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

прийнято як національний стандарт
методом підтвердження за позначенням

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(ISO/IEC 11801-1:2017, IDT)

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Part 1: General requirements

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INFORMATION TECHNOLOGY – GENERIC CABLING FOR CUSTOMER PREMISES –

Part 1: General requirements

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 Category BCT-B, 8.1, and 8.2;

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

f) addition of cabled fibres of Category OS1a, and OM5;

g) removal of silica optical fibre cabling;

h) optical fibre cable OM1, OM2 and OS1 has 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.

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 and related Technical Reports (including the ISO/IEC TR 11801-99xx series, ISO/IEC TR 24704, ISO/IEC TR 24750 and ISO/IEC TR 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.

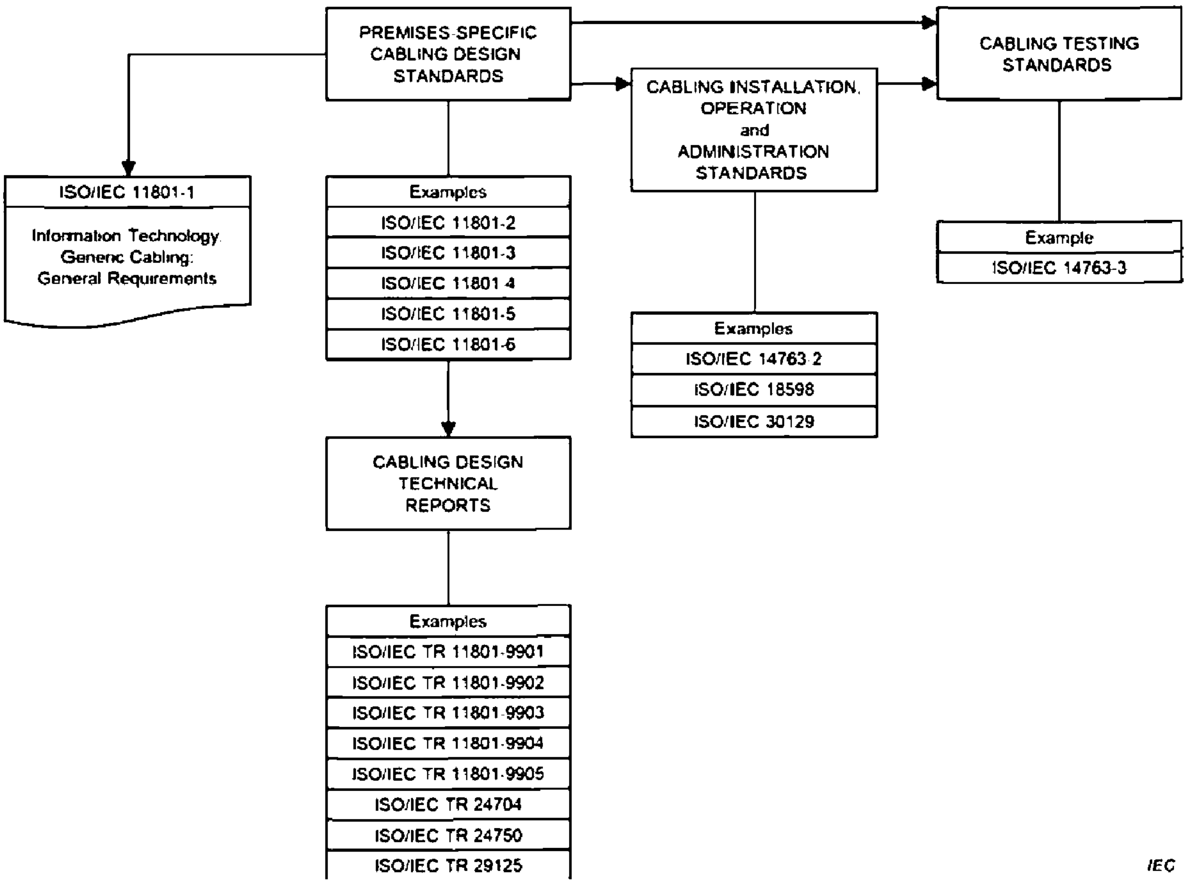


Figure 1 – Relationships between the generic cabling documents produced by ISO/IEC JTC 1/SC 25

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 3000 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 1000 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 3000 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 2000 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 3000 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 1000 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 1000 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 1000 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 1000 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 1200 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
end-to-end 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
connector sharing
using connecting hardware to support the simultaneous transmission of more than one application

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
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 attenuation (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 attenuation (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-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
$\boxed{\text{C}}$	connection
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
TO	index to denominate a characteristic, measured from the TO
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.

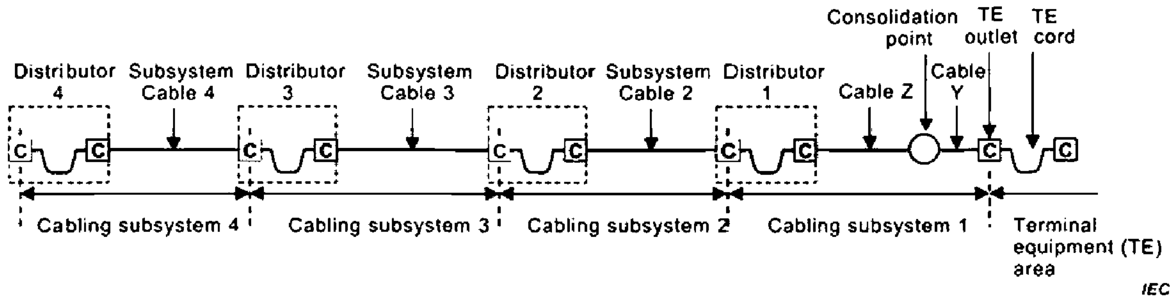


Figure 2 – General functional elements

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.

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.

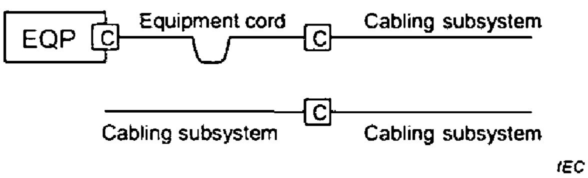


Figure 3 – Interconnect models

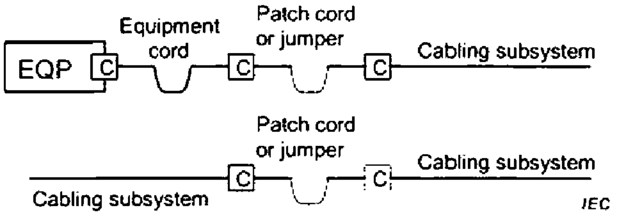


Figure 4 – Cross-connect models

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.

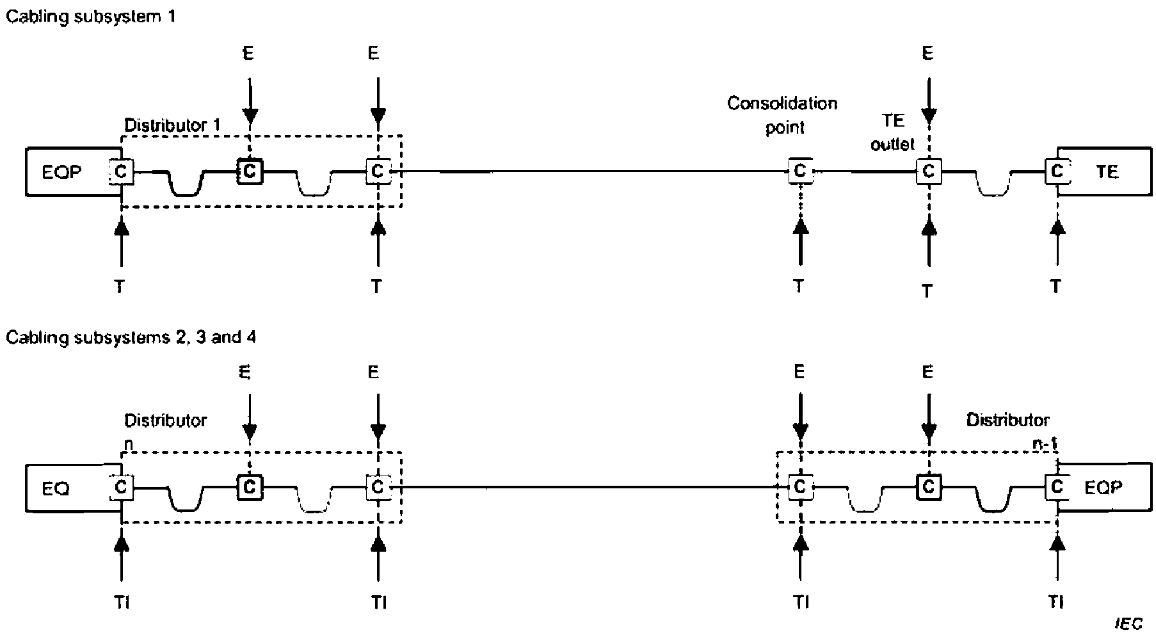


Figure 5 – Equipment and test interfaces

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	< 0,3	< 0,3
Oil (dry-air concentration) (for oil types see [b])	0	< 0,005	< 0,5
Sodium stearate (soap)	None	> 5 × 10^4 aqueous non-gelling	> 5 × 10^4 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 / < 0,01	< 0,05 / < 0,5	< 10 / < 50
Sulphur dioxide	< 0,01 / < 0,03	< 0,1 / < 0,3	< 5 / < 15
Sulphur trioxide (ffs)	< 0,01 / < 0,03	< 0,1 / < 0,3	< 5 / < 15
Chlorine wet (> 50 % humidity)	< 0,000 5 / < 0,001	< 0,005 / < 0,03	< 0,05 / < 0,3
Chlorine dry (< 50 % humidity)	< 0,002 / < 0,01	< 0,02 / < 0,1	< 0,2 / < 1,0
Hydrogen chloride	– / < 0,06	< 0,06 / < 0,3	< 0,6 / 3,0

Hydrogen fluoride	< 0,001 / < 0,005	< 0,01 / < 0,05	< 0,1 / < 1,0
Ammonia	< 1 / < 5	< 10 / < 50	< 50 / < 250
Oxides of nitrogen	< 0,05 / < 0,1	< 0,5 / < 1	<5 / <10
Ozone	< 0,002 / < 0,005	< 0,025 / < 0,05	< 0,1 / < 1
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. 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

Minimum return loss dB									
Frequency MHz	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 maximum implementation, 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	$1 < f \le 500$	$\left(0{,}634\sqrt{f} + 0{,}00156 \times f + \dfrac{0{,}078}{\sqrt{f}}\right)$ [d]
	$500 < f \le 2\,000$	$\left(0{,}60698\sqrt{f} + 0{,}00277 \times f + \dfrac{0{,}078}{\sqrt{f}}\right)$ [e]
II	$1 < f \le 2000$	$0{,}32 \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + 0{,}25/\sqrt{f}\right) + 2 \times 0{,}02 \times \sqrt{f}$ [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 $0{,}312 \times \left(1{,}8\sqrt{f} + 0{,}005 \times f + \dfrac{0{,}25}{\sqrt{f}}\right) + 2 \times \left(0{,}02 \times \sqrt{f}\right) + 0{,}0324 \times \sqrt{f}$

[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:

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

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	$1 \le f \le 100$	$-20\lg\left(10^{\frac{62{,}3-15\lg(f)}{-20}}+2\times10^{\frac{80-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{72{,}3-15\lg(f)}{-20}}+2\times10^{\frac{90-20\lg(f)}{-20}}\right)$
E_A	$1 \le f \le 500$	$-20\lg\left(10^{\frac{72{,}3-15\lg(f)}{-20}}+2\times10^{\frac{90-20\lg(f)}{-20}}\right)$ [b, d]
F	$1 \le f \le 600$	$-20\lg\left(10^{\frac{99{,}4-15\lg(f)}{-20}}+2\times10^{\frac{99{,}4-15\lg(f)}{-20}}\right)$
F_A	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}}+2\times10^{\frac{113{,}3-20\lg(f)}{-20}}\right)$ [c, d]
BCT-B	$1 \le f \le 1\,000$	$-20\lg\left(10^{\frac{102{,}4-15\lg(f)}{-20}}+2\times10^{\frac{113{,}3-20\lg(f)}{-20}}\right)$ [c, d]
I	$1 \le f \le 500$	$-20\lg\left(10^{\frac{72{,}3-15\lg(f)}{-20}}+2\times10^{\frac{91-20\lg(f)}{-20}}\right)$
	$500 < f \le 2\,000$	$-20\lg\left(10^{\frac{72{,}3-15\lg(f)}{-20}}+2\times10^{\frac{37-38\lg(f/500)}{-20}}\right)$
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] 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:

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

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

Frequency MHz	Minimum ACR-N dB								
	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:

$$PS\ ACR\text{-}N_k = PS\ NEXT_k - IL_k \tag{3}$$

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

Frequency MHz	Minimum PS ACR-N dB								
	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:

$$ACR\text{-}F_{ik} = FEXT_{ik} - IL_k \tag{4}$$

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

[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:

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

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

[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

Frequency MHz	Minimum PS ACR-F dB								
	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 only applicable to Classes A through F_A, BCT-B, I, and II.

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 only applicable to cabling Classes A through F_A, BCT-B, Class I, and Class II.

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 maximum propagation delay requirements are applicable to Classes A through F_A, BCT-B, I, and II.

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 maximum delay skew requirements are applicable to Classes A through F_A, BCT-B, I, and II.

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 systems and Class I and II screened systems. 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 systems

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 ≤ f ≤ 16	30 – 5 lg(f)	30 – 5 lg(f)	30 – 5 lg(f)
D, E, E_A	1 ≤ f < 30	53 – 15lg(f)	63 – 15lg(f)	73 – 15lg(f)
	30 ≤ f ≤ f_u [b]	60,3 – 20lg(f)	70,3 – 20lg(f)	80,3 – 20lg(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.

[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 ≤ f ≤ 2 000	unscreened pairs	60,0 – 17lg(f) [a]	60,0 – 17lg(f) [a]	60,0 – 17lg(f) [a]
I	1 ≤ f ≤ 2 000	screened pairs	50,0 – 17lg(f) [b, c]	50,0 – 17lg(f) [b, c]	50,0 – 17lg(f) [b, c]
II	1 ≤ f ≤ 2 000	unscreened pairs	60,0 – 17lg(f) [a]	60,0 – 17lg(f) [a]	60,0 – 17lg(f) [a]
II	1 ≤ f ≤ 2 000	screened pairs	50,0 – 17lg(f) [b, c]	50,0 – 17lg(f) [b, c]	50,0 – 17lg(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

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

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 systems

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	$1 \le f \le 2000$	unscreened pairs	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]
I	$1 \le f \le 2000$	screened pairs	$34{,}6 - 20\lg(f)$ [b, c]	$34{,}6 - 20\lg(f)$ [b, c]	$34{,}6 - 20\lg(f)$ [b, c]
II	$1 \le f \le 2000$	unscreened pairs	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]
II	$1 \le f \le 2000$	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 systems

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 – 20lg(f)	90 – 20lg(f)	100 – 20lg(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 – 20lg(f)	90 – 20lg(f)	100 – 20lg(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 maximum implementation, 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]	$1 \le f < 100$	$80 - 10\lg(f)$
	$100 \le f \le 500$	$90 - 15\lg(f)$
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, $IL_{100\ \mathrm{MHz,avg}}$, is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

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

where

f is the frequency in MHz;

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

$IL_{100\mathrm{MHz},i}$ 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

Minimum PS ANEXT dB				
Frequency MHz	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, $IL_{100MHz,avg}$, is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

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

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 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-F*$_k$ of disturbed pair k is determined according to Equation (8).

$$PS\ AACR\text{-}F_k = PS\ AFEXT_k - IL_k \tag{8}$$

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

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

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 $102 - 15\lg(f)$ 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

Frequency MHz	Minimum PS AACR-F dB 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$_A$	$30 \leq f \leq 100$	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
	$100 \leq f \leq 2000$	$90 - 20\lg(f)$	$105 - 20\lg(f)$
II	$30 \leq f \leq 100$	50	65
	$100 \leq f \leq 2000$	$90 - 20\lg(f)$	$105 - 20\lg(f)$

6.4 Coaxial cabling transmission performance

6.4.1 General

This document specifies Class BCT-C up to 3000 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	$5 \leq f < 470$	18,0
	$470 \leq f < 1\,000$	16,0
	$1\,000 \leq f \leq 3\,000$	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	$1 \leq f \leq 100$	$(0{,}3 + 0.05) \times \left(0{,}625\sqrt{f} + 0{,}0001f\right) + 2 \times 0{,}0001\,f$
	$100 \leq f \leq 3000$	$(0{,}3 + 0.05) \times \left(0{,}597\sqrt{f} + 0{,}0026\,f\right) + 2 \times 0{,}0001\,f$
BCT-C-M	$1 \leq f \leq 100$	$(0{,}69 + 0.05) \times \left(0{,}625\sqrt{f} + 0{,}0001f\right) + 2 \times 0{,}0001\,f$
	$100 \leq f \leq 3000$	$(0{,}69 + 0.05) \times \left(0.597\sqrt{f} + 0.0026\,f\right) + 2 \times 0.0001\,f$

[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.

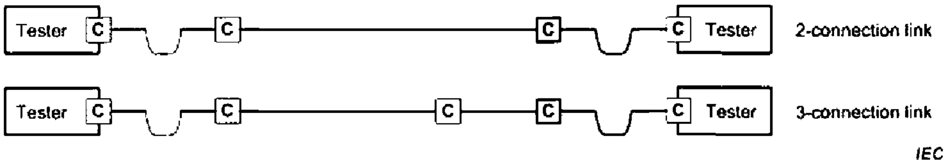
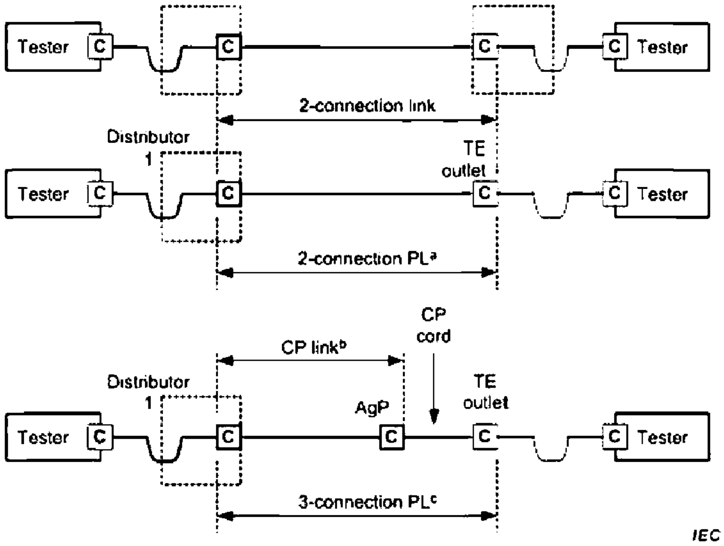


Figure 6 – Link options



[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. Link requirements for unbalance attenuation and coupling attenuation are ffs. 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
	$1600 \leq f < 2000$	$8 - 19\lg(\frac{f}{1600})$
II	$1 \leq f < 3$	$21 + 4\lg(\frac{f}{3})$
	$3 \leq f < 10$	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

Class	Frequency MHz	Minimum return loss [a] dB
	$631 \leq f < 1000$	$38 - 10\lg(f)$
	$1000 \leq f < 1600$	8,0
	$1600 \leq f < 2000$	$8 - 19\lg(\frac{f}{1600})$

[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	$0,1 \le f \le 1$	$25 - 5\lg(f)$
C	$1 \le f \le 16$	$40,1 - 15,8\lg(f)$
D	$1 \le f \le 100$	$-20\lg\left(10^{\frac{65,3-15\lg(f)}{-20}} + 10^{\frac{83-20\lg(f)}{-20}}\right)$
E	$1 \le f \le 250$	$-20\lg\left(10^{\frac{74,3-15\lg(f)}{-20}} + 10^{\frac{94-20\lg(f)}{-20}}\right)$
E_A [h]	$1 \le f \le 300$	$-20\lg\left(10^{\frac{74,3-15\lg(f)}{-20}} + 10^{\frac{94-20\lg(f)}{-20}}\right)$
	$300 < f \le 500$	$87,46 - 21,57\lg(f)$ [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	$1 \le f \le 500$	$-20\lg\left(10^{\frac{75{,}3-15\lg(f)}{-20}}+2\times10^{\frac{94-20\lg(f)}{-20}}\right)$
	$500 < f \le 2000$	$-20\lg\left(10^{\frac{75{,}3-15\lg(f)}{-20}}+2\times10^{\frac{40-38\lg(f/500)}{-20}}\right)$
II	$1 \le f \le 1000$	$-20\lg\left(10^{\frac{105{,}4-15\lg(f)}{-20}}+2\times10^{\frac{116{,}3-20\lg(f)}{-20}}\right)$
	$1000 < f \le 1600$	$-20\lg\left(10^{\frac{105{,}4-15\lg(f)}{-20}}+2\times10^{\frac{56{,}3-90\lg(f/1000)}{-20}}\right)$
	$1600 < f \le 2000$	$-20\lg\left(10^{\frac{105{,}4-15\lg(f)}{-20}}+2\times10^{\frac{37{,}93-40\lg(f/1600)}{-20}}\right)$

[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

Frequency MHz	Minimum NEXT dB										
	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:

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

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	$1 \le f \le 500$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}}+2\times 10^{\frac{91-20\lg(f)}{-20}}\right)$
	$500 < f \le 2000$	$-20\lg\left(10^{\frac{72,3-15\lg(f)}{-20}}+2\times 10^{\frac{37-38\lg(f/500)}{-20}}\right)$
II	$1 \le f \le 1000$	$-20\lg\left(10^{\frac{102,4-15\lg(f)}{-20}}+2\times 10^{\frac{113,3-20\lg(f)}{-20}}\right)$
	$1000 < f \le 1600$	$-20\lg\left(10^{\frac{102,4-15\lg(f)}{-20}}+2\times 10^{\frac{53,3-90\lg(f/1000)}{-20}}\right)$
	$1600 < f \le 2000$	$-20\lg\left(10^{\frac{102,4-15\lg(f)}{-20}}+2\times 10^{\frac{34,93-40\lg(f/1600)}{-20}}\right)$

[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] *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:

$$PS\ ACR\text{-}N_k = PS\ NEXT_k - IL_k \tag{13}$$

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

Frequency MHz	Minimum PS ACR-N dB								
	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:

$$ACR\text{-}F_{ik} = FEXT_{ik} - IL_k \qquad (14)$$

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:

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

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 ≤ f ≤ 1	4,400
C	1 ≤ f ≤ 16	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$
D	1 ≤ f ≤ 100	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$
E	1 ≤ f ≤ 250	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$
E_A	1 ≤ f ≤ 500	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$
F	1 ≤ f ≤ 600	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$
F_A	1 ≤ f ≤ 1 000	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+n\times0{,}002\,5$
BCT-B	1 ≤ f ≤ 1 000	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+2\times0{,}002\,5$
I	1≤ f ≤ 2 000	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+2\times0{,}002\,5$
II	1≤ f ≤ 2 000	$(L/100)\times\left(0{,}534+0{,}036/\sqrt{f}\right)+2\times0{,}002\,5$

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

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	$0,1 \leq f \leq 1$	N/A
C	$1 \leq f \leq 16$	$(L/100) \times 0,045 + n \times 0,001\,25$
D	$1 \leq f \leq 100$	$(L/100) \times 0,045 + n \times 0,001\,25$
E	$1 \leq f \leq 250$	$(L/100) \times 0,045 + n \times 0,001\,25$
E_A	$1 \leq f \leq 500$	$(L/100) \times 0,045 + n \times 0,001\,25$
F	$1 \leq f \leq 600$	$(L/100) \times 0,025 + n \times 0,001\,25$
F_A	$1 \leq f \leq 1\,000$	$(L/100) \times 0,025 + n \times 0,001\,25$
BCT-B	$1 \leq f \leq 1\,000$	$(L/100) \times 0,025 + 2 \times 0,001\,25$
I	$1 \leq f \leq 2\,000$	$(L/100) \times 0,045 + 2 \times 0,001\,25$
II	$1 \leq f \leq 2\,000$	$(L/100) \times 0,025 + 2 \times 0,001\,25$

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

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 ≤ f ≤ 1	N/A
C	1 ≤ f ≤ 16	0,044 [a]
D	1 ≤ f ≤ 100	0,044 [a]
E	1 ≤ f ≤ 250	0,044 [a]
E_A	1 ≤ f ≤ 500	0,044 [a]
F	1 ≤ f ≤ 600	0,026 [b]
F_A	1 ≤ f ≤ 1 000	0,026 [b]
BCT-B-L	1 ≤ f ≤ 1 000	0,004 [c]
BCT-B-M	1 ≤ f ≤ 1 000	0,008 [d]
I	1 ≤ f ≤ 2 000	0,0142 [e]
II	1 ≤ f ≤ 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	$1 \le f \le 2000$	unscreened pairs	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]
I	$1 \le f \le 2000$	screened pairs	$50{,}0 - 17\lg(f)$ [b, c]	$50{,}0 - 17\lg(f)$ [b, c]	$50{,}0 - 17\lg(f)$ [b, c]
II	$1 \le f \le 2000$	unscreened pairs	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]	$60{,}0 - 17\lg(f)$ [a]
II	$1 \le f \le 2000$	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	$1 \leq f \leq 2000$	unscreened pairs	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]
I	$1 \leq f \leq 2000$	screened pairs	$34{,}6 - 20\lg(f)$ [b, c]	$34{,}6 - 20\lg(f)$ [b, c]	$34{,}6 - 20\lg(f)$ [b, c]
II	$1 \leq f \leq 2000$	unscreened pairs	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]	$44{,}6 - 20\lg(f)$ [a, c]
II	$1 \leq f \leq 2000$	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	$30 \le f \le 100$	50	50	60
	$100 \le f \le 2000$	$90 - 20\lg(f)$	$90 - 20\lg(f)$	$100 - 20\lg(f)$

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

Frequency MHz	Minimum coupling attenuation dB					
	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:

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

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, $IL_{100\text{MHz,avg}}$, is less than 7 dB, then subtract the following for $f \ge 100$ MHz:

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

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 73 – Informative PS ANEXT values for links at key frequencies

Minimum PS ANEXT dB				
Frequency MHz	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:

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

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).

$$PSAACR\text{-}F_k = PSAFEXT_k - IL_k \tag{18}$$

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]	$1 \le f \le 2000$	$102 - 20\lg(f)$
II [a, b]	$1 \le f \le 2000$	$102 - 20\lg(f)$

[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:

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

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	$1 \le f \le 500$	$81 - 20\lg(f)$

[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	$30 \le f \le 100$	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
	$100 \le f \le 2000$	$90 - 20\lg(f)$	$105 - 20\lg(f)$
II	$30 \le f \le 100$	50	65
	$100 \le f \le 2000$	$90 - 20\lg(f)$	$105 - 20\lg(f)$

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

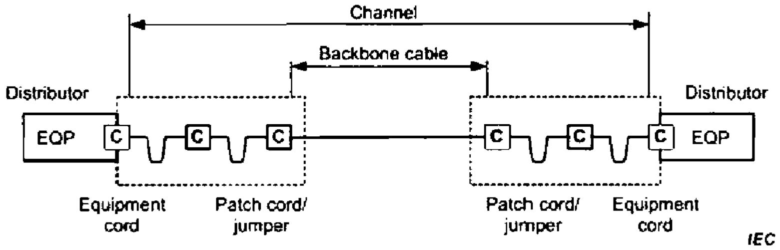
1) specify cables with lower insertion loss specifications than those detailed in 8.2, or
2) provide appropriate protection to reduce the operating temperature of the channel.

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 balanced screened 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, mechanica 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 requiremerts 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	$5 \le f < 470$	20
			$470 \le f < 1\,000$	18
			$1\,000 \le f \le 3\,000$	12
3	Maximum insertion loss	dB/100 m	$1 \le f \le 3\,000$	$0{,}835 \times \sqrt{f} + 0{,}002\,5\, f$
	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	$30 \le f < 300$	85
			$300 \le f < 470$	85
			$470 \le f \le 1\,000$	85
			$1\,000 < f \le 2\,000$	75
			$2\,000 < f \le 3\,000$	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 (0,667c) 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	$\geq 2 \times n$ (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 [i]	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	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

Frequency MHz	Minimum return loss [a] dB						
	Connector category						
	5	6	6_A	7	7_A and BCT-B	8.1	8.2
$1 \le f \le 100$	$60 - 20\lg(f)$	–	–	–	–	–	–
$1 \le f \le 250$	–	$64 - 20\lg(f)$	–	–	–	–	–
$1 \le f \le 500$	–	–	$68 - 20\lg(f)$	–	–	–	–
$1 \le f \le 600$	–	–	–	$68 - 20\lg(f)$	–	–	–
$1 \le f \le 1\,000$	–	–	–	–	$68 - 20\lg(f)$ [b]	–	–
$1 \le f \le 2000$	–	–	–	–	–	$72 - 20\lg(f)$ [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
$1 \le f \le 100$	$0{,}04\sqrt{f}$	–	–	–	–	–	–
$1 \le f \le 250$	–	$0{,}02\sqrt{f}$	–	–	–	–	–
$1 \le f \le 500$	–	–	$0{,}02\sqrt{f}$	–	–	$0{,}02\sqrt{f}$	–
$1 \le f \le 600$	–	–	–	$0{,}02\sqrt{f}$	–	–	–
$1 \le f \le 1\,000$	–	–	–	–	$0{,}02\sqrt{f}$	–	$0{,}02\sqrt{f}$
$500 \le f \le 2\,000$	–	–	–	–	–	$0{,}006\,49\sqrt{f} + 0{,}000\,605 f$	–
$1\,000 \le f \le 2\,000$	–	–	–	–	–	–	$0{,}02\sqrt{f} + 0{,}000\,5(f - 1\,000)$

[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 – 20lg(f)	94 – 20lg(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 – 15lg(f)	116,3 – 20lg(f)	–	116,3 – 20lg(f)
$600 < f \le 1\,000$	–	–	–	–	60,73 – 40lg(f/600)	–	116,3 – 20lg(f)
$500 \le f \le 2\,000$	–	–	–	–	–	37 – 40 lg(f/500)	–
$1\,000 \le f \le 1\,600$	–	–	–	–	–	–	56,3 – 90lg(f/1 000)
$1\,600 \le f \le 2\,000$	–	–	–	–	–	–	37,93 – 40lg(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
1000	–	–	–	–	48,9	21,0	53.3
1600	–	–	–	–	–	14,8	34,9
2000	–	–	–	–	–	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]
$1 \le f \le 100$	75.1 − 20lg(*f*)	–	–	–	–	–	–
$1 \le f \le 250$	–	83,1 − 20lg(*f*)	–	–	–	–	–
$1 \le f \le 500$	–	–	83,1 − 20 lg(*f*)	–	–	–	–
$1 \le f \le 600$	–	–	–	90 − 15lg(*f*)	–	–	–
$1 \le f \le 1000$	–	–	–	–	103.9 − 20lg(*f*)	–	103,9 − 20lg(*f*)
$1 \le f \le 2000$	–	–	–	–	–	83,1 − 20 lg(*f*)	–
$1000 \le f \le 1600$	–	–	–	–	–	–	43,9 − 90lg(*f*/1 000)
$1600 \le f \le 2000$	–	–	–	–	–	–	25,52 − 40lg(*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
$1 \leq f \leq 100$	2,5	–	–	–	–	–	–
$1 \leq f \leq 250$	–	2,5	–	–	–	–	–
$1 \leq f \leq 500$	–	–	2,5	–	–	–	–
$1 \leq f \leq 600$	–	–	–	2,5	–	–	–
$1 \leq f \leq 1\,000$	–	–	–	–	2,5	–	–
$1 \leq f \leq 2\,000$	–	–	–	–	–	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
$1 \leq f \leq 100$	1,25	–	–	–	–	–	–
$1 \leq f \leq 250$	–	1,25	–	–	–	–	–
$1 \leq f \leq 500$	–	–	1,25	–	–	–	–
$1 \leq f \leq 600$	–	–	–	1,25	–	–	–
$1 \leq f \leq 1\,000$	–	–	–	–	1,25	–	–
$1 \leq f \leq 2\,000$	–	–	–	–	–	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]
$1 \leq f \leq 100$	$66 - 20\lg(f)$	–	–	–	–	–	–
$1 \leq f \leq 250$	–	$68 - 20\lg(f)$	–	–	–	–	–
$1 \leq f \leq 500$	–	–	$68 - 20\lg(f)$	–	–	–	–
$1 \leq f \leq 600$	–	–	–	$68 - 20\lg(f)$	–	–	–
$1 \leq f \leq 1\,000$	–	–	–	–	$68 - 20\lg(f)$	–	–
$1 \leq f \leq 2\,000$	–	–	–	–	–	$74 - 20\lg(f)$	$74 - 20\lg(f)$

[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]
$1 \le f \le 100$	$66 - 20\lg(f)$	–	–	–	–	–	–
$1 \le f \le 250$	–	$68 - 20\lg(f)$	–	–	–	–	–
$1 \le f \le 500$	–	–	$68 - 20\lg(f)$	–	–	–	–
$1 \le f \le 600$	–	–	–	$68 - 20\lg(f)$	–	–	–
$1 \le f \le 1\,000$	–	–	–	–	$68 - 20\lg(f)$	–	–
$1 \le f \le 2\,000$	–	–	–	–	–	$78 - 20\lg(f)$	$78 - 20\lg(f)$

[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 – 20lg(f)	85 – 20lg(f)
$100 < f \leq f_u$ [a]	–	85 – 20lg(f)	85 – 20lg(f)	85 – 20lg(f)	85 – 20lg(f)	85 – 20lg(f)	85 – 20lg(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]
$1 \le f \le 500$	$107 - 20\lg(f)$	–	–	–
$1 \le f \le 1000$	–	$122 - 20\lg(f)$	–	–
$1 \le f \le 2000$	–	–	$131 - 20\lg(f)$	$128{,}8 - 20\lg(f)$

[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.

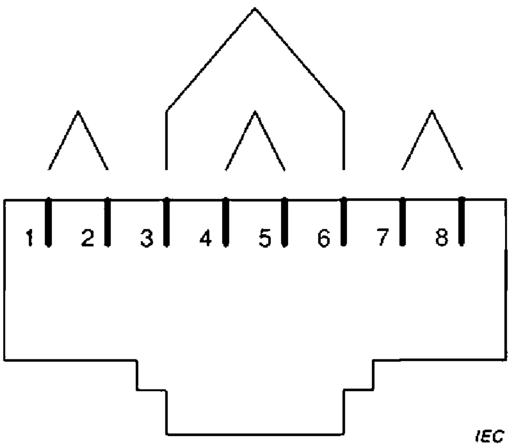
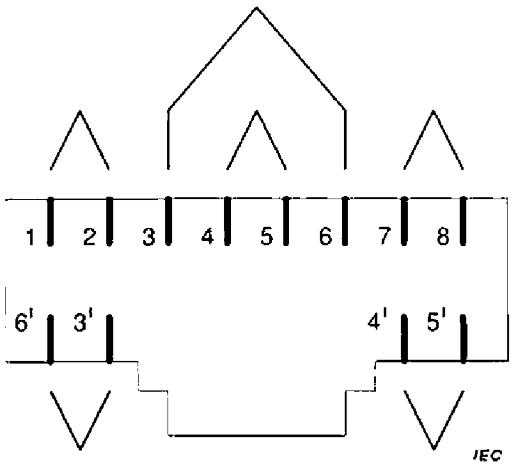


Figure 9 – Pin grouping and pair assignments for IEC 60603-7 series interface for Categories 5, 6, 6_A and 8.1 (front view of fixed connector (jack), not to scale)

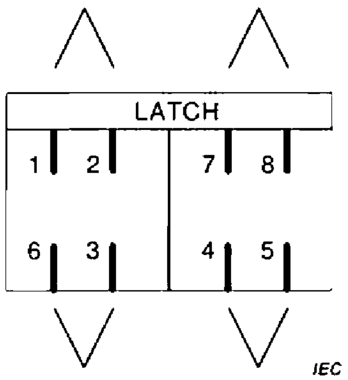


NOTE Pin designations 1. 2, 3', 4', 5', 6', 7 and 8 are used for Categories 7, 7_A, 8.2 and BCT-B, and correspond to pin designations 1, 2, 3, 4, 5, 6, 7 and 8 for Categories 5, 6, and 6_A.

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.

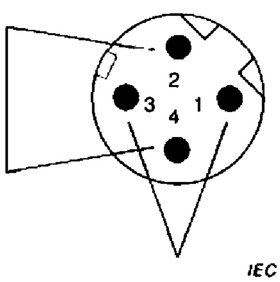


Figure 12 – Four position jack pin and pair grouping assignments for IEC 61076-2-101 connecting hardware (front view of connector)

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.

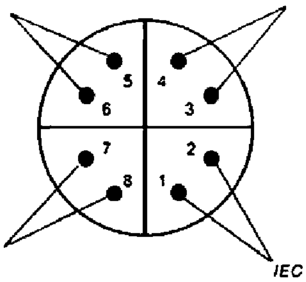


Figure 13 – Eight position jack pin and pair grouping assignments for IEC 61076-2-109 connecting hardware (front view of connector)

10.10 Connecting hardware in accordance with IEC 61169-2 and IEC 61169-24 (Type F)

The conductor assignment shall be as shown in Figure 14.

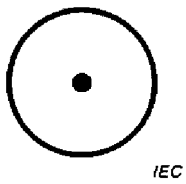
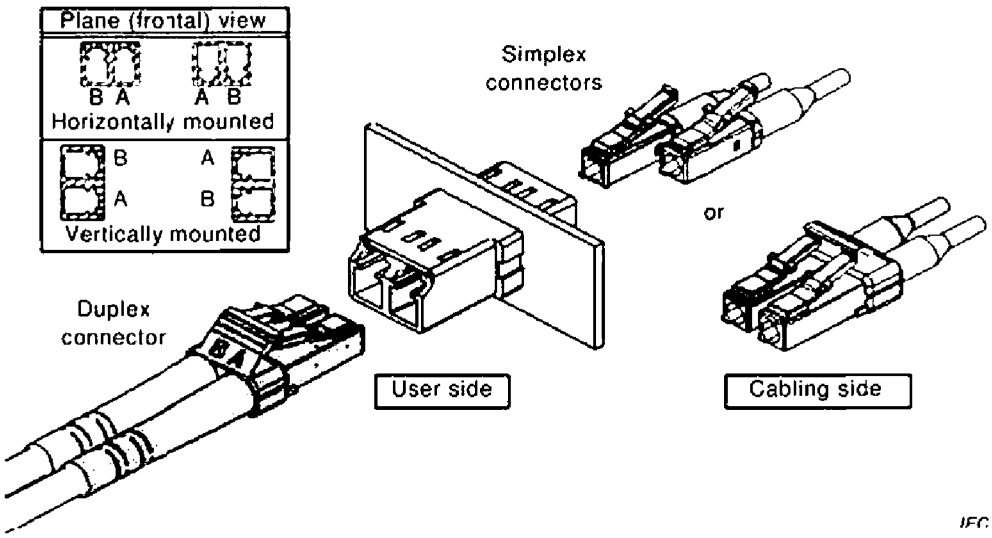


Figure 14 – Conductor assignment of IEC 61169-2 and IEC 61169-24 (Type F) connector

10.11 Connecting hardware for two optical fibres

The optical fibre assignments shall be as shown in Figure 15 (see ISO/IEC 14763-2 for further information regarding polarity maintenance).



NOTE Shading and A/B markings are for information only.

Figure 15 – Optical fibre assignments for connecting hardware for two optical fibres

10.12 Connecting hardware for twelve and twenty-four optical fibres

For the termination of more than two optical fibres in rows of up to twelve optical fibres, the interface should be of an MPO type in accordance with IEC 61754-7-1 (one row) or IEC 61754-7-2 (two rows of 12 fibres).

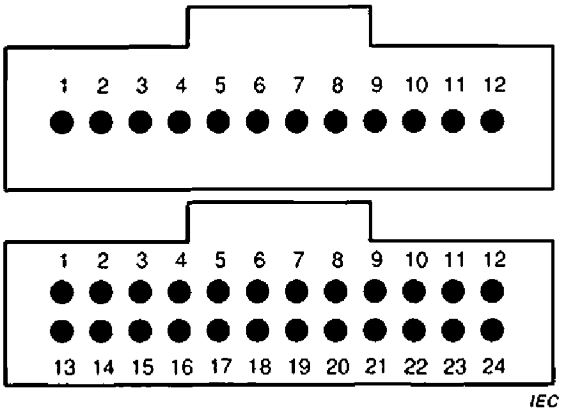


Figure 16 – Optical fibre assignments for connecting hardware for 12 and 24 optical fibres (front view of fixed or free connector)

The optical fibre assignments shall be as shown in Figure 16 (see ISO/IEC 14763-2 for further information regarding polarity maintenance).

11 Cord requirements

11.1 General

The performance of channels is dependent upon the performance of cords. The moves, additions and changes made using cords represent a greater risk to operational channel performance than that of fixed cables within cabling subsystems.

Clause 11 specifies the requirements for terminated cables used as cords.

The use of cables and connecting hardware suitable for use when subject to certain environmental conditions does not automatically assure that the cord meets the applicable transmission performance of Clause 11 when subjected to those environment conditions.

11.2 Operating environment

For information regarding the operating environment, see 9.2.

11.3 Balanced cords of Category 5 through 7_A, 8.1, 8.2 and BCT-B

11.3.1 General

Subclause 11.3 covers balanced cords constructed with balanced cables as specified in the IEC 61156 series and two free connectors (plugs) as specified in 10.2. The components used in these cords shall meet the requirements of 9.3.2 and 10.2, respectively. The cable used to make balanced cords shall meet the requirements of IEC 61156-6 or IEC 61156-10, as appropriate, for the corresponding category. The purpose of cords is to connect to connecting hardware that utilizes fixed connectors (jacks) that are also defined in 10.2. Compliance to transmission parameters that are not specified in 11.3 are considered to be met by design.

NOTE It is expected that cords that use connectors with interfaces other than the IEC 60603-7 series also meet the requirements of 11.3.

Subclause 11.3 specifies the minimum requirements for cords within the reference implementations of Clause 8. Connecting hardware performance is subject to influence by the properties of the plug termination, and therefore cords should be tested to determine the quality of the assembly. Cords constructed and tested in accordance with IEC 61935-2 meet the requirements of 1˙.3. BCT-B cords shall meet the requirements of Category 7_A cords.

11.3.2 Identification

Each cord shall be identified to indicate

a) length,

b) Category of cord,

c) wire-map status where a direct pin-pin relationship does not exist (i.e. cross-over cords).

11.3.3 Operating environment

Detail specifications based upon the blank detail specification IEC 61935-2-X shall be used to specify cord performance requirements under the environmental classifications of Table 2.

11.3.4 Return loss

Balanced cords shall meet *RL* requirements specified in Table 139. The cords shall meet the electrical and mechanical requirements of IEC 61935-2.

The *RL* of each pair of a cord at key frequencies is given in Table 140 for information only.

Table 139 – Minimum return loss for balanced cords

Frequency MHz	Return loss [a] MHz						
	Cord category						
	5	6	6_A	7	7_A	8.1	8.2
$1 \le f \le 25$	$19,8 + 3\lg(f)$	$19,8 + 3\lg(f)$	$19,8 + 3\lg(f)$	$19,8 + 3\lg(f)$	$19,8 + 3\lg(f)$	$19,8 + 3\lg(f)$	$19,8 + 3\lg(f)$
$25 < f \le 100$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$
$100 < f \le 250$	–	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$
$250 < f \le 500$	–	–	$14 - 15\lg(f/250)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$
$500 < f \le 600$	–	–	–	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$	$38,0 - 10\lg(f)$
$600 < f \le 1\,000$	–	–	–	–	$38,0 - 10\lg(f)$ [b]	$38,0 - 10\lg(f)$ [b]	$38,0 - 10\lg(f)$ [b]
$1\,000 < f \le 2\,000$	–	–	–	–	–	8,0	8,0

[a] Return loss values at frequencies below 4 MHz are for information only.

[b] Calculated values below 10,0 dB revert to a 10,0 dB plateau.

Table 140 – Informative values of return loss for balanced cords at key frequencies

Frequency MHz	Return loss dB						
	Cord category						
	5	6	6_A	7	7_A	8.1	8.2
1	19,8	19,8	19,8	19,8	19,8	19,8	19,8
100	18,0	18,0	18,0	18,0	18,0	18,0	18,0
250	–	14,0	14,0	14,0	14,0	14,0	14,0
500	–	–	9,5	11,0	11,0	11,0	11,0
600	–	–	–	10,2	10,2	10,2	10,2
1 000	–	–	–	–	10,0	10,0	10,0
1 600	–	–	–	–	–	8,0	8,0
2 000 ffs	–	–	–	–	–	8,0	8,0

11.3.5 NEXT

Balanced cords shall meet the requirement of Equation (20) when measured in accordance with IEC 61935-2.

$$NEXT_{\text{cord}} = -10\lg\left(10^{\frac{-NEXT_{\text{connectors}}}{10}} + 10^{\frac{-\left(NEXT_{\text{cable,L}} + 2\, IL_{\text{connector}}\right)}{10}}\right) - RFEXT \tag{20}$$

where

$NEXT_{\text{cord}}$	is the $NEXT$ of the cord;
$NEXT_{\text{connectors}}$	is the $NEXT$ of both connectors in the cord, taking insertion loss into account;
$NEXT_{\text{cable,L}}$	is the $NEXT$ of the cable adjusted for length;
$IL_{\text{connector}}$	is the insertion loss of one connector;
$RFEXT$	is the reflected $FEXT$.

NOTE All variables are expressed in decibels.

with

$$NEXT_{\text{connectors}} = -20\lg\left(10^{\frac{-NEXT_{\text{local}}}{20}} + 10^{\frac{-\left(NEXT_{\text{remote}} + 2\left(IL_{\text{cable}} + IL_{\text{connector}}\right)\right)}{20}}\right) \tag{21}$$

$$NEXT_{\text{local}} = NEXT_{\text{remote}} = NEXT_{\text{connector}} \tag{22}$$

$$IL_{\text{cable}} \approx \alpha_{\text{cable,100 m}}\left(\frac{L}{100}\right) \tag{23}$$

where

$NEXT_{\text{local}}$	is the $NEXT$ of the connector at the local end of the cord;
$NEXT_{\text{remote}}$	is the $NEXT$ of the connector at the remote end of the cord;
IL_{cable}	is the insertion loss of the cable;
$IL_{\text{connector}}$	is the insertion loss of the connector;
$NEXT_{\text{connector}}$	is the $NEXT$ of each connector as specified in Table 103, with the exception of Category 5 which is equal to 87 – 20 lg(f);
$\alpha_{\text{cable,100 m}}$	is the insertion loss of 100 m of the cable used for the cord;
L	is the length of the cable in the cord.

NOTE All variables are expressed in dB, except L, which is expressed in metres.

The length corrected near-end crosstalk of the cable of the cord is given by:

$$NEXT_{\text{cable},L} = NEXT_{\text{cable, 100 m}} - 10\lg\left[\frac{1 - 10^{\frac{L}{100}\left(\frac{-\alpha_{\text{cable, 100 m}}}{5}\right)}}{1 - 10^{\left(\frac{-\alpha_{\text{cable, 100 m}}}{5}\right)}}\right] \tag{24}$$

where

$NEXT_{\text{cable, 100 m}}$	is the $NEXT$ of a 100 m long cable section.

Calculations yielding *NEXT* limits in excess of 65 dB shall revert to a minimum requirement of 65 dB. Table 142, Table 143 and Table 144 list informative values of *NEXT* at key frequencies for different length cords using the variable values outlined in Table 141.

Table 141 – Assumptions for cabling components used in the calculation of NEXT informative values

Variable	Component category [a, b]						
	5	6	6_A	7	7_A	8.1	8.2
$\alpha_{cable,100\,m}$	$1{,}5 \times (1{,}9108\sqrt{f} + 0{,}0222f + \frac{0{,}2}{\sqrt{f}})$	$1{,}5 \times (1{,}82\sqrt{f} + 0{,}017f + \frac{0{,}25}{\sqrt{f}})$	$1{,}5 \times (1{,}82\sqrt{f} + 0{,}0091f + \frac{0{,}25}{\sqrt{f}})$	$1{,}5 \times (1{,}8\sqrt{f} + 0{,}01f + \frac{0{,}2}{\sqrt{f}})$	$1{,}5 \times (1{,}8\sqrt{f} + 0{,}005f + \frac{0{,}25}{\sqrt{f}})$		
$NEXT_{cable,\,100\,m}$	$65{,}3 - 15\lg(f)$	$74{,}3 - 15\lg(f)$		$102{,}4 - 15\lg(f)$	$105{,}4 - 15\lg(f)$	$74{,}3 - 15\lg(f)$	$105{,}4 - 15\lg(f)$
$IL_{connector}$	$0{,}04\sqrt{f}$	$0{,}02\sqrt{f}$				See Table 101	
$NEXT_{connector}$	$87 - 20\lg(f)$	$94 - 20\lg(f)$	$94 - 20\lg(f)$, $f \leq 250$ MHz $46{,}04 - 30\lg(f/250)$ $f > 250$ MHz	$102{,}4 - 15\lg(f)$	$116{,}3 - 20\lg(f)$ $f \leq 600$ MHz $60{,}73 - 40\lg(f/600)$ $f > 600$ MHz	See Table 103	
RFEXT	0	0,5					

[a] All formulas apply from 1 MHz to the upper frequency of the category unless otherwise indicated.

[b] Values used for calculations may differ from the values specified in IEC 61156-5 and IEC 61156-6.

Table 142 – Informative values of NEXT for 2 m balanced cords at key frequencies

Frequency MHz	NEXT dB						
	Cord category						
	5	6	6_A	7	7_A	8.1	8.2
1	65,0	65,0	65,0	65,0	65,0	65,0	65,0
100	39,0	46,2	46,2	65,0	65,0	46,2	65,0
250	–	38,7	38,7	60,7	62,6	38,7	62,6
500	–	–	31,0	56,5	57,1	31,0	57,1
600	–	–	–	55,4	55,6	28,3	55,6
1 000	–	–	–	–	47,4	20,4	51,6
1 600	–	–	–	–	–	13,1	34,2
2 000	–	–	–	–	–	9,6	30,7

Table 143 – Informative values of NEXT for 5 m balanced cords at key frequencies

Frequency MHz	NEXT dB						
	Cord category						
	5	6	6_A	7	7_A	8.1	8.2
1	65,0	65,0	65,0	65,0	65,0	65,0	65,0
100	37,4	45,1	45,1	65,0	65,0	45,1	65,0
250	–	38,0	38,0	61,2	63,3	38,0	63,3
500	–	–	31,3	57,2	58,0	31,3	58,0
600	–	–	–	56,2	56,7	28,9	56,7
1 000	–	–	–	–	48,9	21,7	52,9
1 600	–	–	–	–	–	14,6	35,9
2 000	–	–	–	–	–	11,1	32,3

Table 144 – Informative values of NEXT for 10 m balanced cords at key frequencies

Frequency MHz	NEXT dB						
	Cord category						
	5	6	6_A	7	7_A	8.1	8.2
1	65,0	65,0	65,0	65,0	65,0	65,0	65,0
100	36,4	44,2	44,2	65,0	65,0	44,2	65,0
250	–	37,6	37,6	61,9	64,1	37,6	64,1
500	–	–	31,7	58,0	59,1	31,7	59,1
600	–	–	–	57,0	57,8	29,6	57,8
1 000	–	–	–	–	50,2	22,8	54,0
1 600	–	–	–	–	–	15,6	37,0
2 000	–	–	–	–	–	12,0	33,3

11.4 Coaxial cords

Cords shall meet IEC 60966-2-4, IEC 60966-2-5 and IEC 60966-2-6.

11.5 Optical fibre cords

11.5.1 General

Cords shall be assembled using flexible cables in accordance with 9.5 and connectors in accordance with 10.5 with the exception of the equipment connectors used on apparatus attachment and equipment cords that lie outside the scope of this document.

The construction of the flexible cables shall reflect the specified bend radius and any requirements for repetitive bending/flexing of the cord during installation and operation.

The cable shall be terminated to the connectors following the procedures and using the tools specified by the manufacturers of the connectors.

The connecting hardware and the means of maintaining polarity within the cord shall be in accordance with the intended use of the cord and shall be a logical extension to the cabling interface(s) to which it is to be connected.

Connecting hardware shall meet the mechanical and transmission performance requirements of 10.5 and 10.1.4.4 for the relevant environmental classifications of Table 2.

Factory terminated fibre optical cords should be used.

11.5.2 Identification

Each cord shall be identified to indicate

a) length,

b) type of fibre,

c) Category of cable,

d) port-map status where a direct port-port relationship does not exist (i.e. cross-over cords).

11.5.3 Performance requirements for patch cords

11.5.3.1 Attenuation/insertion loss

Attenuation/insertion loss measurements of cords shall not exceed the attenuation/insertion loss requirements of the connection at each end plus the attenuation/insertion loss requirement for the cable, scaled for length. The attenuation/insertion loss performance is achieved by design.

11.5.3.2 Performance specifications

Performance standards based upon IEC 61753-1 shall be used to specify cord performance requirements under the environmental classifications of Table 2.

Annex A
(normative)

Conformance testing procedures for balanced cabling of Classes A to F_A, I and II and optical fibre cabling

A.1 General

Annex A contains requirements and recommendations for testing of channels, and links in order to determine their conformance to this document. It is not intended to represent or replace requirements for contractual installation acceptance testing which are defined within an installation specification. Guidance for such testing is provided in ISO/IEC 14763-2.

A.2 Channel and link performance testing

A.2.1 General

Performance testing can be undertaken either

a) in a laboratory, where channels or links contain specific cabling components in a specific implementation, or

b) in the field, after installation.

There are two kinds of conformance testing, both of which may be performed in order to give greater levels of confidence of compliance:

1) Reference conformance testing (also known as type testing).

   This testing is performed on a sample of installed cabling in a laboratory where an assessment against the conformance criteria of the ISO/IEC 11801 series is required. The assessment documentation shall include details of the number of channels or links tested, test evaluation criteria, supplier's declarations and certification, laboratory accreditation and calibration certification, etc.

   This testing may also be used for

   - the comparison of measurements performed with laboratory and field test instruments,
   - assessing cabling models in a laboratory environment,
   - assessing parameters that cannot be tested in an installation.

2) Installation conformance testing.

   This testing is performed on installed cabling where an assessment against the conformance criteria of the ISO/IEC 11801 series is required. Installation conformance testing may be performed to

   - give a greater degree of confidence in the accuracy of installation acceptance test results,
   - resolve contractual issues,
   - determine performance under the circumstances described in A.2.2.

A.2.2 Conformance testing of balanced cabling channels, and links

Testing to determine conformance with the requirements of Clause 5 is optional. Testing should be performed in the following cases:

a) channels or links with lengths exceeding, or having more components than, those specified in reference implementations of the cabling design documents;

b) links using components whose transmission performance is lower than those specified in Clauses 9 and 10;

c) channels using components whose transmission performance is lower than those specified in Clauses 9, 10 and 11;

d) channels created by adding more than one cord to either end of a link meeting the requirements of Clause 7;

e) evaluation of cabling to determine its capacity to support a certain group of applications;

f) confirmation of performance of cabling designed in accordance with the reference implementations of the ISO/IEC 11801 series using Clauses 9, 10 and 11;

g) channels containing cable segments with lengths that are outside the assumed ranges in Clause 5.

The test procedures for balanced cabling channels and links are specified in IEC 61935-1.

A.2.3 Installation conformance testing of optical fibre cabling channels

Testing to determine conformance with the requirements of Clause 6 is optional. Testing should be performed in the following cases:

a) evaluation of cabling to determine its ability to support applications;

b) confirmation of performance of cabling designed in accordance with Clauses 9, 10 and 11.

The test procedures for optical fibre cabling channels and permanent links are specified in ISO/IEC 14763-3.

A.3 Overview of test schedules

A test regime for each of the two kinds of conformance testing (see A.2.1) is defined for each transmission parameter. The test regime for balanced cabling reference conformance and installation conformance testing is shown in Table A.1. The test regime for optical fibre cabling reference conformance and installation conformance testing is shown in Table A.2.

Table A.1 – Test regime for reference conformance and installation conformance – Balanced cabling of Classes A through F_A, BCT-B, I and II

Transmission parameter [a]	Reference conformance testing	Installation conformance testing
Return loss	N	N
Insertion loss	N	N
Pair-to-pair NEXT	N	N
PS NEXT	C	C
Pair-to-pair ACR-N	C	C
PS ACR-N	C	C
Pair-to-pair ACR-F	N	N
PS ACR-F	C	C
Direct current (DC) loop resistance	N	N
Direct current (DC) resistance unbalance within a pair	N	O
Direct current (DC) resistance unbalance between pairs	N	O
Propagation delay	N	N
Delay skew	N	N
Unbalance attenuation, near-end (TCL)	N	O
Unbalance attenuation, far-end (ELTCTL)	N	O
Coupling attenuation	N	O
PS ANEXT	N	N_S
PS $ANEXT_{avg}$	C	C
PS AACR-F	N	N_S
PS AACR-F_{avg}	C	C
Wire-map	N	N
Continuity: • signal conductors; • screen conductors (if present); • short circuits; • open circuits.	N	N
Length [b]	I	I

C is calculated with pass/fail criteria.
I is informative testing without pass/fail criteria, if not met by design.
N is normative (100 %) testing with pass/fail criteria, if not met by design.
N_s is normative (samplec) testing, if not met by design. The sample size to be tested should be in accordance with ISO/IEC 14763-2
O is optional testing with pass/fail criteria, if not met by design.

NOTE The term "met by design" refers to a requirement which may be met by the selection of appropriate materials and installation techniques.

[a] Only those parameters specified for each Class of cabling need to be tested, as required in Clause 6 and Clause 7.

[b] Length is not a pass/fail criterion.

Table A.2 – Test regime for reference conformance and installation conformance – Optical fibre cabling

Transmission parameter	Reference conformance testing	Installation conformance testing
Attenuation	N	N
Propagation delay [a]	I	I
Polarity	N	N
Length [b, c]	I	N
I is informative (optional) testing. N is normative (100 %) testing.		
[a] Propagation delay is not a pass/fail criterion. [b] Length is not a pass/fail criterion. [c] Length may be determined by sheath marking or physical measurement.		

Annex B
(normative)

Mechanical and environmental performance testing of connecting hardware for balanced cabling

B.1 Overview

The mechanical and environmental performance of connecting hardware is vital to the cabling system. Changes in contact resistance because of operational and environmental stress can negatively affect the transmission characteristics of the cabling system. Product acceptance testing is accomplished by subjecting the product to a number of mechanical and environmental conditions and measuring any resistance deviations at prescribed intervals and after completion of each conditioning sequence. In addition, the product shall not show evidence of degradation with respect to the ease of mechanical termination, safety or other functional attributes during or after environmental conditioning.

Connecting hardware often contains a combination of solderless connections and a separable contact interface (free connector/fixed connector interface). All connections shall be tested. Where a combination of connections and/or separable contact interfaces are tested together, care should be taken to ensure the use of the most stringent test schedule as the test schedules vary by type of connection.

Annex B provides mechanical connection performance requirements for connections that are not covered by a specific IEC connector standard. Annex B is intended to be replaced by reference to international standards, as soon as they become available.

Connection interfaces that conform to the mechanical and environmental performance requirements of IEC 60603-7 (unscreened) or IEC 60603-7-1 (screened) comply with Annex B as these standards specify appropriate tests. Connection interfaces that are covered by international standards other than the IEC 60603-7 series shall comply with at least the equivalent mechanical and environmental performance requirements specified in Annex B.

B.2 Solderless connections

To ensure reliable solderless terminations of balanced cable with insulated conductors, and to ensure reliable solderless connections between component parts within connecting hardware, solderless connections shall meet the requirements of the applicable standards specified in Table B.1.

Table B.1 – Standards for solderless connections

Connection type	Standard
Crimped connection	IEC 60352-2
Accessible IDC	IEC 60352-3
Non-accessible IDC	IEC 60352-4
Press-in connection	IEC 60352-5
IPC	IEC 60352-6
Spring clamp connection	IEC 60352-7
Compression mount	IEC 60352-8

The default criteria and conditions in the relevant standards in Table B.1 apply, except as specified in the remainder of B.2.

The maximum initial contact resistance for an insulation displacement connection shall be 2,5 mΩ and the maximum change in contact resistance during and after conditioning shall be 5 mΩ from the initial value.

The following test conditions are specified, as detailed by the type test requirements of the IEC 60352 series.

a) Vibration test severity: 10 Hz to 500 Hz.

b) Low temperature (LCT): −40 °C.

c) Electrical load anc temperature, test current: 1 A DC.

B.3 Free and fixed connectors (modular plugs and jacks)

Fixed and free connectors (modular plugs and jacks) shall comply with the reliability requirements of the applicable standard specified in Table B.2.

M12 style connectors shall comply with the reliability requirements of the applicable standard specified in Table B.3

Table B.2 – Standards for free and fixed connectors (modular plugs and jacks)

Category and type	Standard
Category 5, unscreened	IEC 60603-7-2
Category 5, screened	IEC 60603-7-3
Category 6, unscreened	IEC 60603-7-4
Category 6, screened	IEC 60603-7-5
Category 6_A, unscreened	IEC 60603-7-41
Category 6_A, screened	IEC 60603-7-51
Category 7, screened	IEC 60603-7-7
Category 7_A, screened	IEC 60603-7-71 (mated with IEC 60603-7-71 or 61076-3-110 plugs) or IEC 61076-3-104 as appropriate
Category 8.1 screened	IEC 60603-7-81
Category 8.2 screened	IEC 60603-7-82 (mated with IEC 60603-7-82 or 61076-3-110 plugs) or IEC 61076-3-104 as appropriate

Table B.3 – Standards for M12 style connectors

Category and type	Standard
Category 5, screened	IEC 61076-2-101
Category 6_A, screened	IEC 61076-2-109

The default criteria and conditions in the relevant standards in Table B.2 and Table B.3 apply, except as specified in the remainder of B.3.

The number of mating cycles (insertions and withdrawals) for free and fixed connectors (modular plugs and jacks), and the number of conductor re-terminations per solderless connection shall comply with the specifications in Table B.4.

Table B.4 – Free and fixed connectors (modular plugs and jacks) operations matrix

Connecting hardware type	Insertion and withdrawal, and conductor re-termination, operations	Minimum number of operations [c]
Free connector (modular plug)	Insertion / withdrawal with fixed connector (modular jack)	750
	Cable re-termination	0
Fixed connector (modular jack)	Insertion / withdrawal with free connector (modular plug)	750
	Cable re-termination	20 [a, b]

[a] Unless not intended for re-termination, in which case this value equals 0.
[b] The range of conductor size and type shall be in accordance with the manufacturer's instructions.
[c] This does not apply for the M12 style connectors.

Between terminations the solderless connection shall be inspected for debris and extraneous material shall be removed.

B.4 Other connecting hardware

Examples of other connecting hardware include

a) cross-connect blocks and plugs,

b) pin and socket connectors.

The reliability of connecting hardware, other than free and fixed connectors (modular plugs and jacks), shall be demonstrated by complying with the applicable requirements of the standards specified in Table B.5. The connecting hardware shall be terminated, mounted, and operated in accordance with the manufacturer's instructions for use. A minimum of 100 individual electrical contact paths (e.g. connecting hardware, input to output) shall be tested without failure.

The following tests shall be as per the manufacturer's specification:

1) examination of dimensions and mass,
2) insertion and withdrawal force requirements,
3) effectiveness of any connector coupling device requirements,
4) gauging and gauging continuity requirements,
5) arrangement for contact resistance test,
6) arrangement for vibration (dynamic stress) test.

Table B.5 – Reference for reliability testing of other connecting hardware

Category and type	Standard	
All Categories, unscreened	IEC 60603-7	Clause 6 and Clause 7 [a]
All Categories, screened	IEC 60603-7 and IEC 60603-7-1	

[a] Excluding subclauses addressing pin and pair grouping assignment, creepage and clearance distances, transmission characteristics, transfer impedance, and test group EP (transmission testing).

The default criteria and conditions in the relevant standards in Table B.5 apply, unless otherwise specified in B.4.

The number of mating cycles (insertions and withdrawals) for other connecting hardware, and the number of conductor re-terminations per solderless connection shall comply with the specifications in Table B.6.

Table B.6 – Other connecting hardware operations matrix

Connecting hardware type	Insertion and withdrawal, and conductor re-termination, operations	Minimum number of operations
Other connecting hardware "free connector (plug)"	Insertion / withdrawal operations with "fixed connector"	200
	Cable re-termination	0
Other connecting hardware "fixed connector (socket)"	Insertion / withdrawal operations with "free connector"	200
	Cable re-termination	20 [a, b]
	Jumper re-termination	200

[a] Unless not intended for re-termination, in which case this value equals 0.

[b] The range of conductor size and type shall be in accordance with the manufacturer's instructions.

Between terminations the solderless connection shall be inspected for debris and extraneous material shall be remcved.

Annex C
(informative)

Electromagnetic characteristics

Cabling consists of passive components and can therefore only be verified for conformance to electromagnetic compliance, see CISPR 32 and CISPR 35, when attached to application-specific equipment. However, electromagnetic characteristics of a network installation are influenced by parameters such as the balance and/or screening properties of the cabling.

Balance is characterized by unbalance attenuation, i.e. the ratio between the unwanted common mode signal power and the injected differential mode signal power. This common mode signal which arises from imperfections in the cabling system, such as asymmetry, causes electromagnetic emission and affects noise immunity. Unbalance attenuation is characterized for components, including cables and connecting hardware. Limits for unbalance attenuation are also given for cabling. Screening effectiveness is characterized for components including cables, connecting hardware and patch cords. At frequencies up to 100 MHz, the effectiveness of component screening can be characterized by transfer impedance. Transfer impedance is the ratio of the longitudinal voltage developed on the secondary side of a screen to the current flowing in the screen. This unwanted current causes radiation and affects immunity. At higher frequencies screening effectiveness may be characterized by screening attenuation, i.e. the ratio between the common mode signal in the conductors enclosed in the screen and the radiated signal outside the screen.

Coupling attenuation is the ratio between the signal power and the radiated power from the cabling, taking into account both the balance of the pair and the effect of the screening. Coupling attenuation can be applied to screened and unscreened cables, connecting hardware and cabling. For the purposes of ISO/IEC 11801-1, coupling attenuation is specified from 30 MHz to the upper frequency of the Category or Class.

Use of components with good electromagnetic characteristics, the use of screened or unscreened components throughout a system, and installation according to manufacturers' instructions, will help to achieve good electromagnetic characteristics of the cabling.

The electromagnetic characteristics of the components referenced in this document may be used for guidance when application-specific electronic equipment is constructed, and tested for compliance with CISPR-32 and CISPR-35. The relationship between the CISPR requirements and these characteristics is a subject for further study.

Annex D
(informative)

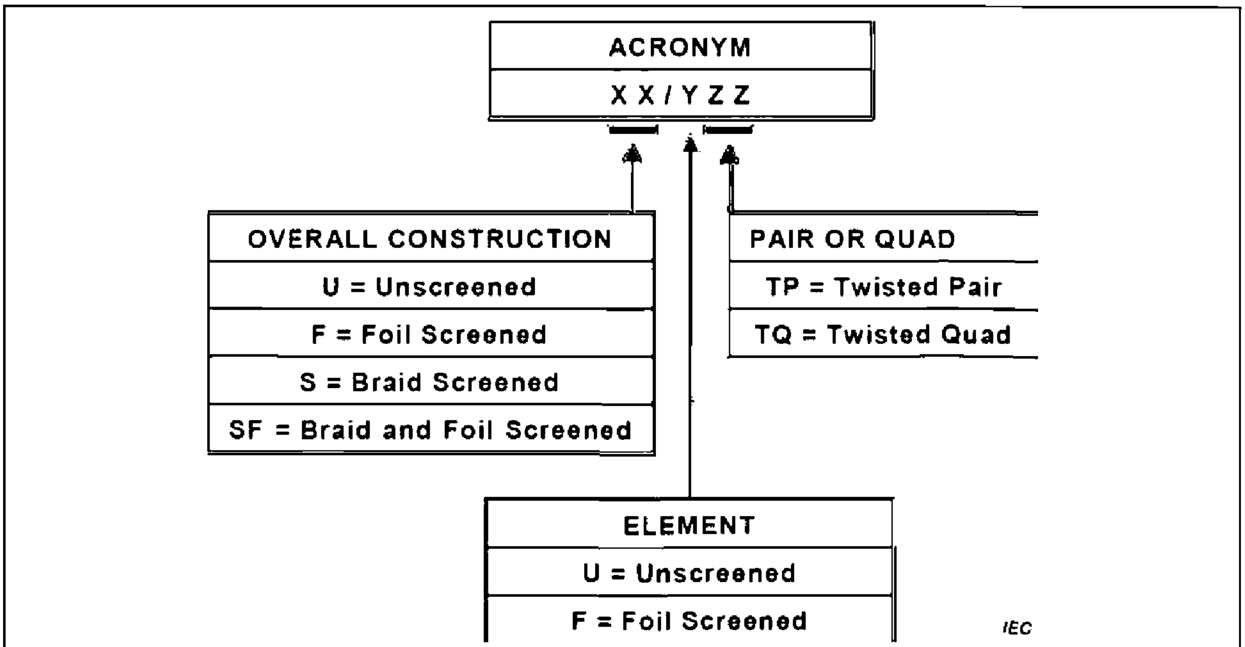
Acronyms for balanced cables

There is a great variety of cable constructions and a number of systems to describe these constructions in a shortened form. These abbreviations have been used to describe the difference in construction as well the difference in impedance. Since such acronyms are used in many commercial documents and have never been clearly specified by a standard, the same term could mean different kinds of constructions in different contexts.

The intention of Annex D is to clarify this situation and give guidance on how to use abbreviations for the main constructions used for communication cables. This document uses the words balanced cable, unscreened/screened cable and unscreened/screened cable element for the cable constructions described in Annex D.

To reduce confusion, a more systematic naming is specified in Figure D.1. It is understood that cable names based on this schema only describe the types of constructions and not any transmission characteristics such as impedance. All screened cables, whether individually or overall, foiled, braided or both, require matching connecting hardware capable of handling all of the screens involved.

Figure D.2 gives examples of cable constructions and their names based on this schema.



EXAMPLES:

U/UTP	overall unscreened cable with unscreened twisted pairs (often referred to as UTP)
F/UTP	overall screened cable with unscreened twisted pairs (often referred to as FTP)
S/FTP	overall braid screened cable with foil screened twisted pairs (often referred to as STP or PiMF)
SF/UTP	overall braid and foil screened cable with unscreened twisted pairs

Figure D.1 – Cable naming schema

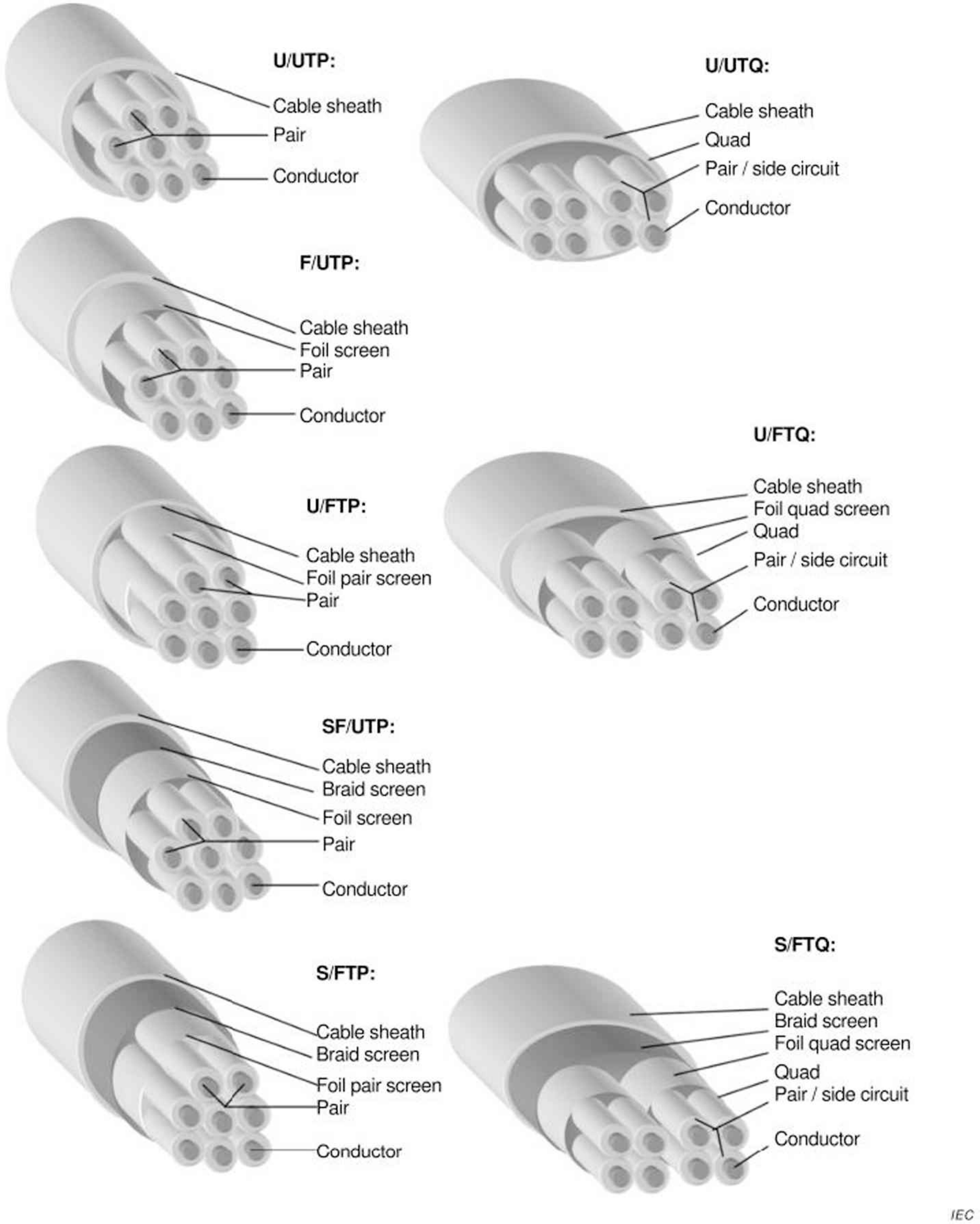


Figure D.2 – Cable types

Annex E
(informative)

Supported applications

E.1 Supported applications for balanced cabling

Balanced cabling specified in this document is intended to support the applications detailed in Annex E. Cabling exceeding 2 km is outside the scope of this document. Other applications, not listed, may be supported too.

Balanced cabling applications are matched to channel performance Classes specified in Clause 5. Generic cabling has been designed to support electrically balanced transmission. Applications using unbalanced transmission are outside the scope of this document.

Table E.1 and Table E.2 contain applications with mature or technically stable international specifications (for example, published ITU recommendations, ISO/IEC standards at least at DIS/CDV development stage, or IEEE 802.3 applications as soon as the documents are released for working group ballot).

Table E.1 – Applications using balanced cabling

Application	Specification reference	Date	Additional name / reference
Class A (defined up to 0,1 MHz)			
PBX	National requirements		
X.21	ITU-T Rec. X.21	1992	
V.11	ITU-T Rec. X.21	1996	
Class B (defined up to 1 MHz)			
S0-Bus (extended)	ITU-T Rec. I.430	1993	ISDN Basic Access (Physical Layer)
S0 Point-to-Point	ITU-T Rec. I.430	1993	ISD2 Basic Access (Physical Layer)
S1/S2	ITU-T Rec. I.431	1993	ISDN Primary Access (Physical Layer)
Class C (defined up to 16 MHz)			
Ethernet 10BASE-T	ISO/IEC/IEEE 8802-3:2017, Clause 14 [a]	2005	10M Ethernet over Twisted Pairs
Class D 1995 (defined up to 100 MHz)			
Ethernet 100BASE-TX[a,b]	ISO/IEC/IEEE 8802-3:2017, Clause 25 [a]	2005	100M Ethernet over Twisted Pairs
PoE Type 1	ISO/IEC/IEEE 8802-3:2017, Clause 33 [b]	2015	Power over Ethernet
Class D 2002 (defined up to 100 MHz)			
Ethernet 1000BASE-T	ISO/IEC/IEEE 8802-3:2017, Clause 40 [a]	2005	Gigabit Ethernet over Twisted Pairs
Fibre Channel 1 Gbit/s	ISO/IEC 14165-115	2007	Twisted-pair Fibre Channel 1G
Firewire 100 Mbit/s	IEEE 1394b	2002	Firewire/Category 5
PoE Type 2	ISO/IEC/IEEE 8802-3:2017, Clause 33 [b]	2015	Power over Ethernet
PoE Type 3	IEEE 802.3bt:2018, Clause 33 [b]	2018	Power over Ethernet, IEEE 802.3bt
PoE Type 4	IEEE 802.3bt:2018, Clause 33 [b]	2018	Power over Ethernet, IEEE 802.3bt
Class E 2002 (defined up to 250 MHz)			
Class E_A 2008 (defined up to 500 MHz)			
Ethernet 2.5GBASE-T	IEEE 802.3bz:2016, Clause 126 [a]	2016	2.5 Gigabit Ethernet over Twisted Pairs, IEEE 802.3bz
Ethernet 5GBASE-T	IEEE 802.3bz:2016, Clause 126 [a]	2016	5 Gigabit Ethernet over Twisted Pairs, IEEE 802.3bz
Ethernet 10GBASE-T	ISO/IEC/IEEE 8802-3:2017, Clause 55 [a]	2006	10 Gigabit Ethernet over Twisted Pairs
Fibre Channel 2 Gbit/s	INCITS 435	2007	Twisted-pair Fibre Channel 2G-FCBASE-T
Fibre Channel 4 Gbit/s	INCITS 435	2007	Twisted-pair Fibre Channel 4G-FCBASE-T
Multimedia distribution	IEEE 1911.2	2015	HDBaseT
Class F 2002 (defined up to 600 MHz)			
FC 100 MByte/s	ISO/IEC 14165-114	2005	FC-100-DF-EL-S
Class F_A 2008 (defined up to 1000 MHz)			
Class I 20xx (defined up to 2000 MHz)			
Ethernet 25GBASE-T	IEEE 802.3bq:2016, Clause 113	2016	25 Gigabit Ethernet over Twisted Pairs, IEEE 802.3bq
Ethernet 40GBASE-T	IEEE 802.3bq:2016, Clause 113	2016	40 Gigabit Ethernet over Twisted Pairs, IEEE 802.3bq
Class II 20xx (defined up to 2000 MHz)			
Ethernet 25GBASE-T	IEEE 802.3bq:2016, Clause 113	2016	25 Gigabit Ethernet over Twisted Pairs, IEEE 802.3bq

Ethernet 40GBASE-T	IEEE 802.3bq:2016, Clause 113	2016	40 Gigabit Ethernet over Twisted Pairs, IEEE 802.3bq

[a] Including support for remote power feeding defined by ISO/IEC/IEEE 8802-3:2017, Clause 33 (Types 1 and 2) and IEEE 802.3bt:2018 (Types 3 and 4).

[b] For channels used to support applications requiring remote power, see ISO/IEC TS 29125.

[c] Remote power feeding for 10GBASE-T defined by IEEE 802.3bt:2018.

The minimum performance of Class E and F channels is insufficient to support 10GBase-T. Channels implemented using Category 6 or 7 components will support 10GBase-T provided they meet the additional requirements specified in ISO/IEC TR 24750. Such support may require mitigation and might be limited to channels shorter than 100 m. Class E_A or better is recommended for new installations.

The minimum performance of Class D 2002 channels is insufficient to support 2.5GBase-T or 5GBASE-T. Channels implemented using Category 5 2002 components will support 2.5GBase-T and 5GBASE-T provided they meet the additional requirements specified in ISO/IEC TR 11801-9904. Such support may require mitigation and might be limited to channels shorter than 100 m. Class E_A or better is recommended for new installations.

The minimum performance of Class E 2002 channels is insufficient to support 5GBASE-T. Channels implemented using Category 6 2002 components will support 5GBASE-T provided they meet the additional requirements specified in ISO/IEC TR 11801-9904. Such support may require mitigation and might be limited to channels shorter than 100 m. Class E_A or better is recommended for new installations.

The minimum performance of Category 6_A, 7 or 7_A components are insufficient to support 30 m 2-connector channels for 25GBASE-T. Channels implemented using Category 6_A (ffs), 7 (ffs) or 7_A components or better will support 25GBASE-T provided they meet the additional requirements specified in ISO/IEC TR 11801-9905. Such support may require mitigation and might be limited to channels shorter than 30 m. Class I or Class II cabling is recommended for new installations.

NOTE Applications supported by a given class are also supported by higher classes. Some applications may run on a lower class in cases where the specific channel in question meets the performance criteria of the application.

Table E.2 – Industrial applications using balanced cabling

Application [a]	Specification reference	Date	Additional name / reference
Foundation Fieldbus	IEC 61784-5-1	2013	
C/P 2/1 (ControlNet™ 2)	IEC 61784-5-2	2013	
CP 2/2 (EtherNet/IP™ 3)	IEC 61784-5-2	2013	
CP 2/3 (DeviceNet™ 4)	IEC 61784-5-2	2013	
PROFINET	IEC 61784-5-3	2013	
P-NET	IEC 61784-5-4	2015	
INTERBUS	IEC 61784-5-6	2013	
CC-Link IE	IEC 61784-5-8	2013	
Vnet/IPTM	IEC 61784-5-10	2015	
TCnet	IEC 61784-5-11	2013	
EtherCAT	IEC 61784-5-12	2015	
Ethernet POWERLINK	IEC 61784-5-13	2013	
EPA Ethernet for Plant Automation	IEC 61784-5-14	2013	
Modbus RTPS	IEC 61784-5-15	2015	
SERCOS III	IEC 61784-5-16	2013	
RAPIEnet	IEC 61784-5-17	2013	
SafetyNET p	IEC 61784-5-18	2013	
Mechatrolink III	IEC 61784-5-19	2013	

[a] Applications are listed for the convenience of users of this document. This does not constitute an endorsement by ISO or IEC of these products.

Applications supported by generic balanced cabling listed in Table E.1 use the pin assignment recorded in Table E.3. This mapping relates the modular connector pinning specified by each application standard to the channel performance Classes specified in Clause 6.

Table E.3 – Modular connector pin assignment for applications

Application	Pins 1 and 2	Pins 3 and 6	Pins 4 and 5	Pins 7 and 8
PBX	Class A [a]	Class A [a]	Class A	Class A [a]
X.21		Class A	Class A	
V.11		Class A	Class A	
S0-Bus (extended)	[b]	Class B	Class B	[b]
S0 Point-to-Point	[b]	Class B	Class B	[b]
S1/S2	Class B	[c]	Class B	[b]
Ethernet 10BASE-T	Class C	Class C	[b]	[b]
Ethernet 100BASE-TX	Class D	Class D		
Ethernet 1000BASE-T	Class D	Class D	Class D	Class D
1G FCBASE-T	Class D	Class D	Class D	Class D
Ethernet 2.5GBASE-T	Class E_A	Class E_A	Class E_A	Class E_A
Ethernet 5GBASE-T	Class E_A	Class E_A	Class E_A	Class E_A
Ethernet 10GBASE-T	Class E_A	Class E_A	Class E_A	Class E_A
Ethernet 25GBASE-T	Class I, II	Class I, II	Class I, II	Class I, II
Ethernet 40GBASE-T	Class I, II	Class I, II	Class I, II	Class I, II
2G FCBase-T	Class E_A	Class E_A	Class E_A	Class E_A
4G FCBase-T	Class E_A	Class E_A	Class E_A	Class E_A
FC-100-DF-EL-S [d]	Class F	Class F		

[a] Option dependent on supplier.

[b] Optional power sources.

[c] Option for continuity of cable screen.

[d] Option outside TE as ISO/IEC 14165-114 specifies IEC 61076-3-104.

E.2 Supported applications for optical fibre cabling

Optical fibre cabling specified in this document is intended to support the applications detailed in Annex E. Other applications, not listed, may also be supported.

Table E.4 contains applications with mature or technically stable international specifications (for example, published ITU recommendations, ISO/IEC standards at least at DIS/CDV development stage or IEEE 802.3 applications as soon as the documents are released for working group ballot). Table E.4 also contains emerging applications being prepared as future international standards.

Details of application support are provided for each cabled optical fibre Category included in Clause 9, and additional information is provided in Table E.4, Table E.5 and Table E.6 concerning maximum channel lengths. Cabled optical fibre categories OM3, OM4, OS1a and OS2 are described in Clause 9.

Maximum channel lengths assume 1,5 dB total connecting hardware attenuation within a channel.

Table E.4 – Maximum channel attenuation for supported applications using optical fibre cabling

Network application	Max. channel attenuation dB		
	Multimode		Single-mode
	850 nm	1 300 nm	1 310 nm
ISO/IEC/IEEE 8802-3:2017, Clause 9: FOIRL	6,8	–	–
ISO/IEC/IEEE 8802-3:2017, Clauses 15-18: 10BASE-FLand FB	6,8	–	–
ISO/IEC/IEEE 8802-3:2017, Clause 38: 1000BASE-SX [a]	3,56	–	–
ISO/IEC/IEEE 8802-3:2017, Clause 38: 1000BASE-LX [a]	–	2,35	4,56
ISO/IEC/IEEE 8802-3:2017, Clause 26: 100BASE-FX	–	6,0	–
ISO/IEC/IEEE 8802-3:2017, Clause 53: 10GBASE-LX4 [a]	–	2,00	6,20
ISO/IEC/IEEE 8802-3:2017, Clause 68: 10GBASE-LRM [a]	–	1,9	–
ISO/IEC/IEEE 8802-3:2017, Clause 52: 10GBASE-ER	–	–	10,9
ISO/IEC/IEEE 8802-3:2017, Clause 52: 10GBASE-SR [a]	2,60 (OM3) 2,90 (OM4)	–	–
ISO/IEC/IEEE 8802-3:2017, Clause 52: 10GBASE-LR	–	–	6,20
ISO/IEC/IEEE 8802-3:2017, Clause 86: 40GBASE-SR4 [a, b]	1,9 (OM3) 1,5 (OM4)	–	–
ISO/IEC/IEEE 8802-3:2017, Clause 87: 40GBASE-LR4	–	–	6,7
ISO/IEC/IEEE 8802-3:2017, Clause 89: 40GBASE-FR			4,0
ISO/IEC/IEEE 8802-3:2017, Clause 95: 100GBASE-SR4 [a, b]	1,8 (OM3) 1,9 (OM4)	–	–
ISO/IEC/IEEE 8802-3:2017, Clause 86: 100GBASE-SR10 [a, b]	1,9 (OM3) 1,5 (OM4)	–	–
ISO/IEC/IEEE 8802-3:2017, Clause 88: 100GBASE-LR4	–	–	6,3
ISO/IEC/IEEE 8802-3:2017, Clause 88: 100GBASE-ER4	–	–	18,0
1 Gbit/s FC (1,0625 GBd) [a]	2,62 (OM3)	–	7,8
2 Gbit/s FC (2,125 GBd) [a]	3,31 (OM3)	–	7,8
4 Gbit/s FC (4,25 GBd) [a]	2,88 (OM3) 2,95 (OM4)	–	4,8
8 Gbit/s FC (8,5 GBd) [a]	2,04 (OM3) 2,19 (OM4)	–	6,4
16 Gbit/s FC (14,025 GBd) [a]	1,86 (OM3) 1,95 (OM4)	–	6,4
32 Gbit/s FC [a]	1,75 (OM3) 1,86 (OM4)	–	6,4

[a] A bandwidth-limited application at the channel lengths shown. The use of lower attenuation components to produce channels exceeding the values shown cannot be recommended.

[b] These are multi-fibre applications and are subject to a delay skew requirement which is met by design if all the optical fibres providing a channel transverse the same cable and cord sheaths from end-to-end.

Table E.5 – Maximum channel lengths supported by optical fibre applications for multimode optical fibre

Network application	Nominal transmission wavelength nm	Maximum channel length m
		50/125 µm optical fibre
ISO/IEC/IEEE 8802-3:2017, Clause 9: FOIRL	850	514
ISO/IEC/IEEE 8802-3:2017, Clauses 15-18:10BASE-FL & FB	850	1 514
ISO/IEC/IEEE 8802-3:2017, Clause 38: 1000BASE-SX [b]	850	550
ISO/IEC/IEEE 8802-3:2017, Clause 52: 10GBASE-SR [b]	850	300[a], 400[c]
ISO/IEC/IEEE 8802-3:2017, Clause 86: 40GBASE-SR4 [b, e]	850	100[a], 150[d]
ISO/IEC/IEEE 8802-3:2017, Clause 95: 100GBASE-SR4 [b, e]	850	70[a], 100[d]
ISO/IEC/IEEE 8802-3:2017, Clause 86: 100GBASE-SR10 [b, e]	850	100[a], 150[d]
1 Gbit/s FC (1,0625 GBd) [b]	850	500
2 Gbit/s FC (2,125 GBd) [b]	850	300
4 Gbit/s FC (4,25 GBd) [b]	850	380 [a], 400 [c]
8 Gbit/s FC (8,5 GBd) [b]	850	150 [a], 190 [c]
16 Gbit/s FC (14,025 GBd) [b]	850	100 [a], 125 [c]
32 Gbit/s FC [b]	850	70 [a], 100 [c]
ISO/IEC/IEEE 8802-3:2017, Clause 26: 100BASE-FX	1 300	2 000
ISO/IEC/IEEE 8802-3:2017, Clause 38: 1000BASE-LX [b]	1 300	550
ISO/IEC/IEEE 8802-3:2017, Clause 53: 10GBASE-LX4 [b]	1 300	300
ISO/IEC/IEEE 8802-3:2017, Clause 68: 10GBASE-LRM [b]	1 300	220

[a] Minimum cabled optical fibre performance of Category OM3 is specified.

[b] These applications are bandwidth limited at the channel lengths shown. The use of lower attenuation components to produce channels exceeding the values shown cannot be recommended.

[c] Minimum cabled optical fibre performance of Category OM4 is specified.

[d] Minimum cabled optical fibre performance of Category OM4 is specified (subject to a maximum total connecting hardware loss of 1,0 dB).

[e] These are multi-fibre applications and are subject to a delay skew requirement which is met by design if all the optical fibres providing a channel transverse the same cable and cord sheaths from end-to-end.

Table E.6 – Maximum channel length supported by optical fibre applications for single-mode optical fibre

Network application	Nominal transmission wavelength nm	Maximum channel length m
ISO/IEC/IEEE 8802-3:2017, Clause 38: 1000BASE-LX	1 310	2 000
ISO/IEC/IEEE 8802-3:2017, Clause 87: 40GBASE-LR4	1 310	2 000
ISO/IEC/IEEE 8802-3:2017, Clause 88: 100GBASE-LR4	1 310	2 000
1 Gbit/s/s FC (1,062 5 GBd)	1 310	2 000
2 Gbit/s/s FC (2,125 GBd)	1 310	2 000
4 Gbit/s/s FC (4,25 GBd)	1 310	2 000
8 Gbit/s/s (8,5 GBd)	1 310	2 000
16 Gbit/s/s (14,025 GBd)	1 310	2 000
32 Gbit/s/s (28,05 Gbd)	1 310	2 000
10 Gbit/s/s FC (10,518 75 Gbd)	1 310	2 000
ISO/IEC/IEEE 8802-3:2017, Clause 52: 10GBASE-LR/LW	1 310	2 000
1 Gbit/s/s FC	1 550	2 000
2 Gbit/s/s FC	1 550	2 000
ISO/IEC/IEEE 8802-3:2017, Clause 52: 10GBASE-ER/EW	1 550	2 000
ISO/IEC/IEEE 8802-3:2017, Clause 88: 100GBASE-ER4	1 550	2 000
ISO/IEC/IEEE 8802-3:2017, Clause 89: 40GBASE-FR	1 550	2 000

E.3 Supported applications for coaxial cabling

Table E.7 and Table E.8 contain established and emerging applications defined by the relevant application committees.

Table E.7 – Supported BCT applications using balanced cabling

Class BCT-B (defined up to 1 000 MHz)			
Analogue TV	ITU-R BT.470-6	(2006)	IEC 60728-1 (PAL-x, SECAM-y)
Analogue radio	ITU-R BS.412-9		IEC 60728-1 (FM Radio)
DVB-T	ITU-RP.1546		IEC 60728-1 (DVB-T, T-DAB)
Digital TV		1998	IEC 60728-1 (DVB-C)
Digital TV		2004	IEC 60728-1 (DVB-T)
Digital radio		2001	IEC 60728-1 (DAB)
Digital radio		1998	IEC 60728-1 (DVB-C)
Data streaming		1998	IEC 60728-1 (DVB-C)

Table E.8 – Supported BCT applications using coaxial cabling

Application	Specification Reference	Date	Interface standard
Analogue TV	ITU-R BT.470-6		IEC 60728-1 (PAL-x, SECAM-y)
Analogue radio	ITU-R BS.412-9		IEC 60728-1 (FM Radio)
DVB-T	ITU-R P.1546		IEC 60728-1 (DVB-T, T-DAB)
Digital TV		1998	IEC 60728-1 (DVB-C)
Digital TV		1997	IEC 60728-1 (DVB-S)
Digital TV		2004	IEC 60728-1 (DVB-T)
Digital radio		2001	IEC 60728-1 (DAB)
Digital radio		1998	IEC 60728-1 (DVB-C)
Data streaming		1998	IEC 60728-1 (DVB-C)

E.4 Supported industrial applications for optical fibre cabling

Table E.9, and Table E.10 contain established and emerging applications defined by the relevant application committees.

Table E.9 contains detailed information of the greatest channel lengths supported by process monitoring and control applications for each recognized cabled all-silica multimode optical fibre Category.

Table E.10 contains detailed information of the greatest channel lengths supported by process monitoring and control applications for each recognized cabled all-silica single-mode optical fibre Category.

Table E.9 – Supported applications and maximum channel lengths with cabled multimode optical fibres

	λ nm	Core diameter µm	OM3	
Network application			CIL[a] dB	L[b] m
ControlNET	1 300	50	6,5	1 514

[a] CIL is the maximum channel insertion loss (or optical power budget, as applicable) as defined in the application standard.

[b] L is the lower of either the maximum channel length specified in the application standard or a calculated length from the CIL with 1,5 dB allocated to connecting hardware.

Table E.10 – Supported applications and maximum channel lengths with cabled all-silica single-mode optical fibres

	λ nm	OS1a		OS2	
Network application		CIL[a] dB	L[b] m	CIL[a] dB	L[b] m
ControlNET	1 310	10,0	8 000	10,0	20 000

[a] CIL is the maximum channel insertion loss (or optical power budget, as applicable) as defined in the application standard.

[b] L is the lower of either the maximum channel length specified in the application standard or a calculated length from the CIL with 2,0 dB allocated to connecting hardware.

Annex F
(informative)

Optical fibre cable OM1, OM2 and OS1

Annex F contains a historical record of, and provides a reference to the requirements of earlier editions and amendments of ISO/IEC 11801. Table F.1 includes the specifications for cabled optical fibre categories OM1, OM2, and OS1. Table F.2 and Table F.3 include information on supported applications as well as maximum channel lengths for cabled optical fibre categories OM1, OM2, and OS1.

Table F.1 – Grandfathered OM1, OM2 and OS1 specifications

Cabled fibre category	Optical fibre type	Wavelength nm	Maximum attenuation dB/km	Minimum overfilled modal bandwidth-length product (MHz·km)
OM1	62,5/125 µm Multimode IEC 60793-2-10 Type A1b	850 1 300	3,5 1,5	200 500
OM2	50/125 µm Multimode IEC 60793-2-10 Type A1a.1	850 1 300	3,5 1,5	500 500
OS1	Single-mode IEC 60793-2-50 Type B1.1	1 310 1 550	1,0 1,0	N/A N/A

Table F.2 – Supported applications and maximum channel lengths with cabled all-silica multimode optical fibres

	λ nm	Core diameter µm	OM1		OM2	
Network application			*CIL*[a] dB	*L*[b] m	*CIL*[a] dB	*L*[b] m
ControlNET	1 300	50	6,5	1 514	6,5	1 514
		62,5	11,3	6 533	11,3	6 533

[a] *CIL* is the maximum channel insertion loss (or optical power budget, as applicable) as defined in the application standard.

[b] *L* is the lower of either the maximum channel length specified in the application standard or a calculated length from the *CIL* with 1,5 dB allocated to connecting hardware.

Table F.3 – Supported applications and maximum channel lengths with cabled all-silica singlemode optical fibres

	λ nm	OS1		
Network application		*CIL*[a] dB	*L*[b] m	Class
ControlNET	1 310	10,0	8 000	OF-5000

[a] *CIL* is the maximum channel insertion loss (or optical power budget, as applicable) as defined in the application standard.

[b] *L* is the lower of either the maximum channel length specified in the application standard or a calculated length from the *CIL* with 2,0 dB allocated to connecting hardware.

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