skew between all pairs of a link, with maximum implementation, at key frequencies is given in Table 65 for information only.

Table 64 – Delay skew for 2-connection or 3-connection link

Class	**Frequency** MHz	**Maximum delay skew** µs
A	f = 0,1	N/A
B	0,1 $\le f \le$ 1	N/A
C	1 $\le f \le$ 16	$(L/100) \times 0{,}045 + n \times 0{,}001\,25$
D	1 $\le f \le$ 100	$(L/100) \times 0{,}045 + n \times 0{,}001\,25$
E	1 $\le f \le$ 250	$(L/100) \times 0{,}045 + n \times 0{,}001\,25$
E_A	1 $\le f \le$ 500	$(L/100) \times 0{,}045 + n \times 0{,}001\,25$
F	1 $\le f \le$ 600	$(L/100) \times 0{,}025 + n \times 0{,}001\,25$
F_A	1 $\le f \le$ 1 000	$(L/100) \times 0{,}025 + n \times 0{,}001\,25$
BCT-B	1 $\le f \le$ 1 000	$(L/100) \times 0{,}025 + 2 \times 0{,}001\,25$
I	1 $\le f \le$ 2 000	$(L/100) \times 0{,}045 + 2 \times 0{,}001\,25$
II	1 $\le f \le$ 2 000	$(L/100) \times 0{,}025 + 2 \times 0{,}001\,25$

$L = L_{FC} + L_{CP}$

where

L_{FC} is the length of fixed cable (m);

L_{CP} is the length of consolidation point cord, where present (m).

n = 2 for 2-connection link configurations (see Figure 6)

n = 3 for 3-connection link configurations (see Figure 6)

Table 65 – Informative delay skew for links with maximum implementation

Class	Frequency MHz	Maximum delay skew µs
A	$f = 0,1$	N/A
B	$0,1 \leq f \leq 1$	N/A
C	$1 \leq f \leq 16$	0,044 [a]
D	$1 \leq f \leq 100$	0,044 [a]
E	$1 \leq f \leq 250$	0,044 [a]
E_A	$1 \leq f \leq 500$	0,044 [a]
F	$1 \leq f \leq 600$	0,026 [b]
F_A	$1 \leq f \leq 1\,000$	0,026 [b]
BCT-B-L	$1 \leq f \leq 1\,000$	0,004 [c]
BCT-B-M	$1 \leq f \leq 1\,000$	0,008 [d]
I	$1 \leq f \leq 2\,000$	0,0142 [e]
II	$1 \leq f \leq 2\,000$	0,009 [f]

[a] This is the result of the calculation 0,9 × 0,045 + 3 × 0,001 25.
[b] This is the result of the calculation 0,9 × 0,025 + 3 × 0,001 25.
[c] This is the result of the calculation 0,078 × 0,025 + 2 × 0,001 25.
[d] This is the result of the calculation 0,21 × 0,025 + 2 × 0,001 25.
[e] This is the result of the calculation 0,26 × 0,045 + 2 × 0,001 25.
[f] This is the result of the calculation 0,26 × 0,025 + 2 × 0,001 25.

7.2.11 Unbalance attenuation and coupling attenuation

7.2.11.1 General

Unbalance attenuation (*TCL* and *ELTCTL*) and coupling attenuation are specified for Class I and Class II screened systems.

7.2.11.2 Unbalance attenuation, near-end

The unbalance attenuation near-end is measured as transverse conversion loss (*TCL*).

Minimum *TCL* requirements are applicable to Class I and II screened systems. The *TCL* of a Class I or II permanent link shall meet the requirements of Table 66.

The *TCL* of each pair of a link, with maximum implementation, at key frequencies is given in Table 67 for information only.

The *TCL* requirements shall be met at both ends of the cabling and shall be achieved by design and installation in accordance with manufacturer's instructions.

Table 66 – TCL for Class I and II screened permanent links

Class	Frequency MHz	Cable pair screening	Environmental classification		
			E_1	E_2	E_3
			Minimum TCL dB		
I	$1 \leq f \leq 2\,000$	unscreened pairs	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]
I	$1 \leq f \leq 2\,000$	screened pairs	$50{,}0 - 17\lg(f)$ [b, c]	$50{,}0 - 17\lg(f)$ [b, c]	$50{,}0 - 17\lg(f)$ [b, c]
II	$1 \leq f \leq 2\,000$	unscreened pairs	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]
II	$1 \leq f \leq 2\,000$	screened pairs	$50{,}0 - 17\lg(f)$ [b, c]	$50{,}0 - 17\lg(f)$ [b, c]	$50{,}0 - 17\lg(f)$ [b, c]

[a] Calculated values of greater than 40 dB shall revert to a minimum requirement of 40 dB.

[b] Calculated values of greater than 30 dB shall revert to a minimum requirement of 30 dB.

[c] Calculated values of less than 3 dB shall revert to a requirement of 3 dB.

Table 67 – Informative TCL values for Class I and II screened permanent links at key frequencies

Frequency MHz	Minimum TCL dB											
	Class											
	I (unscreened pairs)			I (screened pairs)			II (unscreened pairs)			II (screened pairs)		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
1	40,0	40,0	40,0	30,0	30,0	30,0	40,0	40,0	40,0	30,0	30,0	30,0
100	26,0	26,0	26,0	16,0	16,0	16,0	26,0	26,0	26,0	16,0	16,0	16,0
250	19,2	19,2	19,2	9,2	9,2	9,2	19,2	19,2	19,2	9,2	9,2	9,2
500	14,1	14,1	14,1	4,1	4,1	4,1	14,1	14,1	14,1	4,1	4,1	4,1
1 000	9,0	9,0	9,0	3,0	3,0	3,0	9,0	9,0	9,0	3,0	3,0	3,0
1 600	5,5	5,5	5,5	3,0	3,0	3,0	5,5	5,5	5,5	3,0	3,0	3,0
2 000	3,9	3,9	3,9	3,0	3,0	3,0	3,9	3,9	3,9	3,0	3,0	3,0

7.2.11.3 Unbalance attenuation, far-end

The unbalance attenuation far-end is measured as equal level transverse conversion transfer loss (*ELTCTL*).

Minimum *ELTCTL* requirements are only applicable to permanent link Classes I and II. The *ELTCTL* of a Class I or II channel shall meet the requirements of Table 68.

The *ELTCTL* of each pair of a link, with maximum implementation, at key frequencies is given in Table 69 for information only.

The *ELTCTL* requirements shall be met at both ends of the cabling and shall be achieved by design and installation in accordance with manufacturer's instructions.

Table 68 – ELTCTL for Class I and II permanent links

Class	Frequency MHz	Cable pair screening	Environmental classification		
			E_1	E_2	E_3
			Minimum ELTCTL dB		
I	$1 \leq f \leq 2\,000$	unscreened pairs	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]
I	$1 \leq f \leq 2\,000$	screened pairs	$34{,}6 - 20\lg(f)$ [b, c]	$34{,}6 - 20\lg(f)$ [b, c]	$34{,}6 - 20\lg(f)$ [b, c]
II	$1 \leq f \leq 2\,000$	unscreened pairs	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]
II	$1 \leq f \leq 2\,000$	screened pairs	$34{,}6 - 20\lg(f)$ [b, c]	$34{,}6 - 20\lg(f)$ [b, c]	$34{,}6 - 20\lg(f)$ [b, c]

[a] Calculated values of greater than 40 dB shall revert to a minimum requirement of 40 dB.

[b] Calculated values of greater than 30 dB shall revert to a minimum requirement of 30 dB.

[c] Calculated values of less than 3 dB shall revert to a requirement of 3 dB.

Table 69 – Informative ELTCTL values for Class I and II permanent links at key frequencies

Frequency MHz	Minimum ELTCTL dB											
	Class											
	I (unscreened pairs)			I (screened pairs)			II (unscreened pairs)			II (screened pairs)		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
1	40,0	40,0	40,0	30,0	30,0	30,0	40,0	40,0	40,0	30,0	30,0	30,0
100	4,6	4,6	4,6	3,0	3,0	3,0	4,6	4,6	4,6	3,0	3,0	3,0
250	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
500	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
1 000	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
1 600	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
2 000	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0

7.2.11.4 Coupling attenuation

Minimum coupling attenuation requirements are only applicable to permanent link Classes I and II. The coupling attenuation of a permanent link that is intended to be subjected to an environmental classification E_x shall meet the requirements in Table 70.

The coupling attenuation of each pair of a link, with maximum implementation, at key frequencies is given in Table 71 for information only.

The coupling attenuation requirements shall be met at both ends of the cabling and shall be achieved by design and installation in accordance with manufacturer's instructions.

Table 70 – Coupling attenuation for a screened permanent link

Class	Frequency MHz	Environmental classification		
		E_1	E_2	E_3
		Minimum coupling attenuation dB		
I, II	$30 \leq f \leq 100$	50	50	60
	$100 \leq f \leq 2000$	$90 - 20\lg(f)$	$90 - 20\lg(f)$	$100 - 20\lg(f)$

Table 71 – Informative coupling attenuation values for screened permanent links at key frequencies

Minimum coupling attenuation dB						
Frequency MHz	Class					
	I			II		
	E_1	E_2	E_3	E_1	E_2	E_3
1	–	–	–	–	–	–
30	50,0	50,0	60,0	50,0	50,0	60,0
100	50,0	50,0	60,0	50,0	50,0	60,0
250	42,0	42,0	52,0	42,0	42,0	52,0
500	36,0	36,0	46,0	36,0	36,0	46,0
1 000	30,0	30,0	40,0	30,0	30,0	40,0
1 600	25,9	25,9	35,9	25,9	25,9	35,9
2 000	24,0	24,0	34,0	24,0	24,0	34,0

7.2.12 Alien crosstalk

7.2.12.1 General

The following alien crosstalk requirements are applicable to Classes E_A, F_A, I and II. Alien crosstalk of Class F is considered to be as good as the alien crosstalk performance specified for Class E_A. For information on alien crosstalk performance of Class E cabling, see ISO/IEC TR 24750. For qualification of alien crosstalk using coupling attenuation see 7.2.12.6.

7.2.12.2 Power sum alien NEXT

The *PS ANEXT* of each pair of a 2-connection or 3-connection link shall meet the requirements derived by the formulas in Table 72.

The *PS ANEXT* of each pair of a link, with maximum implementation, at key frequencies is given in Table 73 for information only.

The *PS ANEXT* requirements shall be met at both ends of the cabling.

$PS\ ANEXT_k$ of pair k is computed as follows:

$$PSANEXT_k = -10\lg\left[\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{\frac{-ANEXT_{l,i,k}}{10}}\right] \tag{16}$$

where

k	is the number of the disturbed pair in the disturbed link;
i	is the number of the disturbing pair in a disturbing link l;
l	is the number of the disturbing link;
N	is the total number of disturbing links;
n	is the number of disturbing pairs in disturbing link l;
$ANEXT_{l,i,k}$	is the alien near-end crosstalk loss coupled from pair i of disturbing link l to the pair k of the disturbed link.

Table 72 – PS ANEXT for 2-connection or 3-connection link

Class	Frequency MHz	Minimum PS ANEXT dB
E_A [a, b]	$1 \le f < 100$	$80 - 10\lg(f)$
	$100 \le f \le 500$	$90 - 15\lg(f)$
F_A [a, b]	$1 \le f < 100$	$95 - 10\lg(f)$
	$100 \le f \le 1\,000$	$105 - 15\lg(f)$
I [c]	$1 \le f < 100$	$105 - 10\lg(f)$
	$100 \le f \le 2\,000$	$115 - 15\lg(f)$
II [c]	$1 \le f < 100$	$105 - 10\lg(f)$
	$100 \le f \le 2\,000$	$115 - 15\lg(f)$

[a] *PS ANEXT* at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[b] If the average insertion loss of all disturbed pairs at 100 MHz, $IL_{100MHz,avg}$, is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

$$\text{minimum}\left\{7 \times \frac{f-100}{400} \times \frac{7 - IL_{100MHz,avg}}{IL_{100MHz,avg}},\ 6 \times \frac{f-100}{400}\right\}$$

where

f is the frequency in MHz;

$IL_{100MHz,avg} = \frac{1}{4}\sum_{i=1}^{4} IL_{100MHz,i}$;

$IL_{100MHz,i}$ is the insertion loss of a pair i at 100 MHz.

[c] *PS ANEXT* at frequencies that correspond to calculated values of greater than 75,0 dB shall revert to a minimum requirement of 75,0 dB.

Table 73 – Informative PS ANEXT values for links at key frequencies

Frequency MHz	Minimum PS ANEXT dB			
	Class			
	E_A	F_A	I	II
1	67,0	67,0	75,0	75,0
100	60,0	67,0	75,0	75,0
250	54,0	67,0	75,0	75,0
500	49,5	64,5	74,5	74,5
1 000	–	60,0	70,0	70,0
1 600	–	–	66,9	66,9
2 000	–	–	65,5	65,5

7.2.12.3 PS ANEXT$_{avg}$

The *PS ANEXT*$_{avg}$ of each 2-connection or 3-connection link shall meet the requirements derived by the formulas in Table 74.

The *PS ANEXT*$_{avg}$ of each pair of a link, with maximum implementation, at key frequencies is given in Table 75 for information only.

The *PS ANEXT*$_{avg}$ requirements shall be met at both ends of the cabling.

$PS\ ANEXT_{avg}$ is computed as follows:

$$PSANEXT_{avg} = \frac{1}{n}\left[\sum_{k=1}^{n} PSANEXT_k\right] \quad (17)$$

where

k is the number of the disturbed pair in the disturbed link;

n is the number of pairs in the disturbed link.

Table 74 – PS ANEXT$_{avg}$ for 2-connection or 3-connection link

Class	Frequency MHz	Minimum PS ANEXT$_{avg}$ [a, b] dB
E_A	$1 \le f < 100$	82,25 – 10 lg (f)
	$100 \le f \le 500$	92,25 – 15 lg (f)

[a] PS ANEXT$_{avg}$ at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[b] If the average insertion loss of all disturbed pairs at 100 MHz, $IL_{100MHz,avg}$, is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

$$\text{minimum}\left\{7 \times \frac{f-100}{400} \times \frac{7 - IL_{100MHz,avg}}{IL_{100MHz,avg}},\ 6 \times \frac{f-100}{400}\right\}$$

where

f is the frequency in MHz;

$$IL_{100MHz,avg} = \frac{1}{4}\sum_{i=1}^{4} IL_{100MHz,i};$$

$IL_{100MHz,i}$ is the insertion loss of a pair i at 100 MHz.

Table 75 – Informative PS ANEXT$_{avg}$ values for links at key frequencies

Frequency MHz	**Minimum Class E$_A$** **PS ANEXT$_{avg}$** dB
1	67,0
100	62,3
250	56,3
500	51,8

7.2.12.4 Power sum alien ACR-F for Class E$_A$, F$_A$, I, and II 2-connection or 3-connection link

The *PS AACR-F* of each pair of a 2-connection or 3-connection link shall meet the requirements derived by the formula in Table 76.

The *PS AACR-F* of each pair of a link, with maximum implementation, at key frequencies is given in Table 77 for information only.

The *PS AACR-F* shall be met at both ends of the cabling.

The *PS AACR-F* is computed based on *AFEXT*, and insertion losses of disturbing and disturbed links.

The *PS AACR-F*$_k$ of disturbed pair k is determined according to Equation (18).

$$PSAACR\text{-}F_k = PSAFEXT_k - IL_k \qquad (18)$$

Table 76 – PS AACR-F for 2-connection or 3-connection link

Class	**Frequency** MHz	**Minimum PS AACR-F** dB
E$_A$ [a]	$1 \le f \le 500$	$77 - 20\lg(f)$
F$_A$ [a]	$1 \le f \le 1\,000$	$92 - 20\lg(f)$
I [a, b]	$1 \le f \le 2\,000$	$102 - 20\lg(f)$
II [a, b]	$1 \le f \le 2\,000$	$102 - 20\lg(f)$

[a] *PS AACR–F* at frequencies that correspond to calculated *PS AFEXT* values of greater than 67,0 dB or 102 − 15 lg(f) dB shall be for information only.

[b] *PS AACR-F* at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

Table 77 – Informative PS AACR-F values for links at key frequencies

Minimum PS AACR-F dB				
Frequency MHz	**Class**			
	E$_A$	**F$_A$**	**I**	**II**
1	67,0	67,0	75,0	75,0
100	37,0	52,0	62,0	62,0
250	29,0	44,0	54,0	54,0
500	23,0	38,0	48,0	48,0
1 000	–	32,0	42,0	42,0
1 600	–	–	37,9	37,9
2 000	–	–	36,0	36,0

7.2.12.5 PS AACR-F$_{avg}$

The *PS AACR-F*$_{avg}$ of each 2-connection or 3-connection link shall meet the requirements derived by the formulas in Table 78.

The *PS AACR-F*$_{avg}$ of each pair of a link, with maximum implementation, at key frequencies is given in Table 79 for information only.

The *PS AACR-F*$_{avg}$ requirements shall be met at both ends of the cabling.

PS AACR-F$_{avg}$ is computed as follows:

$$PSAACR\text{-}F_{avg} = \frac{1}{n}\left[\sum_{k=1}^{n} PSAACR\text{-}F_k\right] \tag{19}$$

where

k is the number of the disturbed pair in the disturbed link;

n is the number of pairs in the disturbed link.

Table 78 – PS AACR-F$_{avg}$ for a 2-connection or 3-connection link

Class	**Frequency** MHz	**Minimum PS AACR-F$_{avg}$** [a, b, c] dB
E$_A$	$1 \leq f \leq 500$	$81 - 20\lg(f)$

[a] *PS AACR–F*$_{avg}$ at frequencies that correspond to calculated *PS AFEXT*$_{avg}$ values of greater than 67,0 dB or $102 - 15\ \lg(f)$ dB shall be for information only.

[b] *PS AACR–F*$_{avg}$ at frequencies that correspond to calculated values of greater than 67,0 dB shall revert to a minimum requirement of 67,0 dB.

[c] *PS AACR–F*$_{avg}$ for Class F$_A$ links is met if the Class F$_A$ *PS AACR-F* specification limits in Table 25 are met.

Table 79 – Informative PS AACR-F_{avg} values for links at key frequencies

Frequency MHz	**Minimum Class E_A** **PS AACR-F_{avg}** dB
1	67,0
100	41,0
250	33,0
500	27,0

7.2.12.6 Alien crosstalk and coupling attenuation for screened links

When coupling attenuation for a link meets or exceeds the values of Table 80 the PS ANEXT limits are met by design.

When coupling attenuation for a link meets or exceeds the values of Table 80, the PS AACR-F limits are met by design.

Table 80 – Alien crosstalk and coupling attenuation for screened links

Class	**Frequency** MHz	**Minimum coupling attenuation to meet PS ANEXT limits** dB	**Minimum coupling attenuation to meet PS AACR-F limits** dB
E_A	$30 \leq f \leq 100$	50	50
	$100 \leq f \leq 500$	$90 - 20\lg(f)$	$90 - 20\lg(f)$
F	$30 \leq f \leq 100$	50	50
	$100 \leq f \leq 600$	$90 - 20\lg(f)$	$90 - 20\lg(f)$
F_A	$30 \leq f \leq 100$	65	65
	$100 \leq f \leq 1000$	$105 - 20\lg(f)$	$105 - 20\lg(f)$
I	$30 \leq f \leq 100$	50	65
	$100 \leq f \leq 2\,000$	$90 - 20\lg(f)$	$105 - 20\lg(f)$
II	$30 \leq f \leq 100$	50	65
	$100 \leq f \leq 2\,000$	$90 - 20\lg(f)$	$105 - 20\lg(f)$

7.3 Coaxial cabling

7.3.1 General

Clause 7.3 contains requirements for coaxial links of Class BCT-C.

The requirements in 7.3 are given by limits computed, to one decimal place, using the formula for a defined frequency range. The limits for the propagation delay are computed to three decimal places. Where relevant, in the informative tables for maximum implementation at key frequencies, L = 30,0 for Class BCT-C-L and L = 69,0 for Class BCT-C-M. The insertion loss specifications in 7.3 have a plateau in the specified requirement. These plateaus do not accurately depict the system performance. They have been added for measurement purposes.

7.3.2 Return loss

See 6.4.3.1.

7.3.3 Insertion loss

The insertion loss (*IL*) of a link shall meet the requirements in Table 81.

The *IL* of a link, with maximum implementation, at key frequencies is given in Table 82 for information only.

Table 81 – Insertion loss for link

Class	**Frequency** MHz	**Maximum insertion loss** [a] dB
BCT-C	$1 \le f \le 100$	$L/100 \times \left(0{,}625\sqrt{f} + 0{,}0001f\right) + 2 \times 0{,}0001f$
	$100 \le f \le 3000$	$L/100 \times \left(0{,}597\sqrt{f} + 0{,}0026f\right) + 2 \times 0{,}0001f$

[a] Insertion loss (*IL*) at frequencies that correspond to calculated values of less than 2,0 dB shall revert to a maximum requirement of 2,0 dB.

Table 82 – Informative insertion loss values for link at key frequencies

Frequency MHz	**Maximum insertion loss** dB	
	Class BCT-C-L	**Class BCT-C-M**
1	2,0	2,0
10	2,0	2,0
100	2,0	4,3
200	2,7	6,2
600	5,0	11,3
1 000	6,6	15,0
2 400	11,1	25,0
3 000	12,7	28,5

7.3.4 Direct current loop resistance

The DC loop resistance of a link shall meet the requirements in Table 83.

Table 83 – DC loop resistance for link

Maximum DC loop resistance Ω	
Class BCT-C-L	**Class BCT-C-M**
2,7	6,2

7.3.5 DC current carrying capacity

See 6.4.3.4.

7.3.6 Screening attenuation

See 6.4.3.6.

7.4 Optical fibre cabling

The attenuation of links (by reference to Figure 6 and Figure 7) at a specified wavelength shall not exceed the sum of the specified attenuation values for the components at that wavelength (where the attenuation of a length of cabled optical fibre is calculated from its attenuation coefficient multiplied by its length).

For the purpose of defining link limits, the cable requirements of Table 93 and the connecting hardware requirements of Table 136 shall be used.

8 Reference implementation for backbone cabling subsystems

8.1 General

Clause 8 contains reference implementations for campus and building backbone cabling subsystems (see 5.3.3). For detailed information on reference implementations of other cabling subsystems, see the appropriate premises-specific cabling design standard.

8.2 Balanced cabling

8.2.1 Component choice

The selection of balanced components will be determined by the channel lengths required and the class of applications to be supported. Refer to Annex E for guidance.

The balanced cabling reference implementations described in 8.2 contain reductions in channel length where operating temperatures are in excess of 20 °C. In order to maintain specific channel lengths under such conditions (due to the effect of ambient temperature and/or the impact of applications supported by the cabling) it may be necessary to either

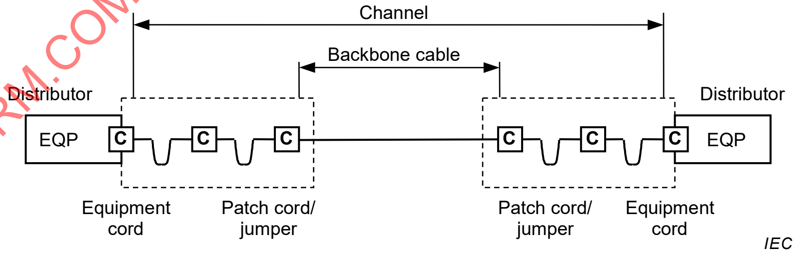
1) specify cables with lower insertion loss specifications than those detailed in 8.2, or
2) provide appropriate protection to reduce the operating temperature of the channel.

Using the configurations of 8.2.2,

a) Category 5 components provide Class D balanced cabling performance,
b) Category 6 components provide Class E balanced cabling performance,
c) Category 6_A components or Category 8.1 components provide Class E_A balanced cabling performance,
d) Category 7 components provide Class F balanced cabling performance,
e) Category 7_A components or Category 8.2 components provide Class F_A balanced cabling performance.

8.2.2 Dimensions

Figure 8 shows the model used to correlate cabling dimensions specified in 8.2 with the channel specifications in Clause 6. The backbone channel shown (either building or campus) contains a cross-connect at each end. This represents the maximum configuration for a Class D, E, E_A, F or F_A backbone channel.



Key

C connection (mated pair)

Figure 8 – Backbone cabling model

The channel includes additional cords comprising patch cords/jumpers and equipment cords.

In Table 84 it is assumed that

a) the flexible cable within these cords may have a higher insertion loss than that used in the backbone cable,
b) all the cords in the channel have a common insertion loss specification.

In order to accommodate the higher insertion loss of cables used for patch cords, jumpers and equipment cords, the length of the cables used within a channel of a given Class shall be determined by the equations shown in Table 84.

The following general restrictions apply for Classes D, E, E_A, F and F_A.

1) The physical length of channels shall not exceed 100 m.
2) When four connections are used in a channel, the physical length of the backbone cable should be at least 15 m.

The maximum length of the backbone cable will depend on the total length of cords to be supported within a channel. The maximum lengths of cords shall be set during the design phase and a management system is required to ensure that these lengths are not exceeded during the operation of the cabling system.

Table 84 – Backbone link length equations

	Implementation equations [a]							
Component Category	**Class A**	**Class B**	**Class C**	**Class D**	**Class E**	**Class E_A**	**Class F**	**Class F_A**
5	2 000	l_b = 250 − $l_a \cdot X$	l_b = 170 − $l_a \cdot X$	l_b = 105 − $l_a \cdot X$	–	–	–	–
6	2 000	l_b = 260 − $l_a \cdot X$	l_b = 185 − $l_a \cdot X$	l_b = 111 − $l_a \cdot X$	l_b = 102 − $l_a \cdot X$	–	–	–
6_A or 8.1	2 000	l_b = 260 − $l_a \cdot X$	l_b = 189 − $l_a \cdot X$	l_b = 114 − $l_a \cdot X$	l_b = 105 − $l_a \cdot X$	l_b = 102 − $l_a \cdot X$	–	–
7	2 000	l_b = 260 − $l_a \cdot X$	l_b = 190 − $l_a \cdot X$	l_b = 115 − $l_a \cdot X$	l_b = 106 − $l_a \cdot X$	l_b = 104 − $l_a \cdot X$	l_b = 102 − $l_a \cdot X$	–
7_A or 8.2	2 000	l_b = 260 − $l_a \cdot X$	l_b = 192 − $l_a \cdot X$	l_b = 117 − $l_a \cdot X$	l_b = 108 − $l_a \cdot X$	l_b = 107 − $l_a \cdot X$	l_b = 102 − $l_a \cdot X$	l_b = 107 − $l_a \cdot X$

l_b the maximum length of the backbone cable (m)

l_a combined length of patch cords/jumpers and equipment cords (m)

X the ratio of cord cable insertion loss (dB/m) to backbone cable insertion loss (dB/m)

For operating temperatures above 20 °C, l_b should be reduced by

1) 0,2 % per °C for screened balanced cables up to 60 °C,
2) 0,4 % per °C for unscreened balanced cables up to 40 °C,
3) 0,6 % per °C for unscreened balanced cables between 40 °C and 60 °C.

These are default values and should be used where the actual characteristic of the cable is not known.

Manufacturer's or supplier's information shall be consulted where the intended operating temperature exceeds 60 °C

NOTE Where channels contain a different number of connections than in the model shown in Figure 8, the fixed cable length is reduced (where more connections exist) or increased (where fewer connections exist) by 2 m per connection for Category 5 cables and 1 m per connection for Category 6, 6_A, 7 and 7_A cables. Additionally, the *NEXT*, return loss (*RL*) and *ACR-F* performance should be verified.

[a] Applications limited by propagation delay, delay skew or DC resistance may not be supported if channel lengths exceed 100 m.

8.3 Optical fibre cabling

8.3.1 General

Optical fibre components are referenced in Clauses 9, 10, and 11. The optical fibres are defined in terms of physical construction (core/cladding diameter) and their transmission performance Category within a cable.

Within the reference implementations of 8.3, the optical fibres used in each cabling channel shall have the same physical construction specification and the cabled optical fibres shall be of the same Category.

When more than one physical construction or cabled optical fibre Category is used in a cabling subsystem, the cabling shall be marked to allow each cabling type to be clearly identified.

8.3.2 Component selection

The selection of optical fibre components shall be determined by the channel lengths required and the applications to be supported. Refer to Annex E for guidance.

8.3.3 Dimensions

The channel length is limited by channel length restrictions of the cabled optical fibre Category used, see Annex E. It should be noted that the connection system, used to terminate optical cabling, may contain mated connecting hardware and splices (permanent or re-useable) and that cross-connects may comprise re-useable splices.

In order to accommodate increased quantities of mated connections and splices used within a channel, the total length of the channel may have to be reduced to accommodate the additional attenuation.

Additional connections may be used if the maximum channel insertion loss (or optical power budget, as applicable) of the application allows (see Annex E).

9 Cable requirements

9.1 General

Clause 9 specifies the minimum requirements for cables installed within generic cabling subsystems as specified within the reference implementations in the ISO/IEC 11801 series. The requirements in Clause 9 are specified at a temperature of 20 °C.

9.2 Operating environment

For each M, I, C or E group, the classification of a given environment is determined by the most demanding parameter within the M, I, C or E group. However, the selection of components shall be based on the specific demands of each of the parameters within the M, I, C or E group, which may be less demanding than the overall classification of the group.

In general, conformance to the limits and test methods specified by, and product specifications referenced in, Clause 9 for individual transmission parameters cannot be considered to provide assurance of performance when simultaneously subjected to the full range of environmental conditions of a given environmental classification.

It is assumed that if a channel is constructed entirely of components meeting requirements based on a $M_1I_1C_1E_1$ classification according to the reference implementations of the relevant part of the ISO/IEC 11801 series, then the required channel transmission performance is achieved in a $M_1I_1C_1E_1$ environment based upon a statistical approach of performance modelling.

The maintenance of functional performance under specific combinations of environmental conditions within a given environmental classification of Table 2 should be indicated by the supplier. Agreement shall be reached between customer and supplier that the product maintains transmission performance when subjected to specific combinations of environmental conditions.

9.3 Balanced cables

9.3.1 Basic requirements

Both mechanical and electrical requirements of cables meeting the minimum requirements to support the transmission performance Classes A through F_A, BCT-B, I and II as specified in 6.3 are given in the generic specification IEC 61156-1 and the relevant sectional specifications detailed in Table 85.

Table 85 – Basic requirements of balanced cables

IEC 61156-2	Multicore and symmetrical pair/quad cables for digital communications – Part 2: Symmetrical pair/quad cables with transmission characteristics up to 100 MHz – Horizontal floor wiring – Sectional specification
IEC 61156-3	Multicore and symmetrical pair/quad cables for digital communications – Part 3: Work area cable – Sectional specification
IEC 61156-4	Multicore and symmetrical pair/quad cables for digital communications – Part 4: Riser cables – Sectional specification
IEC 61156-5	Multicore and symmetrical pair/quad cables for digital communications – Part 5: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz –Horizontal floor wiring – Sectional specification
IEC 61156-6	Multicore and symmetrical pair/quad cables for digital communications – Part 6: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz – Work area wiring – Sectional specification
IEC 61156-7	Multicore and symmetrical pair/quad cables for digital communications – Part 7: Symmetrical pair cables with transmission characteristics up to 1 200 MHz – Sectional specification for digital and analog communication cables
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

9.3.2 Balanced cables of Category 5 through 7_A, 8.1 and 8.2

9.3.2.1 General

In addition to 9.3.1, the environmental, mechanical and electrical requirements given in 9.3.2 shall be met. Measurements shall be performed according to IEC 61156-1. In case of conflict with referenced standards, the limits in this document apply.

9.3.2.2 Environmental characteristics

Balanced cable shall meet mechanical and environmental requirements of the relevant Category in conjunction with a completed detail specification based upon those within IEC 61156-5-1 and IEC 61156-6-1, as appropriate.

9.3.2.3 Mechanical characteristics

Balanced cables shall meet the mechanical requirements of 9.3.1 as appropriate in conjunction with the requirements detailed in Table 86.

Table 86 – Mechanical characteristics of balanced cables of Category 5, 6, 6_A, 7 and 7_A

	Cable characteristics	Units	Requirements
1.1	Diameter of conductor[a]	mm	0,4 to 0,8
1.2	Diameter over-insulated conductor[b]	mm	≤ 1,6
1.3	Outer diameter of backbone cable	mm	≤ 90
1.4	Temperature range without mechanical or electrical degradation	°C	installation: 0 to +50 operation: −20 to +60

[a] Conductor diameters below 0,5 mm and above 0,65 mm may not be compatible with all connecting hardware.

[b] Diameters over the insulated conductor up to 1,7 mm may be used if they meet all other performance requirements. These cables may not be compatible with all connecting hardware.

9.3.2.4 Electrical characteristics

9.3.2.4.1 General

The Category 5 of this document corresponds to the Category 5e of the International Standards referenced in Table 85.

Category 8.2 cables are backward compatible and interoperable with cables of all other categories. Category 8.1 cables are backward compatible and interoperable with Category 6_A and lower.

9.3.2.4.2 Characteristic impedance

Refer to IEC 61156-5, measured according to IEC 61156-1, on a standard length of 100 m. The nominal impedance shall be 100 Ω.

Alternative test methodologies that have been shown to correlate with these requirements may also be used.

9.3.2.4.3 Attenuation

For the attenuation of Category 5 cable, the constants specified in 6.3.3.2 of IEC 61156-5:2009 shall be used. They result in a lower attenuation than given in IEC 61156-5:2009, 6.3.3.1 (Table 4), for example in 21,3 dB/100 m at 100 MHz.

Calculations that result in attenuation below 4 dB shall revert to a requirement of 4 dB.

9.3.2.4.4 Coupling attenuation

Screened cables shall meet the requirements of Type II as specified in IEC 61156-5:2012, and IEC 61156-9:2016, as applicable.

9.3.2.4.5 Unbalance attenuation, near-end

Unscreened cables shall meet the requirements of level 2 as specified in IEC 61156-5.

9.3.2.5 Hybrid and multi-unit cables

9.3.2.5.1 Cable sharing

Subsystem 2, 3 and 4 cables required to support multiple signals shall meet the requirements of 9.3.2.5.2.

In the subsystem cable 1 cabling subsystem, when more than one terminal equipment (TE) outlet is served by a single cable, the near-end crosstalk of cable elements that extend to any two or more outlets shall meet the requirements of 9.3.2.5.3. The requirements of 9.3.2.5.3 also apply between units of hybrid and multi-unit cables used in either the subsystem cable 1, 2, 3 or 4 subsystems.

9.3.2.5.2 Power summation in subsystem 2, 3, and 4 cables

Examples of the types of cables covered by 9.3.2.5.2 include cables with two or more elements within a cable unit that are used for backbone subsystems.

Cables shall meet the requirements for the corresponding cable Category and type. Additionally, these cables shall meet the *PS NEXT* requirements for crosstalk, i.e. IEC 61156-5.

NOTE PS NEXT takes the total crosstalk power into account. Therefore a higher count of adjacent pairs requires a higher pair-pair NEXT to achieve the same PS NEXT.

9.3.2.5.3 Hybrid, multi-unit and cables connected to more than one terminal equipment outlet

Examples of the types of cables that are covered by 9.3.2.5.3 include hybrid cables and multi-unit cables and any cable connected to more than one terminal equipment (TE) outlet. The units may be of the same type or of different types, and of the same Category or of different Categories.

Cables shall meet the requirements for the corresponding cable Category and type. Additionally, *PS NEXT* between any balanced cable unit or element shall meet the requirements specified in IEC 61156-5.

NOTE 1 The above requirement is intended to minimize the potential for sheath sharing incompatibilities. Cables that meet the power summation requirement for *NEXT* may not support services with different signalling schemes.

The use of different applications, supported by metallic cabling, with a maximum power budget exceeding 3 dB is not assured within a common sheath.

NOTE 2 The *PS NEXT* of Category 6 is 1 dB more restrictive than needed to fulfil Clause 5 using the reference implementations of the ISO/IEC 11801 series.

9.3.2.5.4 Alien crosstalk

Cables used in class E_A, F_A, I and II channels shall meet alien crosstalk requirements for Category 6_A, 7_A, 8.1 and 8.2 cables, respectively, as specified in IEC 61156-5, IEC 61156-6, IEC 61156-9, and IEC 61156-10.

9.3.2.6 Additional performance requirements for flexible cables

The electrical performance of these cables shall meet the general requirements for balanced cables as specified in 9.3.2.4 for the respective Category with the exception of attenuation and DC loop resistance, which are specified in 9.3.2.6.

The attenuation in decibels per 100 m and DC loop resistance shall not be more than 50 % higher than specified in 9.3.2.4. The impact of this increased attenuation is indicated in the reference implementations within the reference cabling design standards.

Return loss (*RL*) shall be measured on a test length of 100 m. Alternate test methodologies that have been shown to correlate with these requirements may also be used.

9.3.3 Balanced cables of Category BCT-B

9.3.3.1 General

In addition to 9.3.1, the environmental, mechanical and electrical requirements given in 9.3.3 shall be met. Measurements shall be performed according to IEC 61156-1. In case of conflict with referenced standards, the limits in this document apply.

9.3.3.2 Environmental characteristics

BCT-B cables shall meet the environmental requirements of balanced cables, see 9.3.2.2.

9.3.3.3 Mechanical characteristics

BCT-B cables shall meet the minimum requirements for mechanical characteristics specified in Table 87.

Table 87 – Mechanical characteristics of balanced cables of Category BCT-B

	Cable characteristics	Units	Value
1	Diameter of conductor	mm	0,4 to 0,8 [a]
2	Diameter over insulated conductor	mm	≤ 1,6 [b]
3	Number of conductors in a cable element	per pair / per quad	2 / 4
4	Screen around cable element		Optional
5	Number of cables	pairs	≥ 4
	Elements in a unit	quads	≥ 2
6	Screen around cable unit		Optional
7	Screen around cable		Required
8	Outer diameter of cable [c]	mm	≤ 9
9	Temperature range [d]	°C	installation: 0 to +50 operation: −20 to +60
10	Minimum bending radius for pulling during installation		8 times outer cable diameter
11	Minimum bending radius installed		4 times outer cable diameter
12	Fire rating		According to IEC 61156-1, or in accordance with national or local regulations
13	Colour coding		As required by local regulations or customer, preferred IEC 60708-1
14	Cable marking		As required by customer

[a] Conductor diameters below 0,5 mm and above 0,65 mm may not be compatible with all connecting hardware.

[b] Diameters over the insulated conductor up to 1,7 mm may be used if they meet all other performance requirements. These cables may not be compatible with all connecting hardware.

[c] Should be minimized to make best use of duct and cross-connect capacity. In case of under-carpet cable, the value is not applicable.

[d] For certain applications (e.g. precabling buildings in a cold climate), a cable with a lower temperature bending performance of −30 °C may be required.

9.3.3.4 Electrical characteristics

BCT-B cables shall meet

a) the Category 7_A requirements of 9.3.1,

b) the attenuation requirements of IEC 61156-7, for 1 MHz ≤ f ≤ 1 000 MHz (subject to a minimum of 4 dB),

c) the return loss requirements of IEC 61156-7, for 600 MHz < f ≤ 1 000 MHz,

d) minimum requirements specified in Table 88.

See IEC 61156-7 for specifications of cables that meet these requirements.

Table 88 – Minimum transmission performance requirements BCT-B balanced pairs

Frequency MHz	**Minimum coupling attenuation** [a] dB
30 ≤ f < 300	85
300 ≤ f < 470	80
470 ≤ f ≤ 1 000	75

[a] The channel performance of 6.3.3.12.4 is not ensured when using minimally compliant components.

9.3.3.5 Additional performance requirements for flexible cables

The electrical performance of these cables shall meet the general requirements for balanced cables as specified in 9.3.3 with the exception of attenuation, DC loop resistance and return loss (*RL*), which are specified in 9.3.3.5.

The attenuation in decibels per 100 m and DC loop resistance shall not be more than 50 % higher than specified in 9.3.3. The impact of this increased attenuation is indicated in the reference implementations within the reference cabling design standards.

Return loss (*RL*) shall be measured on a test length of 100 m. Alternate test methodologies that have been shown to correlate with these requirements may also be used.

9.4 Coaxial cables

9.4.1 General

Mechanical, electrical and environmental requirements of coaxial cables meeting the minimum requirements to support the transmission performance of BCT-C cabling as specified in 6.4 are given in the generic specification IEC 61196-1, and the relevant sectional specifications detailed in Table 89.

Table 89 – Basic requirements of coaxial cables

IEC 61196-6	Coaxial communication cables – Part 6: Sectional specification for CATV drop cables
IEC 61196-7	Coaxial communication cables – Part 7: Sectional specification for cables for BCT cabling in accordance with ISO/IEC 15018 – Indoor drop cables for systems operating at 5 MHz – 3 000 MHz

9.4.2 Environmental characteristics

Coaxial cables shall meet the environmental requirements of 9.3.2.2.

9.4.3 Mechanical characteristics

BCT-C cables shall meet the minimum requirements for mechanical characteristics specified in Table 90 for compatibility with connectors specified in 10.3.

Table 90 – Mechanical performance requirements for coaxial BCT cables

	Cable characteristics	Units	Value
1	Diameter of inner conductor [a]	mm	0,6 to 1,2
2	Diameter over dielectric [a]	mm	3 to 6
3	Outer diameter of outer conductor	mm	3,5 to 6,5
4	Number of coaxial cable elements in a cable	pairs	≥ 1
5	Outer diameter of cable [b]	mm	≤ 11
6	Temperature range [c]	°C	installation: 0 to +50 operation: −20 to +60
7	Minimum bending radius for pulling during installation		10 times outer cable diameter
8	Minimum bending radius installed		4 times outer cable diameter
9	Cable marking		as required

[a] Conductor diameters below 0,6 mm and above 1,2 mm may not be compatible with all connecting hardware. The two measured values using the IEC method shall be averaged and then compared to the limit for compliance verification.

[b] Should be minimized to make best use of duct and cross-connect capacity. In case of under-carpet cable, the value is not applicable.

[c] For certain applications (e.g. precabling buildings in a cold climate), a cable with a lower temperature bending performance of −30 °C may be required.

9.4.4 Electrical characteristics

BCT-C cables shall meet the minimum requirements for electrical characteristics specified in Table 91.

Table 91 – Minimum electrical performance requirements for cables of Category BCT-C

No.	Electrical characteristics	Units	Frequency MHz	Requirements
1	Mean characteristic impedance	Ω	100	75 ± 3
2	Minimum return loss (RL) on 100 m cable	dB	$5 \leq f < 470$	20
			$470 \leq f < 1\,000$	18
			$1\,000 \leq f \leq 3\,000$	12
3	Maximum insertion loss	dB/100 m	$1 \leq f \leq 3\,000$	$0{,}835 \times \sqrt{f} + 0{,}002\,5\,f$
	Informative values at key frequencies		$f = 5$	4,0
			$f = 10$	4,0
			$f = 100$	8,6
			$f = 200$	12,3
			$f = 600$	22,0
			$f = 1\,000$	28,9
			$f = 2\,400$	46,9
			$f = 3\,000$	53,2
4	Maximum (DC) loop resistance	Ω/100 m	DC	9
5	DC current carrying capacity	A	DC	0,5
6	Operating voltage	V	DC	72
7	Velocity ratio	%		> 66
8	Minimum screening attenuation	dB	$30 \leq f < 300$	85
			$300 \leq f < 470$	85
			$470 \leq f \leq 1\,000$	85
			$1\,000 < f \leq 2\,000$	75
			$2\,000 < f \leq 3\,000$	65
9	Maximum transfer impedance	mΩ/m	$f = 5$	5
			$f = 30$	5

9.5 Optical fibre cable (cabled optical fibres)

9.5.1 Mechanical and environmental characteristics

Optical fibre cable shall meet mechanical and environmental requirements of the relevant Category in conjunction with a completed detail specification based upon those within IEC 60794-2, IEC 60794-3 or IEC 60794-5, as appropriate.

The mechanical and environmental test methods for optical fibre cables are referenced in IEC 60794-1-21 and IEC 60794-1-22.

Optical fibre cables used for simplex and duplex cords shall meet IEC 60794-2-51 and cables used for cords with multiple optical fibres shall meet the relevant product specification in IEC 60794-2.

9.5.2 Cabled optical fibre Categories

9.5.2.1 General

The limits to be met for cabled optical fibre transmission performance are specified in Table 92 and Table 93. Attenuation shall be measured in accordance with IEC 60793-1-40.

Table 92 – Cabled optical fibre attenuation (maximum), dB/km

Cabled optical fibre attenuation (maximum) dB/km										
	OM3 and OM4 multimode		OM5 multimode		OS1a single-mode			OS2 single-mode		
Wavelength	850 nm	1 300 nm	850 nm	1 300 nm	1 310 nm	1 383 nm	1 550 nm	1 310 nm	1 383 nm	1 550 nm
Attenuation	3,5	1,5	3,0	1,5	1,0	1,0	1,0	0,4	0,4	0,4

Table 93 – Multimode optical fibre modal bandwidth

		Minimum modal bandwidth MHz × km				
		Overfilled launch bandwidth			Effective modal bandwidth	
Wavelength		850 nm	953 nm	1 300 nm	850 nm	953 nm
Category	Nominal core diameter µm					
OM3	50	1 500	N/A	500	2 000	N/A
OM4	50	3 500	N/A	500	4 700	N/A
OM5	50	3 500	1 850	500	4 700	2 470

NOTE 1 Modal bandwidth requirements apply to the optical fibre used to produce the relevant cabled optical fibre category and are assured by the parameters and test methods specified in IEC 60793-2-10.

NOTE 2 In addition to supporting the same 850 nm and 1 300 nm bandwidth as OM4, OM5 offers advantage for future applications using wavelength division multiplexing in the 850 nm to 953 nm wavelength range.

9.5.2.2 Cabled multimode optical fibres of Category OM3, OM4 and OM5

The cabled optical fibre Categories designated as OM3, OM4 and OM5 are achieved using a multimode, graded-index optical fibre waveguide with nominal 50/125 µm core/cladding diameter and numerical aperture complying with A1a.2, A1a.3 and A1a.4 optical fibre, respectively, of IEC 60793-2-10.

9.5.2.3 Cabled single-mode optical fibre of Categories OS1a and OS2

The cabled optical fibre categories designated as OS1a and OS2 are achieved using a single-mode optical fibre complying with B1.3 or B6 of IEC 60793-2-50. Two cabled optical fibre designs are specified, one for indoor use (OS1a) and one for outdoor use (OS2).

The requirements for cabled optical fibre transmission performance are specified for the cut-off wavelength being less than 1 260 nm when measured in accordance with IEC 60793-1-44.

NOTE If concatenating different cabled optical fibres manufactured with different optical fibre types, refer to IEC TR 62000:2010 for additional guidance.

B6 optical fibre is recommended when it is expected that the optical fibre or the cable will have to support smaller bend radii than 25 mm.

9.5.2.4 Propagation delay

A conservative conversion value for unit propagation delay of 5,00 ns/m (0,667 c) may be used. This value can be used to calculate channel delay without verification.

10 Connecting hardware requirements

10.1 General requirements

10.1.1 Overview

Clause 10 specifies the minimum requirements for connecting hardware installed within generic cabling subsystems as specified within the reference implementations in the cabling design documents.

Connecting hardware for connecting cables shall only provide direct onward attachment for each conductor and shall not provide any contact between more than one incoming and one outgoing conductor (e.g. bridge taps shall not be used).

Unless otherwise specified, this document specifies the minimum performance of mated connectors as part of a link or channel. The requirements used in Clause 10 apply to mated connections. The requirements of the detail specifications for free connectors and fixed connectors referenced in Clause 10 shall also be met.

These requirements apply to individual connectors which include terminal equipment (TE) outlets, patch panels, consolidation point connectors, splices and cross-connects. Requirements for balanced cords are provided in Clause 11.

NOTE Clause 10 does not address requirements for devices with passive or active electronic circuitry, including those whose main purpose is to serve a specific application or to provide compliance with other rules and regulations. Examples include media adapters, impedance matching transformers, terminating resistors, LAN equipment, filters and protection apparatus. Such devices are outside the scope of generic cabling and may have significant detrimental effects on network performance. Therefore, it is important that their compatibility with the cabling system and equipment be considered before use.

Performance of the connecting hardware shall be maintained over temperatures ranging from −10 °C to +60 °C.

10.1.2 Location

Connecting hardware shall be compatible with the environment at its intended location as defined by the environmental classification of 6.2.

10.1.3 Design

In addition to its primary purpose, connecting hardware should be designed to provide

a) a means to identify cabling for installation and administration as specified in ISO/IEC 14763-2,

b) a means to permit orderly cable management,

c) a means of access to monitor or test cabling and equipment,

d) protection against physical damage and ingress of contaminants,

e) a termination density that is space efficient, but that also provides ease of cable management and ongoing administration of the cabling system,

f) a means to accommodate screening and bonding requirements, when applicable.

When connections of the same mechanical type as the terminal equipment (TE) outlet are used at the distributors, they shall meet the transmission requirements specified for the terminal equipment (TE) outlet, and they shall meet the environmental requirements as specified at that location. Connecting hardware should be protected from physical damage and from direct exposure to moisture and other corrosive elements. This protection can be accomplished by installation indoors or in an appropriate enclosure for the environment according to the relevant IEC standard.

It shall be possible to protect connecting hardware in a non-mated state to meet the stated environmental class of 6.2.2. Such protection can, for example, take the form of blind inserts, protective caps or overall enclosures of the connection or connections.

10.1.4 Operating environment

10.1.4.1 General

For information regarding the operating environment, see 9.2.

10.1.4.2 Connecting hardware for balanced cabling

Connecting hardware for balanced cabling shall meet the mechanical and transmission performance requirements of 10.2 as appropriate in conjunction with the performance requirements detailed in Table 94 for the relevant environmental classifications of Table 2.

Table 94 – Environmental performance specifications for balanced cabling connecting hardware

Mechanical	**M_1**	**M_2**	**M_3**	**Reference**
Bump	a	a	a	IEC 60512-6-2
Shock	a	a	a	IEC 60512-6-3
Vibration sinusoidal	a	a	a	IEC 60512-6-4
Tensile strength	10 N	50 N	100 N	IEC 60512-16-4
Cable clamp resistance to cable torsion	b	b	b	IEC 60512-17-4
Cable clamp resistance to rotation	b	b	b	IEC 60512-17-4
Ingress	**I_1**	**I_2**	**I_3**	
Particulate	IP 2X	IP 6X	IP 6X	IEC 60529
Liquid / Immersion	IP X0	IP X5	IP X5 and X7	IEC 60529
Climatic and chemical	**C_1**	**C_2**	**C_3**	
Ambient temperature	a	a	a	IEC 60512-11-9 and IEC 60512-11-10
Rapid change of temperature	a	a	a	IEC 60512-11-4
Solar radiation	a	a	a	ISO 4892-1 ISO 4892-2
Damp heat cyclic	a	a	a	IEC 60512-11-12
Fluid resistance	a	a	a	IEC 60512-19-3
Flowing mixed gas corrosion test	a	a	a	IEC 60512-11-7
Electromagnetic	**E_1**	**E_2**	**E_3**	
Shielding effectiveness	a	a	a	IEC 60512-23-3, and IEC 60512-4-2 for partial discharge
RF	a	a	a	IEC 60512-23-3
Voltage proof	a	a	a	IEC 60512-4-1

NOTE Although not contained in Table 2, "weld splatter" may also be considered during the development of a detail specification.

[a] Connecting hardware shall maintain mechanical and electrical performance during exposure to the relevant environmental conditions specified in Table 2.

[b] Connecting hardware shall maintain mechanical and electrical performance during exposure to the relevant environmental conditions.

All two-piece connections that are not covered by 10.2.4.2 shall comply with the mechanical and environmental performance requirements specified in Annex B. All electrical requirements shall be met before and after mechanical and environmental performance testing, as prescribed in Annex B.

10.1.4.3 Connecting hardware for coaxial cabling

Connecting hardware for coaxial cabling shall meet the mechanical and transmission performance requirements of 10.4 as appropriate in conjunction with the performance requirements detailed in Table 95 for the relevant environmental classifications of Table 2.

Table 95 – Environmental performance specifications for coaxial cabling connecting hardware

Mechanical	M_1	M_2	M_3	Reference
Bump	[a]	[a]	[a]	IEC 61169-1
Shock	[a]	[a]	[a]	IEC 61169-1
Vibration sinusoidal	[a]	[a]	[a]	IEC 61169-1
Tensile strength	10 N	50 N	100 N	IEC 61169-1
Cable clamp resistance to cable torsion	[b]	[b]	[b]	IEC 61169-1
Cable clamp resistance to rotation	[b]	[b]	[b]	IEC 61169-1
Ingress	I_1	I_2	I_3	
Particulate	IP 2X	IP 6X	IP 6X	IEC 60966-1
Liquid / Immersion	IP X0	IP X5	IP X5 and X7	IEC 61169-1
Climatic and chemical	C_1	C_2	C_3	
Ambient temperature	[a]	[a]	[a]	IEC 61169-1
Rapid change of temperature	[a]	[a]	[a]	IEC 61169-1
Solar radiation	[a]	[a]	[a]	ISO 4892-1 ISO 4892-2
Damp heat cyclic	[a]	[a]	[a]	IEC 61169-1
Fluid resistance	[a]	[a]	[a]	IEC 61169-1
Flowing mixed gas corrosion test	[a]	[a]	[a]	IEC 61169-1
Electromagnetic	E_1	E_2	E_3	
Shielding effectiveness	[a]	[a]	[a]	IEC 61169-1
RF	[a]	[a]	[a]	IEC 61169-1
Voltage proof	[a]	[a]	[a]	IEC 61169-1

NOTE Although not contained in Table 2, "weld splatter" may also be considered during the development of a detail specification.

[a] Connecting hardware shall maintain mechanical and electrical performance during exposure to the relevant environmental conditions specified in Table 2.

[b] Connecting hardware shall maintain mechanical and electrical performance during exposure to the relevant environmental conditions.

10.1.4.4 Connecting hardware for optical fibre cabling

Connecting hardware for optical fibre cabling shall meet the mechanical and transmission performance requirements of 10.5 as appropriate in conjunction with the performance requirements detailed in Table 96 for the relevant environmental classifications of Table 2. The IEC fibre optic connector product specifications are based on the IEC 61753 performance standard.

Table 96 – Environmental performance specifications for optical fibre cabling connecting hardware

Mechanical	**M_1**	**M_2**	**M_3**	**Reference**
Bump	a	a	a	Requested from IEC SC 86B
Shock	a	a	a	IEC 61300-2-9
Vibration sinusoidal	a	a	a	IEC 61300-2-1
Fibre and cable retention	10 N	50 N	100 N	IEC 61300-2-4
Torsion	b	b	b	IEC 61300-2-5
Flexing of the strain relief of fibre optic devices	b	b	b	IEC 61300-2-44
Ingress	**I_1**	**I_2**	**I_3**	
Particulate	IP 2X	IP 6X	IP 6X	In development by IEC SC 86B
Liquid / Immersion	IP X0	IP X5	IP X5 and X7	In development by IEC SC 86B
Climatic and chemical	**C_1**	**C_2**	**C_3**	
Dry Heat – High Temperature endurance	a	a	a	IEC 61300-2-18
Change of temperature	a	a	a	IEC 61300-2-22
Solar radiation achieved by measuring UV radiation	a	a	a	ISO 4892-1 ISO 4892-2
Damp heat cyclic	a	a	a	IEC 61300-2-46
Resistance to solvents and contaminating fluids of interconnecting components and closures	a	a	a	IEC 61300-2-34
Flowing mixed gas corrosion test	a	a	a	Requested from IEC SC 86B

[a] Connecting hardware shall maintain mechanical and optical performance during exposure to the relevant environmental conditions specified in Table 2.

[b] Connecting hardware shall maintain mechanical and optical performance during exposure to the relevant environmental conditions.

10.1.5 Mounting

Connecting hardware should be designed to provide flexibility for mounting, either directly or by means of an adapter plate or enclosure. For example, connecting hardware should have mounting provisions for placement on walls, in walls, in racks, or on other types of distribution frames, and mounting fixtures.

10.1.6 Installation practices

The manner and care with which the cabling is implemented are significant factors in the performance and ease of administration of installed cabling systems. Installation and cable management precautions should include the elimination of cable stress as caused by tension, sharp bends and tightly bunched cables.

The connecting hardware shall be installed to permit

a) minimal signal impairment and maximum screen effectiveness (where screened cabling is used) by proper cable preparation, termination practices (in accordance with manufacturer's guidelines) and well organized cable management,

b) room for mounting telecommunications equipment associated with the cabling system. Racks should have adequate clearances for access and cable dressing space.

The connecting hardware shall be identified according to the requirements of ISO/IEC 14763-2. Planning and installation of connecting hardware should be carried out in accordance with ISO/IEC 14763-2.

NOTE 1 Some connections are used to perform a crossover function between two elements to properly configure cabling links for transmit and receive connections.

NOTE 2 Improper termination of any balanced cable element or screen can degrade transmission performance, increase emissions and reduce immunity.

10.1.7 Marking and colour coding

In order to maintain consistent and correct point-to-point connections, provisions shall be made to ensure that terminations are properly located with respect to connector positions and their corresponding cable elements. Such provisions may include the use of colours, alphanumeric identifiers or other means designed to ensure that cables are connected in a consistent manner throughout the system.

When two physically similar cabling types are used in the same subsystem, they shall be marked in such a way as to allow each cabling type to be clearly identified. For example, different performance categories, different nominal impedance and different optical fibre core diameters should carry unique markings or colours to facilitate visual identification.

Connecting hardware shall be marked or colour coded for identification purposes. The means of identification can be used to indicate transmission and environmental performance in accordance with Clause 10. The means of identification may be an element of the administration system.

Where a protective housing prevents the identification of the connecting hardware type, the protective housing shall be suitably marked or colour coded.

10.2 Category 5 through 7_A, 8.1, and 8.2 connecting hardware for balanced cabling

10.2.1 General

The following requirements apply to all connecting hardware used to provide electrical connections with balanced cables that comply with the requirements of 9.3. It is desirable that hardware used to directly terminate balanced cable elements be of the insulation piercing connection (IPC) type or the insulation displacement connection (IDC) type. In addition to these requirements, connecting hardware used with screened cabling shall be in full compliance with ISO/IEC 14763-2.

Connecting hardware should be designed in such a way that the untwisted length in a cable element, resulting from its termination to connecting hardware is as short as possible. Connecting hardware should permit a minimum length of exposed pairs between the end of the cable sheath and the point of termination. In addition, only the length of cable sheath required for termination and trimming should be removed or stripped back. These recommendations are provided to minimize the impact of terminations on transmission performance and are not intended to constrain twist length for cable or jumper construction.

Earthing requirements and screen continuity considerations are specified in ISO/IEC 14763-2.

10.2.2 Performance marking

Connecting hardware intended for use with balanced cabling should be marked to designate transmission performance at the discretion of the manufacturer. The markings, if any, shall be visible during installation and do not replace other markings specified in 10.1.7, ISO/IEC 14763-2 or those required by local codes or regulations.

10.2.3 Mechanical characteristics

Connecting hardware intended for use with balanced cabling shall meet the requirements specified in Table 97.

Table 97 – Mechanical characteristics of connecting hardware for use with balanced cabling

Mechanical characteristics			Requirement	Component or test standard
a)	Physical dimensions (TE only)	Category 5 unscreened	Mating dimensions and gauging	IEC 60603-7-2
		Category 5 screened	Mating dimensions and gauging	IEC 60603-7-3
		Category 6 unscreened	Mating dimensions and gauging	IEC 60603-7-4
		Category 6 screened	Mating dimensions and gauging	IEC 60603-7-5
		Category 6_A unscreened	Mating dimensions and gauging	IEC 60603-7-41
		Category 6_A screened	Mating dimensions and gauging	IEC 60603-7-51
		Category 7 screened	Mating dimensions and gauging	IEC 60603-7-7 [h]
		Category 7_A screened	Mating dimensions and gauging	IEC 60603-7-71 [h,i]
		Category 8.1 screened	Mating dimensions and gauging	IEC 60603-7-81
		Category 8.2 screened	Mating dimensions and gauging	IEC 60603-7-82 [h,i]
b)	Cable termination compatibility			
	Nominal conductor diameter – mm		0,5 to 0,65 [a]	–
	Cable type	Patching [d]	Stranded or solid conductors	–
		Jumpers	Stranded or solid conductors	–
		Other	Solid conductors	–
	Nominal diameter of insulated conductor mm	Categories 5 and 6	0,7 to 1,4 [b, c]	–
		Categories 6_A, 7, 7_A and BCT-B	0,7 to 1,6 [b, c]	
	Number of conductors	Terminal equipment (TE) outlet	8	Visual inspection
		Other	≥ 2 × n (n = 1, 2, 3, ...)	
	Cable outer diameter mm	Outlet	≤ 20	–
		Free connector (plug)	≤ 9 [e]	
	Means to connect screen [f]		Mechanical and environmental performance	Annex B and ISO/IEC 14763-2
c)	Mechanical operation (durability)			
	Cable termination (cycles)	Non-reusable IDC	1	IEC 60352-3 or IEC 60352-4
		Reusable IDC	≥ 20	IEC 60352-3 or IEC 60352-4
		Non-reusable IPC	1	IEC 60352-6
	Jumper termination (cycles)		≥ 200 [g]	IEC 60352-3 or IEC 60352-4
	TE-type interface (cycles)		≥ 750 [j]	IEC 60603-7 (unscreened) or IEC 60603-7-1 (screened)
	Other connections		≥ 200	Annex B

[a] It is not required that connecting hardware be compatible with cables outside of this range. However, when cables with conductor diameters as low as 0,4 mm or as high as 0,8 mm are used, special care should be taken to ensure compatibility with connecting hardware to which they connect.

[b] Use of the free connector (plug) specified in series IEC 60603-7 is typically limited to cables having insulated conductor diameters in the range of 0,8 mm to 1,0 mm.

[c] It is not required that connecting hardware be compatible with cables outside of this range. However, when cables with insulated conductor diameters as high as 1,6 mm are used, special care should be taken to ensure compatibility with connecting hardware to which they connect.

[d] Free connectors (plugs) shall be compatible with the solid or stranded cable selected for work area or equipment cords.

[e] Applicable only to individual cable units.

[f] If it is intended to use screened cabling, the connector should be designed to terminate the screen. There may be a difference between connectors designed to terminate balanced cables with overall screens only, as opposed to cables having both individually screened elements and an overall screen (see Annex D).

[g] This durability requirement is only applicable to connections designed to administer cabling system changes (i.e. at a distributor).

[h] In installations where other factors, such as BCT applications (see ISO/IEC 11801-4), take preference over the backward compatibility offered with IEC 60603-7-7 and IEC 60603-7-71, the interface specified in IEC 61076-3-104 may be used.

[i] If backwards compatibility is not required, the free connector (plug) specified in IEC 61076-3-110 may be used.

[j] See IEC 60512-99-001 for information on PoE support for unmating under load.

Where the design of the TE interface allows and is required by the environmental classification of the location, the protective housing for TE outlets shall meet the mechanical and physical requirements of IEC 61076-3-106, Variant 04, by the use of appropriate inserts (IEC 61754-20-100).

10.2.4 Electrical characteristics

10.2.4.1 General

Free and fixed connectors (plugs and jacks) that are physically intermateable (e.g. IEC 60603-7 series) shall be backward compatible with those of different performance Categories. Table 98 does not imply intermateability of diverse connector types allowed in this document (e.g. IEC 61076-3-104 fixed connectors are not intermateable with IEC 61076-3-110 free connectors).

Backward compatibility means that the mated connections with free and fixed connectors (plugs and jacks) from different categories shall meet all of the requirements for the lower category component. See Table 98 for a matrix of backward compatible mated free and fixed connectors (plug and jack) performance that is representative of backward compatible connectivity.

Table 98 – Matrix of backward compatible mated free and fixed connector (plug and jack) performance

		Fixed connector (jack) performance at the TE						
		Category 5	**Category 6**	**Category 6_A**	**Category 8.1**	**Category 7**	**Category 7_A**	**Category 8.2**
Free connector (plug)	**Category 5**	Category 5	Category 5	Category 5	Category 5	Category 5	Category 5	Category 5
	Category 6	Category 5	Category 6	Category 6	Category 6	Category 6	Category 6	Category 6
	Category 6A	Category 5	Category 6	Category 6_A	Category 6_A	Category 6_A [a]	Category 6_A [a]	Category 6_A
	Category 8.1	Category 5	Category 6	Category 6_A	Category 8.1	Category 6_A [a]	Category 6A	Category 8.1
	Category 7	Category 5	Category 6	Category 6_A [a]	Category 6_A [a]	Category 7	Category 7	Category 7
	Category 7A	Category 5	Category 6	Category 6_A	Category 6_A	Category 7	Category 7_A	Category 7_A
	Category 8.2	Category 5	Category 6	Category 6_A	Category 8.1	Category 7	Category 7_A	Category 8.2

[a] Not including alien crosstalk.

Connecting hardware intended for use with balanced cabling shall meet the performance requirements of 10.2.4.2 irrespective of the mating interface used. Connecting hardware shall be tested with terminations and test leads that match the nominal characteristic impedance of the types of cable that they are intended to terminate (see 9.3).

10.2.4.2 Performance requirements

In Table 99 to Table 129, requirements are provided for a range of frequencies. Performance values at discrete frequencies are provided for reference only.

Table 99 – Return loss

	Minimum return loss [a] dB						
Frequency MHz	**Connector category**						
	5	**6**	**6_A**	**7**	**7_A and BCT-B**	**8.1**	**8.2**
$1 \leq f \leq 100$	$60 - 20 \lg(f)$	–	–	–	–	–	–
$1 \leq f \leq 250$	–	$64 - 20 \lg(f)$	–	–	–	–	–
$1 \leq f \leq 500$	–	–	$68 - 20 \lg(f)$	–	–	–	–
$1 \leq f \leq 600$	–	–	–	$68 - 20 \lg(f)$	–	–	–
$1 \leq f \leq 1000$	–	–	–	–	$68 - 20 \lg(f)$[b]	–	–
$1 \leq f \leq 2000$	–	–	–	–	–	$72 - 20 \lg(f)$[c]	$72 - 20 \lg(f)$[c]

[a] Return loss at frequencies that correspond to calculated values of greater than 30,0 dB shall revert to a minimum requirement of 30,0 dB.

[b] Calculated values below 10,0 dB revert to a 10,0 dB plateau.

[c] Calculated values below 12,0 dB revert to a 12,0 dB plateau.

Table 100 – Informative return loss values for connector at key frequencies

Frequency MHz	Minimum return loss dB						
	Connector category						
	5	6	6_A	7	7_A and BCT-B	8.1	8.2
1	30,0	30,0	30,0	30,0	30,0	30,0	30,0
100	20,0	24,0	28,0	28,0	28,0	30,0	30,0
250	–	16,0	20,0	20,0	20,0	24,0	24,0
500	–	–	14,0	14,0	14,0	18,0	18,0
600	–	–	–	12,4	12,4	16,4	16,4
1 000	–	–	–	–	10,0	12,0	12,0
1 600	–	–	–	–	–	12,0	12,0
2 000	–	–	–	–	–	12,0	12,0

Table 101 – Insertion loss

Frequency MHz	Maximum insertion loss [a] dB						
	Connector category						
	5	6	6_A	7	7_A and BCT-B	8.1	8.2
$1 \leq f \leq 100$	$0{,}04\sqrt{f}$	–	–	–	–	–	–
$1 \leq f \leq 250$	–	$0{,}02\sqrt{f}$	–	–	–	–	–
$1 \leq f \leq 500$	–	–	$0{,}02\sqrt{f}$	–	–	$0{,}02\sqrt{f}$	–
$1 \leq f \leq 600$	–	–	–	$0{,}02\sqrt{f}$	–	–	–
$1 \leq f \leq 1\,000$	–	–	–	–	$0{,}02\sqrt{f}$	–	$0{,}02\sqrt{f}$
$500 \leq f \leq 2\,000$	–	–	–	–	–	$0{,}006\,49\sqrt{f} + 0{,}000\,605\,f$	–
$1\,000 \leq f \leq 2\,000$	–	–	–	–	–	–	$0{,}02\sqrt{f} + 0{,}000\,5(f - 1000)$

[a] Insertion loss at frequencies that correspond to calculated values of less than 0,1 dB shall revert to a requirement of 0,1 dB maximum.

Table 102 – Informative insertion loss values for connector at key frequencies

Frequency MHz	**Maximum insertion loss** dB						
	Connector category						
	5	**6**	**6**$_A$	**7**	**7**$_A$ **and BCT-B**	**8.1**	**8.2**
1	0,10	0,10	0,10	0,10	0,10	0,10	0,10
100	0,40	0,20	0,20	0,20	0,20	0,20	0,20
250	–	0,32	0,32	0,32	0,32	0,32	0,32
500	–	–	0,45	0,45	0,45	0,45	0,45
600	–	–	–	0,49	0,49	0,52	0,49
1 000	–	–	–	–	0,63	0,81	0,63
1 600	–	–	–	–	–	1,23	1,10
2 000	–	–	–	–	–	1,50	1,39

Table 103 – Near-end crosstalk (NEXT)

Frequency MHz	**Minimum NEXT** dB						
	Connector category						
	5 [a]	**6** [a]	**6**$_A$ [a]	**7** [a]	**7**$_A$ [a]	**8.1** [b]	**8.2** [b]
$1 \le f \le 100$	$83 - 20\lg(f)$	–	–	–	–	–	–
$1 \le f \le 250$	–	$94 - 20\lg(f)$	$94 - 20\lg(f)$	–	–	$94 - 20\lg(f)$	–
$250 < f \le 500$	–	–	$46{,}04 - 30\lg(f/250)$	–	–	$46{,}04 - 30\lg(f/250)$	–
$1 \le f \le 600$	–	–	–	$102{,}4 - 15\lg(f)$	$116{,}3 - 20\lg(f)$	–	$116{,}3 - 20\lg(f)$
$600 < f \le 1\,000$	–	–	–	–	$60{,}73 - 40\lg(f/600)$	–	$116{,}3 - 20\lg(f)$
$500 \le f \le 2\,000$	–	–	–	–	–	$37 - 40\lg(f/500)$	–
$1\,000 \le f \le 1\,600$	–	–	–	–	–	–	$56{,}3 - 90\lg(f/1\,000)$
$1\,600 \le f \le 2\,000$	–	–	–	–	–	–	$37{,}93 - 40\lg(f/1\,600)$

[a] *NEXT* at frequencies that correspond to calculated values of greater than 75,0 dB shall revert to a minimum requirement of 75,0 dB.

[b] *NEXT* at frequencies that correspond to calculated values of greater than 80,0 dB shall revert to a minimum requirement of 80,0 dB.

Table 104 – Informative NEXT values for connector at key frequencies

Frequency MHz	Minimum NEXT dB						
	Connector category						
	5	**6**	**6_A**	**7**	**7_A**	**8.1**	**8.2**
1	75,0	75,0	75,0	75,0	75,0	80,0	80,0
100	43,0	54,0	54,0	72,4	75,0	54,0	76,3
250	–	46,0	46,0	66,4	68,3	46,0	68,3
500	–	–	37,0	61,9	62,3	37,0	62,3
600	–	–	–	60,7	60,7	33,8	60,7
1 000	–	–	–	–	51,9	25,0	56,3
1 600	–	–	–	–	–	16,8	37,9
2 000	–	–	–	–	–	12,9	34,1

Table 105 – Power sum near-end crosstalk (PS NEXT)
(for information only)

Frequency MHz	Minimum PS NEXT [a] dB						
	Connector category						
	5	**6**	**6_A**	**7**	**7_A**	**8.1**	**8.2**
$1 \leq f \leq 100$	$80 - 20\lg(f)$	–	–	–	–	–	–
$1 \leq f \leq 250$	–	$90 - 20\lg(f)$	$90 - 20\lg(f)$	–	–	$90 - 20\lg(f)$	–
$250 < f \leq 500$	–	–	$42{,}04 - 30\lg(f/250)$	–	–	$42{,}04 - 30\lg(f/250)$	–
$1 \leq f \leq 600$	–	–	–	$99{,}4 - 15\lg(f)$	$113{,}3 - 20\lg(f)$	–	$113{,}3 - 20\lg(f)$
$600 < f \leq 1\,000$	–	–	–	–	$57{,}73 - 40\lg(f/600)$	–	$113{,}3 - 20\lg(f)$
$500 \leq f \leq 2\,000$	–	–	–	–	–	$33 - 40\lg(f/500)$	–
$1\,000 \leq f \leq 1\,600$	–	–	–	–	–	–	$53{,}3 - 90\lg(f/1\,000)$
$1\,600 \leq f \leq 2\,000$	–	–	–	–	–	–	$34{,}93 - 40\lg(f/1\,600)$

[a] *PS NEXT* at frequencies that correspond to calculated values of greater than 72,0 dB shall revert to a minimum requirement of 72,0 dB.

Table 106 – Informative PS NEXT values for connector at key frequencies

Frequency MHz	Minimum PS NEXT dB						
	Connector category						
	5	6	6_A	7	7_A	8.1	8.2
1	72,0	72,0	72,0	72,0	72,0	72,0	72,0
100	40,0	50,0	50,0	69,4	72,0	50,0	72,0
250	–	42,0	42,0	63,4	65,3	42,0	65,3
500	–	–	33,0	58,9	59,3	33,0	59,3
600	–	–	–	57,7	57,7	29,8	57,7
1 000	–	–	–	–	48,9	21,0	53.3
1 600	–	–	–	–	–	14,8	34,9
2 000	–	–	–	–	–	8,9	31,1

Table 107 – Far-end crosstalk (FEXT)

Frequency MHz	Minimum FEXT [c] dB						
	Connector category						
	5 [a]	6 [a]	6_A [a]	7 [a]	7_A [a]	8.1 [b]	8.2 [b]
$1 \leq f \leq 100$	75,1 – 20lg(f)	–	–	–	–	–	–
$1 \leq f \leq 250$	–	83,1 – 20lg(f)	–	–	–	–	–
$1 \leq f \leq 500$	–	–	83,1 – 20 lg(f)	–	–	–	–
$1 \leq f \leq 600$	–	–	–	90 – 15 lg(f)	–	–	–
$1 \leq f \leq 1\,000$	–	–	–	–	103,9 – 20 lg(f)	–	103,9 – 20 lg(f)
$1 \leq f \leq 2\,000$	–	–	–	–	–	83,1 – 20 lg(f)	–
$1\,000 \leq f \leq 1\,600$	–	–	–	–	–	–	43,9 – 90 lg(f/1 000)
$1\,600 \leq f \leq 2\,000$	–	–	–	–	–	–	25,52 – 40 lg(f/1 600)

[a] *FEXT* at frequencies that correspond to calculated values of greater than 75,0 dB shall revert to a minimum requirement of 75,0 dB.

[b] *FEXT* at frequencies that correspond to calculated values of greater than 80,0 dB shall revert to a minimum requirement of 80,0 dB.

[c] For connectors, the difference between *FEXT* and *ACR-F* is minimal. Therefore, connector *FEXT* requirements are used to model *ACR-F* performance for links and channels.

Table 108 – Informative FEXT values for connector at key frequencies

Frequency MHz	Minimum FEXT dB						
	Connector category						
	5	6	6_A	7	7_A	8.1	8.2
1	75,0	75,0	75,0	75,0	75,0	80,0	80,0
100	35,1	43,1	43,1	60,0	63,9	43,1	63,9
250	–	35,1	35,1	54,0	55,9	35,1	55,9
500	–	–	29,1	49,5	49,9	29,1	49,9
600	–	–	–	48,3	48,3	27,5	48,3
1 000	–	–	–	–	43,9	23,1	43,9
1 600	–	–	–	–	–	19,0	25,5
2 000	–	–	–	–	–	17,1	21,6

Table 109 – Power sum far-end crosstalk (PS FEXT)
(for information only)

Frequency MHz	Minimum PS FEXT [a, b] dB						
	Connector category						
	5	6	6_A	7	7_A	8.1	8.2
$1 \le f \le 100$	$72{,}1 - 20\lg(f)$	–	–	–	–	–	–
$1 \le f \le 250$	–	$80{,}1 - 20\lg(f)$	–	–	–	–	–
$1 \le f \le 500$	–	–	$80{,}1 - 20\lg(f)$	–	–	–	–
$1 \le f \le 600$	–	–	–	$87 - 15\lg(f)$	–	–	–
$1 \le f \le 1\,000$	–	–	–	–	$100{,}9 - 20\lg(f)$	–	$100{,}9 - 20\lg(f)$
$1 \le f \le 2\,000$	–	–	–	–	–	$80{,}1 - 20\lg(f)$	–
$1\,000 \le f \le 1\,600$	–	–	–	–	–	–	$40{,}9 - 90\lg(f/1\,000)$
$1\,600 \le f \le 2\,000$	–	–	–	–	–	–	$22.52 - 40\lg(f/1\,600)$

[a] *PS FEXT* at frequencies that correspond to calculated values of greater than 72,0 dB shall revert to a minimum requirement of 72,0 dB.

[b] For connectors, the difference between *PS FEXT* and *PS ACR-F* is minimal. Therefore, connector *PS FEXT* requirements are used to model *PS ACR-F* performance for links and channels.

Table 110 – Informative PS FEXT values for connector at key frequencies

Frequency MHz	Minimum PS FEXT dB						
	Connector category						
	5	6	6_A	7	7_A	8.1	8.2
1	72,0	72,0	72,0	72,0	72,0	72,0	72,0
100	32,1	40,1	40,1	57,0	60,9	40,1	60,9
250	–	32,1	32,1	51,0	52,9	32,1	52,9
500	–	–	26,1	46,5	46,9	26,1	46,9
600	–	–	–	45,3	45,3	24,5	45,3
1 000	–	–	–	–	40,9	20,1	40,9
1 600	–	–	–	–	–	16,0	22,5
2 000	–	–	–	–	–	14,1	18,6

Table 111 – Input to output resistance

Frequency	Maximum input to output resistance mΩ						
	Connector category						
	5	6	6_A	7	7_A	8.1	8.2
DC	200	200	200	200	200	200	200

Table 112 – Input to output resistance unbalance

Frequency	Maximum input to output resistance unbalance mΩ						
	Connector category						
	5	6	6_A	7	7_A	8.1	8.2
DC	50	50	50	50	50	50	50

Table 113 – DC current carrying capacity

Frequency	Minimum DC current carrying capacity [a, b] A						
	Connector category						
	5	6	6_A	7	7_A	8.1	8.2
DC	0,75	0,75	0,75	0,75	0,75	0,75	0,75

[a] Applicable for an ambient temperature of 60 °C.

[b] Applicable to each conductor including the screen, if present.

Table 114 – Propagation delay

Frequency MHz	Maximum propagation delay [a] ns						
	Connector category						
	5	**6**	**6_A**	**7**	**7_A**	**8.1**	**8.2**
$1 \le f \le 100$	2,5	–	–	–	–	–	–
$1 \le f \le 250$	–	2,5	–	–	–	–	–
$1 \le f \le 500$	–	–	2,5	–	–	–	–
$1 \le f \le 600$	–	–	–	2,5	–	–	–
$1 \le f \le 1\,000$	–	–	–	–	2,5	–	–
$1 \le f \le 2\,000$	–	–	–	–	–	2,5	2,5

[a] This parameter shall be met by design.

Table 115 – Delay skew

Frequency MHz	Maximum delay skew [a] ns						
	Connector category						
	5	**6**	**6_A**	**7**	**7_A**	**8.1**	**8.2**
$1 \le f \le 100$	1,25	–	–	–	–	–	–
$1 \le f \le 250$	–	1,25	–	–	–	–	–
$1 \le f \le 500$	–	–	1,25	–	–	–	–
$1 \le f \le 600$	–	–	–	1,25	–	–	–
$1 \le f \le 1\,000$	–	–	–	–	1,25	–	–
$1 \le f \le 2\,000$	–	–	–	–	–	1,25	1,25

[a] This parameter shall be met by design.

Table 116 – Transverse conversion loss (TCL)

Frequency MHz	Minimum transverse conversion loss (*TCL*) dB						
	Connector category						
	5 [a]	**6** [a]	**6_A** [a]	**7** [a]	**7_A** [a]	**8.1** [b]	**8.2** [b]
$1 \le f \le 100$	$66 - 20\lg(f)$	–	–	–	–	–	–
$1 \le f \le 250$	–	$68 - 20\lg(f)$	–	–	–	–	–
$1 \le f \le 500$	–	–	$68 - 20\lg(f)$	–	–	–	–
$1 \le f \le 600$	–	–	–	$68 - 20\lg(f)$	–	–	–
$1 \le f \le 1\,000$	–	–	–	–	$68 - 20\lg(f)$	–	–
$1 \le f \le 2\,000$	–	–	–	–	–	$74 - 20\lg(f)$	$74 - 20\lg(f)$

[a] *TCL* at frequencies that correspond to calculated values of greater than 50,0 dB shall revert to a minimum requirement of 50,0 dB.

[b] *TCL* at frequencies that correspond to calculated values of greater than 40,0 dB shall revert to a minimum requirement of 40,0 dB.

Table 117 – Informative TCL values for connector at key frequencies

Frequency MHz	Minimum transverse conversion loss (*TCL*) dB						
	Connector category						
	5	6	6_A	7	7_A	8.1	8.2
1	50,0	50,0	50,0	50,0	50,0	40,0	40,0
100	26,0	28,0	28,0	28,0	28,0	34,0	34,0
250	–	20,0	20,0	20,0	20,0	26,0	26,0
500	–	–	14,0	14,0	14,0	20,0	20,0
600	–	–	–	12,4	12,4	18,4	18,4
1 000	–	–	–	–	8,0	14,0	14,0
1 600	–	–	–	–	–	9,9	9,9
2 000	–	–	–	–	–	8,0	8,0

Table 118 – Transverse conversion transfer loss (TCTL)

Frequency MHz	Minimum transverse conversion transfer loss (*TCTL*) dB						
	Connector category						
	5 [a]	6 [a]	6_A [a]	7 [a]	7_A [a]	8.1 [b]	8.2 [b]
$1 \leq f \leq 100$	$66 - 20 \lg(f)$	–	–	–	–	–	–
$1 \leq f \leq 250$	–	$68 - 20 \lg(f)$	–	–	–	–	–
$1 \leq f \leq 500$	–	–	$68 - 20 \lg(f)$	–	–	–	–
$1 \leq f \leq 600$	–	–	–	$68 - 20 \lg(f)$	–	–	–
$1 \leq f \leq 1\,000$	–	–	–	–	$68 - 20 \lg(f)$	–	–
$1 \leq f \leq 2\,000$	–	–	–	–	–	$78 - 20 \lg(f)$	$78 - 20 \lg(f)$

[a] TCTL at frequencies that correspond to calculated values of greater than 50,0 dB shall revert to a minimum requirement of 50,0 dB.

[b] TCTL at frequencies that correspond to calculated values of greater than 40,0 dB shall revert to a minimum requirement of 40,0 dB.

Table 119 – Informative TCTL values for connector at key frequencies

Frequency MHz	Minimum transverse conversion loss (*TCTL*) dB						
	Connector category						
	5	6	6_A	7	7_A	8.1	8.2
1	50,0	50,0	50,0	50,0	50,0	40,0	40,0
100	26,0	28,0	28,0	28,0	28,0	38,0	38,0
250	–	20,0	20,0	20,0	20,0	30,0	30,0
500	–	–	14,0	14,0	14,0	24,0	24,0
600	–	–	–	12,4	12,4	22,4	22,4
1 000	–	–	–	–	8,0	18,0	18,0
1 600	–	–	–	–	–	13,9	13,9
2 000	–	–	–	–	–	12,0	12,0

Table 120 – Transfer impedance (screened connectors only)

Frequency MHz	**Maximum transfer impedance** Ω						
	Connector category						
	5	**6**	**6_A**	**7**	**7_A**	**8.1**	**8.2**
$1 \leq f \leq 10$	$0{,}1\ f^{0{,}3}$	$0{,}1\ f^{0{,}3}$	$0{,}1\ f^{0{,}3}$	$0{,}05\ f^{0{,}3}$	$0{,}05\ f^{0{,}3}$	$0{,}05\ f^{0{,}3}$	$0{,}05\ f^{0{,}3}$
$10 < f \leq 80$	$0{,}02\ f$	$0{,}02\ f$	$0{,}02\ f$	$0{,}01\ f$	$0{,}01\ f$	$0{,}01\ f$	$0{,}01\ f$

Table 121 – Informative transfer impedance values (screened connectors only) at key frequencies

Frequency MHz	**Maximum transfer impedance** Ω						
	Connector category						
	5	**6**	**6_A**	**7**	**7_A**	**8.1**	**8.2**
1	0,10	0,10	0,10	0,05	0,05	0,05	0,05
10	0,20	0,20	0,20	0,10	0,10	0,10	0,10
80	1,60	1,60	1,60	0,80	0,80	0,80	0,80

Table 122 – Coupling attenuation (screened connectors only)

Frequency MHz	**Minimum coupling attenuation** dB						
	Connector category						
	5	**6**	**6_A**	**7**	**7_A**	**8.1**	**8.2**
$30 \leq f \leq 100$	≥ 45,0	≥ 45,0	≥ 45,0	≥ 45,0	≥ 45,0	85 − 20 lg(f)	85 − 20 lg(f)
$100 < f \leq f_u$ [a]	–	85 − 20 lg(f)	85 − 20 lg(f)	85 − 20 lg(f)	85 − 20 lg(f)	85 − 20 lg(f)	85 − 20 lg(f)

[a] f_u is the upper frequency of the Class.

Table 123 – Informative coupling attenuation values (screened connectors only) at key frequencies

Frequency MHz	**Minimum coupling attenuation** dB						
	Connector category						
	5	**6**	**6_A**	**7**	**7_A**	**8.1**	**8.2**
30	45,0	45,0	45,0	45,0	45,0	55,5	55,5
100	45,0	45,0	45,0	45,0	45,0	45,0	45,0
250	–	37,0	37,0	37,0	37,0	37,0	37,0
500	–	–	31,0	31,0	31,0	31,0	31,0
600	–	–	–	29,4	29,4	29,4	29,4
1 000	–	–	–	–	25,0	25,0	25,0
1 600	–	–	–	–	–	20,9	20,9
2 000	–	–	–	–	–	19,0	19,0

Table 124 – Insulation resistance

Frequency	Minimum insulation resistance MΩ						
	Connector category						
	5	6	6_A	7	7_A	8.1	8.2
DC	100	100	100	100	100	100	100

Table 125 – Voltage proof

Electrical characteristics	Frequency	Minimum voltage proof V						
		Connector category						
		5	6	6_A	7	7_A	8.1	8.2
Conductor to conductor	DC	1 000	1 000	1 000	1 000	1 000	1 000	1 000
Conductor to test panel (and screen, if present)	DC	1 500	1 500	1 500	1 500	1 500	1 500	1 500

Table 126 – Power sum alien near-end crosstalk (PS ANEXT)

Frequency MHz	Minimum power sum alien near-end crosstalk (PS ANEXT) dB			
	Connector category			
	6_A [a]	7_A [a]	8.1 [b]	8.2 [b]
$1 \leq f \leq 500$	$110{,}5 - 20\lg(f)$	–	–	–
$1 \leq f \leq 1\,000$	–	$125{,}5 - 20\lg(f)$	–	–
$1 \leq f \leq 2\,000$	–	–	$135{,}5 - 20\lg(f)$	$135{,}5 - 20\lg(f)$

[a] PS ANEXT at frequencies that correspond to calculated values of greater than 72,0 dB shall revert to a minimum requirement of 72,0 dB.

[b] PS ANEXT at frequencies that correspond to calculated values of greater than 84,0 dB shall revert to a minimum requirement of 84,0 dB.

Table 127 – Informative PS ANEXT values at key frequencies

Frequency MHz	Minimum power sum alien near-end crosstalk (PS ANEXT) dB			
	Connector category			
	6_A	7_A	8.1	8.2
1	72,0	72,0	84,0	84,0
100	70,5	72,0	84,0	84,0
250	62,5	72,0	84,0	84,0
500	56,5	71,5	81,5	81,5
1 000	–	65,5	75,5	75,5
1 600	–	–	71,4	71,4
2 000	–	–	69,5	69,5

Table 128 – Power sum alien far-end crosstalk (PS AFEXT)

Frequency MHz	**Minimum power sum alien far-end crosstalk (PS AFEXT)** [c] dB			
	Connector category			
	6_A [a]	**7_A** [a]	**8.1** [b]	**8.2** [b]
1 ≤ *f* ≤ 500	107 − 20 lg(*f*)	–	–	–
1 ≤ *f* ≤ 1 000	–	122 − 20 lg(*f*)	–	–
1 ≤ *f* ≤ 2 000	–	–	131 − 20 lg(*f*)	128,8 − 20 lg(*f*)

[a] *PS AFEXT* at frequencies that correspond to calculated values of greater than 72,0 dB shall revert to a minimum requirement of 72,0 dB.

[b] *PS AFEXT* at frequencies that correspond to calculated values of greater than 84,0 dB shall revert to a minimum requirement of 84,0 dB.

[c] For connectors, the difference between *PS AFEXT* and *PS AACR-F* is minimal. Therefore, connector *PS AFEXT* requirements are used to model *PS AACR-F* performance for links and channels.

Table 129 – Informative PS AFEXT values at key frequencies

Frequency MHz	**Minimum power sum alien far-end crosstalk (PS AFEXT)** dB			
	Connector category			
	6_A	**7_A**	**8.1**	**8.2**
1	72,0	72,0	84,0	84,0
100	67,0	72,0	84,0	84,0
250	59,0	72,0	83,0	80,8
500	53,0	68,0	77,0	74,8
1 000	–	62,0	71,0	68,8
1 600	–	–	66,9	64,7
2 000	–	–	65,0	62,8

10.2.5 Additional requirements

10.2.5.1 3-connector permanent links

If the consolidation point link of a Class F_A 3-connection permanent link (see Figure 7) uses cable in accordance with IEC 61156-5, the connecting hardware at the connection B in Figure 7 requires NEXT and PS NEXT performance that is 6 dB better than the Category 7_A requirements specified in Table 103 and Table 105.

10.2.5.2 Cross-connections without cords/jumpers

For connecting devices that provide cross-connections without patch cords or jumpers, electrical performance shall not be worse than the equivalent of two connectors and 5 m of patch cord of the same Category. Applicable parameters include insertion loss, input to output resistance, input to output resistance unbalance, propagation delay, delay skew, and transfer impedance. In addition, crosstalk, return loss and unbalance attenuation (near-end, TCL) of such devices shall not exceed 6 dB worse than the minimum values specified in 10.2.4.2. Cross-connections with "internal" switching that replaces jumpers or patch cords are an example of such devices.

10.3 BCT-B connecting hardware

The performance of BCT-B connecting hardware shall meet the requirements for Category 7_A connecting hardware as specified in 10.2.4 with the exception of coupling attenuation, which is specified in 10.3.

The coupling attenuation of BCT-B connecting hardware shall meet the requirements in Table 130.

Table 130 – Coupling attenuation for BCT-B connecting hardware

Frequency MHz	**Minimum coupling attenuation** [a] dB
$30 \leq f \leq 100$	$\geq 85{,}0$
$100 < f \leq 1\,000$	$125 - 20\ \lg(f)$

[a] The channel performance of 6.3.3.12.4 is not ensured when using minimally compliant components.

10.4 Connecting hardware for use with coaxial cabling for BCT applications

10.4.1 General requirements

The following requirements apply to all connecting hardware used to provide electrical connections with balanced cables that comply with the requirements of 9.4. In addition to these requirements, connecting hardware used with screened cabling shall be in full compliance with ISO/IEC 14763-2.

10.4.2 Performance marking

Connecting hardware intended for use with balanced cabling should be marked to designate transmission performance at the discretion of the manufacturer. The markings, if any, shall be visible during installation and do not replace other markings specified in 10.1.7, ISO/IEC 14763-2 or those required by local codes or regulations.

10.4.3 Electrical characteristics

In Table 131 to Table 135, requirements are provided for a range of frequencies. Performance values at discrete frequencies are provided for reference only.

Table 131 – Formulae for return loss limits for BCT-C connecting hardware

Category	**Frequency** MHz	**Minimum return loss** dB
BCT-C	$1 \leq f < 2\,000$	23,0
	$2\,000 \leq f \leq 3\,000$	$23 - 73\lg(f/2000)$

Table 132 – Return loss limits for BCT-C connecting hardware at key frequencies

Frequency MHz	**Minimum return loss** dB
5	23,0
10	23,0
100	23,0
200	23,0
1 000	23,0
2 000	23,0
2 400	17,2
3 000	10,0

Table 133 – Formulae for insertion loss limits for BCT-C connecting hardware

Category	**Frequency** MHz	**Maximum insertion loss** dB
BCT-C	$1 \leq f \leq 3\ 000$	$0{,}000\ 1 \times f$, 0,10 min.

Table 134 – Insertion loss limits for BCT-C connecting hardware at key frequencies

Frequency MHz	**Maximum insertion loss** dB
1	0,10
10	0,10
100	0,10
200	0,10
1 000	0,10
2 000	0,20
2 400	0,24
3 000	0,30

Table 135 – Screening attenuation limits for BCT-C connecting hardware

Frequency MHz	**Minimum screening attenuation** dB
$30 \leq f < 300$	85
$300 \leq f < 470$	80
$470 \leq f \leq 1\ 000$	75
$1000 \leq f \leq 3\ 000$	55

10.5 Optical fibre connecting hardware

10.5.1 General requirements

The requirements of 10.5.3 apply to all connecting hardware used to provide connections between optical fibre cables described in 9.5.2.

Optical fibre adapters and connectors should be protected from dust and other contaminants, specifically while they are in an unmated state. Connector end-faces shall be inspected for contamination with low resolution microscopes, according to ISO/IEC 14763-3 and cleaned, if necessary. Prior to any connection being made, the connector end-faces shall be re-inspected to verify that the cleaning has been effective. The quality of plugs on the test cords may be inspected using the inspection requirements as stated in Annex B of ISO/IEC 14763-3:2014.

Additionally, all optical ports should comply with IEC 60825-2.

10.5.2 Marking and colour coding

Consistent coding of connectors and adapters, for example by colour, should be used to identify connections between

- different cabled multimode optical fibre types, and
- incompatible single-mode connecting hardware (e.g. blue for connectors with PC ferrules and green for connectors with APC ferrules).

In addition, keying and the identification of optical fibre positions may be used to ensure that correct polarity is maintained for duplex links.

NOTE 1 These markings are in addition to, and do not replace, other markings required by local codes or regulations.

NOTE 2 The following colour codes apply to IEC 62664 series LC duplex connectors but can also be used for other connector types.

Multimode 50 µm:	Beige
Single-mode PC:	Blue
Single-mode APC:	Green

10.5.3 Mechanical and optical characteristics

All multimode connections shall be in accordance with a published standard in the IEC 61754 series and shall provide the optical performance of Table 136 and Table 137 in conjunction with the optical fibres of 9.5.2.2. The mechanical and environmental conditions specified in IEC 61753-022-2 shall be applied.

NOTE 1 This requirement does not specify dimensions.

All single-mode connections shall be in accordance with a published standard in the IEC 61754 series and shall provide the optical performance of Table 136 and Table 137 in conjunction with the optical fibres of 9.5.2.3. The mechanical and environmental conditions specified in IEC 61753-021-2 shall be applied. Where the connecting hardware is to be used in more extreme environments the mechanical and environmental conditions specified in IEC 61753-021-3 or IEC 61753-1-3 provide appropriate references.

NOTE 2 This requirement does not specify dimensions.

Table 136 – Attenuation of connecting hardware for optical fibre

Optical characteristics	Maximum attenuation dB
Mated connectors	0,75
Splice	0,3

Table 137 – Return loss of optical fibre connecting hardware

Optical characteristics	Minimum return loss dB
Multimode	20,0
Single-mode PC	35,0
Single-mode APC	60,0

Where the design of the TE interface allows and as required by the environmental classification of the location, the protective housing for TE outlets shall meet the mechanical and physical requirements of IEC 61076-3-106, Variant 04, by the use of appropriate inserts (IEC 61754-20-100).

10.6 Connecting hardware in accordance with IEC 60603-7 series

Where the cabling design standards specify the use of connecting hardware in accordance with the IEC 60603-7 series, they shall be as referenced in Table 138.

Table 138 – Electrical characteristics of terminal equipment outlets intended for use with balanced cabling

Electrical characteristics of the terminal equipment outlet		Requirement	Component or test standard
Interface type	Frequency range MHz		
Category 5 unscreened	DC, 1 to 100	All	IEC 60603-7-2
Category 5 screened	DC, 1 to 100	All	IEC 60603-7-3
Category 6 unscreened	DC, 1 to 250	All	IEC 60603-7-4
Category 6 screened	DC, 1 to 250	All	IEC 60603-7-5
Category 6_A unscreened	DC, 1 to 500	All	IEC 60603-7-41
Category 6_A screened	DC, 1 to 500	All	IEC 60603-7-51
Category 7 screened	DC, 1 to 600	All	IEC 60603-7-7 [a]
Category 7_A screened	DC, 1 to 1 000	All	IEC 60603-7-71 [a]
Category 8.1 screened	DC, 1 to 2 000	All	IEC 60603-7-81
Category 8.2 screened	DC, 1 to 2 000	All	IEC 60603-7-82 [a]

[a] In installations where other factors, such as BCT applications (see ISO/IEC 11801-4), take preference over the backward compatibility offered with IEC 60603-7-7 and IEC 60603-7-71, the interface specified in IEC 61076-3-104 may be used.

Pin and pair grouping assignments shall be as shown in Figure 9 or Figure 10.

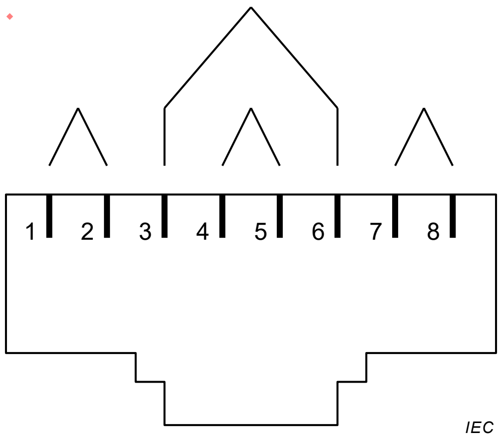
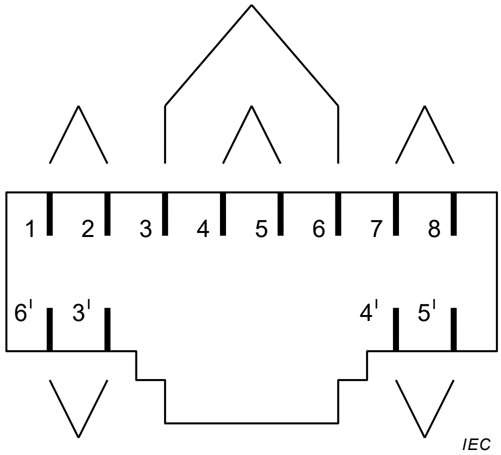


Figure 9 – Pin grouping and pair assignments for IEC 60603-7 series interface for Categories 5, 6, 6_A and 8.1 (front view of fixed connector (jack), not to scale)

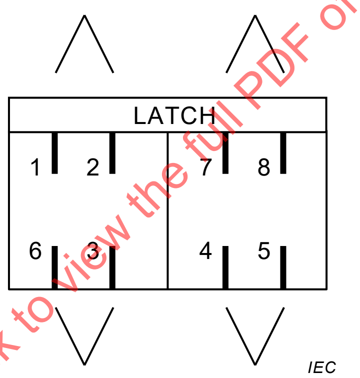


NOTE Pin designations 1, 2, 3^{I} , 4^{I} , 5^{I}, 6^{I}, 7 and 8 are used for Categories 7, 7_A , 8.2 and BCT-B, and correspond to pin designations 1, 2, 3, 4, 5, 6, 7 and 8 for Categories 5, 6, and 6_A.

Figure 10 – Pin grouping and pair assignment for the IEC 60603-7 series interface for Categories 7, 7_A, 8.2 and BCT-B (front view of fixed connector (jack), not to scale)

10.7 Connecting hardware in accordance with IEC 61076-3-104

Pin and pair grouping assignments shall be as shown in Figure 11.



NOTE Pin designations correspond to those of the IEC 60603-7 series interface.

Figure 11 – Pin grouping and pair assignments for the IEC 61076-3-104 interface for Categories 7, 7_A, 8.2 and BCT-B (front view of fixed connector (jack), not to scale)

10.8 Connecting hardware in accordance with IEC 61076-2-101 (Type D, 4 poles)

The pin grouping and pair assignments shall be as shown in Figure 12.

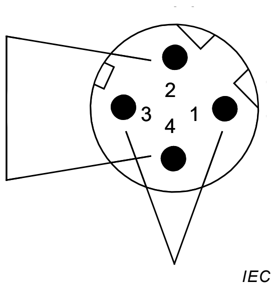


Figure 12 – Four position connector pin and pair assignments for IEC 61076-2-101 connecting hardware (front view of male connector)

10.9 Connecting hardware in accordance with IEC 61076-2-109 (Type X, 8 poles)

The pin grouping and pair assignments shall be as shown in Figure 13.