INTERNATIONAL STANDARD

ISO/IEC 11801

Edition 1.2
2000-01

Edition 1:1995 consolidated with amendments 1:1999 and 2:1999

Information technology – Generic cabling for customer premises

Technologies de l'information –
Câblage générique des locaux d'utilisateurs

Reference number
ISO/IEC 11801:1995+A1:1999+A2:1999(E)

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FOREWORD

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialised 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. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

International Standard ISO/IEC 11801 was prepared by the Joint Technical Committee ISO/IEC JTC 1, Information Technology, Subcommittee 25, Interconnection of Information Technology Equipment.

This International Standard has taken into account requirements specified in application standards listed in annex G. It refers to International Standards for components and test methods whenever an appropriate International Standard was available.

This consolidated version of ISO/IEC 11801 is based on the first edition (1995), its amendments 1 (1999) and 2 (1999) and the corrigendum 1 (December 1996) and the corrigendum 2 (June 1997).

It bears the edition number 1.2.

A vertical line in the margin shows where the base publication has been modified by amendments 1 and 2, and corrigenda 1 and 2.

Annexes A, B and C form an integral part of this International Standard.
Annexes D, E, F, G, H and J are for information only.

INTRODUCTION

Within customer premises, the importance of the cabling infrastructure is similar to that of other fundamental building utilities such as heating, lighting and mains power. As with other utilities, interruptions to service can have serious impact. Poor quality of service due to lack of design foresight, use of inappropriate components, incorrect installation, poor administration or inadequate support can threaten an organisation's effectiveness.

Historically, the cabling within a premises comprised both application specific and multipurpose networks. Appropriate use of this International Standard will enable a controlled migration to generic cabling. Certain circumstances may warrant the introduction of application specific cabling; these instances should be minimised.

This International Standard provides:

a) users with an application independent generic cabling system and an open market for cabling components;

b) users with a flexible cabling scheme such that modifications are both easy and economical;

c) building professionals (for example, architects) with guidance allowing the accommodation of cabling before specific requirements are known; that is, in the initial planning either for construction or refurbishment;

d) industry and applications standardisation bodies with a cabling system which supports current products and provides a basis for future product development.

This International Standard specifies a multi-vendor cabling, and is related to:

a) International Standards for cabling components developed by committees of the IEC; for example, copper cables IEC/TC 46 [1)], copper connectors IEC/TC 48, optical fibre cables and connectors IEC/TC 86;

b) applications developed by the sub-committees of ISO/IEC JTC 1 [2)] and study groups of ITU-T [3)]: for example, LANs: ISO/IEC JTC 1/SC 6 and SC 25/WG 4 [4)]; ISDN: ITU-T SG 13 [5)];

c) planning and installation guides for the implementation and use of generic cabling systems.

The applications listed in annex G have been analysed to determine the requirements for a generic cabling system. These requirements, together with statistics concerning premises geography from different countries and the model described in 6.1.1, have been used to develop the requirements for cabling components and to stipulate their arrangement into cabling systems. As a result, generic cabling defined within this International Standard is targeted at, but not limited to, the general office environment.

It is anticipated that the generic cabling system defined by this International Standard will have a life expectancy in excess of 10 years.

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1) International Electrotechnical Commission – Technical Committee 46

2) International Organization for Standardization/International Electrotechnical Commission – Joint Technical Committee 1

3) International Telecommunication Union – Telecommunications

4) Subcommittee 25 – Working Group 4

5) Study Group 13

INFORMATION TECHNOLOGY – GENERIC CABLING FOR CUSTOMER PREMISES

1 Scope

International Standard ISO/IEC 11801 specifies generic cabling for use within commercial premises, which may comprise single or multiple buildings on a campus.

The International Standard is optimised for premises having a geographical span of up to 3 000 m, with up to 1 000 000 m² of office space, and a population between 50 and 50 000 persons. It is recommended that the principles of this International Standard be applied to installations that do not fall within this range.

Cabling defined by this International Standard supports a wide range of services including voice, data, text, image and video.

This International Standard specifies:

a) the structure and minimum configuration for generic cabling [1],

b) implementation requirements,

c) performance requirements for individual cabling links and

d) conformance requirements and verification procedures.

Although safety (electrical, fire, etc.) and Electromagnetic Compatibility (EMC) requirements are outside the scope of this International Standard, and may be covered by other standards and regulations, information given in this International Standard may be of assistance in meeting these requirements.

[1] Cables and cords used to connect application specific equipment to the generic cabling system are outside of the scope of this standard. Since they have significant effect on the transmission characteristics of the channel, assumptions and guidance are provided on their performance and length.

2 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of ISO/IEC 11801. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60068-1:1988, *Basic environmental testing procedures – Environmental testing – Part 1: General and guidance*

IEC 60068-2-2:1974, *Basic environmental testing procedures – Part 2: Tests – Tests B: Dry heat*

IEC 60068-2-6:1982, *Basic environmental testing procedures – Part 2: Tests – Tests Fc and guidance: Vibration (sinusoidal)*

IEC 60068-2-14:1984, *Basic environmental testing procedures – Part 2: Tests – Test N: Change of temperature*

IEC 60068-2-38:1974, *Basic environmental testing procedures – Part 2: Tests – Test Z/AD: Composite temperature/humidity cyclic test*

IEC 60068-2-60 TTD:1990, *Basic environmental testing procedures – Part 2: Tests – Test Ke: Corrosion tests in artificial atmosphere at very low concentration of polluting gas(es)* [Technical Trend Document]

IEC 60096-1:1986, *Radio-frequency cables – Part 1: General requirements and measuring methods*

IEC 60189-1:1986, *Low-frequency cables and wires with p.v.c. insulation and p.v.c. sheath – Part 1: General test and measuring methods*

IEC 60227-2:1979, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 2: Test methods*

IEC 60512-1:1994, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 1: General*

IEC 60512-2:1985, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 2: General examination, electrical continuity and contact resistance tests, insulation tests and voltage stress tests*
Amendment 1 (1988)

IEC 60603-7:1990, *Connectors for frequencies below 3 MHz for use with printed boards – Part 7: Detail specification for connectors, 8 way, including fixed and free connectors with common mating features*

IEC 60708-1:1981, *Low-frequency cables with polyolefin insulation and moisture barrier polyolefin sheath – Part 1: General design details and requirements*

IEC 60793-1:1992, *Optical fibres – Part 1: Generic specification*

IEC 60793-1 (all parts), *Optical fibres – Part 1: Generic specification*

IEC 60793-2:1992, *Optical fibres – Part 2: Product specifications*

IEC 60794-1:1993, *Optical fibre cables – Part 1: Generic specification*

IEC 60794-2:1989, *Optical fibre cables – Part 2: Product specifications*

IEC 60807-8:1992, *Rectangular connectors for frequencies below 3 MHz – Part 8: Detailed specification for connectors, four signal contacts and earthing contacts for cable screen*

IEC 60811-1-1:1993, *Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section 1: Measurement of thickness and overall dimensions – Tests for determining the mechanical properties*

IEC 60874-1:1993, *Connectors for optical fibres and cables – Part 1: Generic specification*

IEC 60874-10:1992, *Connectors for optical fibres and cables – Part 10: Sectional specification for fibre optic connector – Type BFOC/2,5*

IEC 60874-14:1993, *Connectors for optical fibres and cables – Part 14: Sectional specification for fibre optic connector – Type SC*

IEC 60874-19 (all parts), *Connectors for optical fibres and cables*

IEC 61035-1, *Specification for conduit fittings for electrical installations – Part 1: General requirements*

IEC 61073-1:1994, *Splices for optical fibres and cables – Part 1: Generic specification – Hardware and accessories*

IEC 61156-1:1994, *Multicore and symmetrical pair/quad cables for digital communications – Part 1: Generic specification*

IEC 61280-4 (all parts), *Fibre optic communication subsystem basic test procedures – Part 4: Fibre optic requirements*

IEC 61935-1, — *Generic specification for the testing of generic cabling in accordance with ISO/IEC 11801 – Part 1: Test methods* [1)]

ISO/IEC 8802-5:1992, *Information technology – Local and metropolitan area networks – Part 5: Token ring access method and physical layer specifications*

CISPR 22:1993, *Limits and methods of measurement of radio disturbance characteristics of information technology equipment*

ITU-T Rec. G.117:1988, *Transmission aspects of unbalance about earth (definitions and methods)*

ITU-T Rec. G.650:1993, *Transmission media characteristics – Definition and test methods for the relevant parameters of single-mode fibres*

ITU-T Rec. G.651:1993, *Characteristics of a 50/125 µm multimode graded index optical fibre cable*

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1) To be published.

ITU-T Rec. G.652:1993, *Characteristics of a single-mode optical fibre cable*

ITU-T Rec. O.9:1988, *Measuring arrangements to assess the degree of unbalance about earth*

3 Definitions and abbreviations

3.1 Definitions

For the purposes of this International Standard, the following definitions are applicable.

3.1.1
application
a system, with its associated transmission method which is supported by telecommunications cabling

3.1.2
balanced cable
a cable consisting of one or more metallic symmetrical cable elements (twisted pairs or quads)

3.1.3
building backbone cable
a cable that connects the building distributor to a floor distributor. Building backbone cables may also connect floor distributors in the same building

3.1.4
building distributor
a distributor in which the building backbone cable(s) terminate(s) and at which connections to the campus backbone cable(s) may be made

3.1.5
building entrance facility
a facility that provides all necessary mechanical and electrical services, that complies with all relevant regulations, for the entry of telecommunications cables into a building

3.1.6
cable
an assembly of one or more cable units of the same type and category in an overall sheath. It may include an overall shield

3.1.7
cable element
the smallest construction unit (for example pair, quad, or single fibre) in a cable. A cable element may have a shield

3.1.8
cable unit
a single assembly of one or more cable elements of the same type or category. The cable unit may have a shield

NOTE A binder group is an example of a cable unit.

3.1.9
cabling
a system of telecommunications cables, cords, and connecting hardware that can support the connection of information technology equipment

3.1.10
campus
a premises containing one or more buildings

3.1.11
campus backbone cable
a cable that connects the campus distributor to the building distributor(s). Campus backbone cables may also connect building distributors directly

3.1.12
campus distributor
the distributor from which the campus backbone cabling emanates

3.1.13
channel
the end-to-end transmission path connecting any two pieces of application specific equipment. Equipment and work area cables are included in the channel

3.1.14
cross-connect
a facility enabling the termination of cable elements and their connection, primarily by means of patch cords or jumpers

3.1.15
distributor
the term used for the functions of a collection of components (such as, patch panels, patch cords) used to connect cables

3.1.16
equipment cable
a cable connecting equipment to a distributor

3.1.17
equipment room
a room dedicated to housing distributors and application specific equipment

3.1.18
floor distributor
the distributor used to connect between the horizontal cable and other cabling subsystems or equipment. (See telecommunications closet)

3.1.19
generic cabling
a structured telecommunications cabling system, capable of supporting a wide range of applications. Generic cabling can be installed without prior knowledge of the required applications. Application specific hardware is not a part of generic cabling

3.1.20
horizontal cable
a cable connecting the floor distributor to the telecommunications outlet(s)

3.1.21
hybrid cable
an assembly of two or more different types of cable units, cables or categories covered by an overall sheath. It may be covered by an overall shield

3.1.22
individual work area
the minimum building space which would be reserved for an occupant

3.1.23
interconnect
a location at which equipment cables are terminated and connected to the cabling subsystems without using a patch cord or jumper

3.1.24
interface
a point at which connections are made to the generic cabling

3.1.25
jumper
a cable unit or cable element without connectors, used to make a connection on a cross-connect

3.1.26
keying
a mechanical feature of a connector system, which guarantees correct orientation of a connection, or prevents the connection to a jack or optical fibre adapter of the same type intended for another purpose

3.1.27
link
the transmission path between any two interfaces of generic cabling. It excludes equipment and work area cables

3.1.28
optical fibre cable (or optical cable)
a cable comprising one or more optical fibre cable elements

3.1.29
optical fibre duplex adapter
a mechanical device designed to align and join two duplex connectors

3.1.30
optical fibre duplex connector
a mechanical termination device designed to transfer optical power between two pairs of optical fibres

3.1.31
pair
a twisted pair or one side circuit (two diametrically facing conductors) in a star quad

3.1.32
patch cord
flexible cable unit or element with connector(s), used to establish connections on a patch panel

3.1.33
patch panel
a cross-connect designed to accommodate the use of patch cords. It facilitates administration for moves and changes

3.1.34
permanent link
the transmission path between two mated interfaces of generic cabling, excluding equipment cables, work area cables and cross-connections

3.1.35
public network interface
a point of demarcation between public and private network. In many cases the public network interface is the point of connection between the network provider's facilities and the customer premises cabling

3.1.36
quad
see star quad

3.1.37
side circuit
see pair

3.1.38
shielded cables
an assembly of two or more balanced twisted pair cable elements, or one or more quad cable elements, wrapped by an overall screen or shield contained within a common sheath or tube

3.1.39
shielded twisted pair cables
an electrically conducting cable comprising one or more elements, each of which is individually shielded. There may be an overall shield, in which case the cable is referred to as a shielded twisted pair cable with an overall shield

3.1.40
splice
a joining of conductors and fibres, generally from separate sheaths

3.1.41
star quad
a cable element which comprises four insulated conductors twisted together. Two diametrically facing conductors form a transmission pair

NOTE Cables containing star quads can be used interchangeably with cables consisting of pairs, provided the electrical characteristics meet the same specifications.

3.1.42
telecommunications
a branch of technology concerned with the transmission, emission and reception of signs, signals, writing, images and sounds; that is, information of any nature by cable, radio, optical or other electromagnetic systems. The term telecommunications has no legal meaning when used in this International Standard

3.1.43
telecommunications closet
an enclosed space for housing telecommunications equipment, cable terminations, and cross-connect cabling. The telecommunications closet is a recognized cross-connect point between the backbone and horizontal cabling subsystems

3.1.44
telecommunications outlet
a fixed connecting device where the horizontal cable terminates. The telecommunications outlet provides the interface to the work area cabling

3.1.45
transition point
a location in the horizontal cabling where a change of cable form takes place; for example flat cable connects to round cable or cables with differing numbers of elements are joined

3.1.46
twisted pair
a cable element which consists of two insulated conductors twisted together in a regular fashion to form a balanced transmission line

3.1.47
unshielded twisted pair cable
an electrically conducting cable comprising one or more pairs none of which is shielded. There may be an overall shield, in which case the cable is referred to as unshielded twisted pair with an overall shield

3.1.48
work area
a building space where the occupants interact with telecommunications terminal equipment

3.1.49
work area cable
a cable connecting the telecommunications outlet to the terminal equipment

3.2 Abbreviations

a.c.	alternating current
ACR	Attenuation to Crosstalk Ratio
BD	Building Distributor
BEF	Building Entrance Facilities
BFOC	Bayonet Fibre Optic Connector
B-ISDN	Broadband ISDN
BRI	Basic Rate ISDN
CD	Campus Distributor
c	speed of light
CISPR	International Special Committee on Radio Interference
CSMA/CD	Carrier Sense Multiple Access with Collision Detection
d.c.	direct current
DCE	Data Circuit Terminating Equipment
DTE	Data Terminal Equipment
DUT	Device Under Test
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ER	Equipment Room
FD	Floor Distributor
FDDI	Fibre Distributed Data Interface
f.f.s.	for further study
FOIRL	Fibre Optic Inter-Repeater Link
FWHM	Full Width Half Maximum
IC	Integrated Circuit
IDC	Insulation Displacement Connection
IEC	International Electrotechnical Commission
ISDN	Integrated Services Digital Network
ISO	International Organization for Standardization

ITU-T	International Telecommunication Union – Telecommunications (formerly CCITT)
JTC	Joint Technical Committee
LAN	Local Area Network
LCL	Longitudinal Conversion Loss
LCTL	Longitudinal Conversion Transfer Loss
N/A	Not Applicable
N-BNC	N type to BNC Convertor
NEXT	Near End Crosstalk
OTDR	Optical Time Domain Reflectometer
PBX	Private Branch Exchange
PDAM	Proposed Draft Amendment
PMD	Physical Layer Medium Dependent
PVC	Polyvinyl chloride
SC	Subscriber Connector (optical fibre connector)
SC-D	Duplex SC connector
STI	Surface Transfer Impedance
TC	Telecommunications Closet
TDR	Time Domain Reflectometer
TO	Telecommunications Outlet
TP	Transition Point

4 Conformance

For a cabling installation to conform to this International Standard the following applies.

a) The configuration shall conform to the requirements outlined in clause 5.

b) The interfaces to the cabling shall conform to the requirements of clause 9.

c) The entire system shall be composed of links that meet the necessary level of performance specified in clause 7. This shall be achieved by installing components which meet the requirements of clauses 8 and 9, according to the design parameters of clause 6, or by a system design and implementation ensuring that the prescribed performance class of clause 7, and the reliability requirements of clause 9, are met.

d) System administration shall meet the requirements of clause 11.

e) Local regulations concerning safety and EMC shall be met.

The link performance specified in clause 7 is in accordance with clause 6. The link performance is met when components specified in clauses 8 and 9 are installed in a workmanlike manner and in accordance with supplier's and designer's instructions, over distances not exceeding those specified in clause 6. It is not required to test the transmission characteristics of the link in that case.

Conformance testing to the specifications of clause 7 should be used in the following cases:

a) the design of links with lengths exceeding those specified in clause 6;

b) the design of links using components different from those described in clauses 8 and 9;

c) the evaluation of installed cabling to determine its capacity to support a certain group of applications;

d) performance verification, as required, of an installed system designed in accordance with clauses 6, 8 and 9.

Specifications marked "f.f.s." (for further study) are preliminary specifications, and are not required for conformance to this International Standard.

References to the requirements and classifications specified in this International Standard shall specifically differentiate components and systems conforming to ISO/IEC 11801 (1995) from those that are qualified according to ISO/IEC 11801 (1995), including amendment 1 (1999) and amendment 2 (1999), by specifically referencing ISO/IEC 11801 (1995), including amendment 1 (1999) and amendment 2 (1999). For the purpose of component marking and system identification, it is appropriate to directly reference the year of publication of the second amendment, or to use a specific designation that provides linkage to it.

5 Structure of the generic cabling system

This clause identifies the functional elements of generic cabling, describes how they are connected together to form subsystems, and identifies the interfaces at which application specific components are interconnected by the generic cabling. General requirements for implementing generic cabling are also provided.

Applications are supported by connecting equipment to the telecommunications outlets and distributors. The components used to make this connection do not form part of generic cabling.

5.1 Structure

5.1.1 Functional elements

The functional elements of generic cabling are as follows:

Campus Distributor	[CD]
Campus Backbone Cable	
Building Distributor	[BD]
Building Backbone Cable	
Floor Distributor	[FD]
Horizontal Cable	
Transition Point (optional)	[TP]
Telecommunications Outlet	[TO]

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

5.1.2 Cabling subsystems

Generic cabling contains three cabling subsystems: campus backbone, building backbone and horizontal cabling. The composition of the subsystems are described in 5.1.3, 5.1.4 and 5.1.5. The cabling subsystems are connected together to create a generic cabling structure as shown in figure 1. The distributors provide the means to configure the cabling to support different topologies like bus, star and ring.

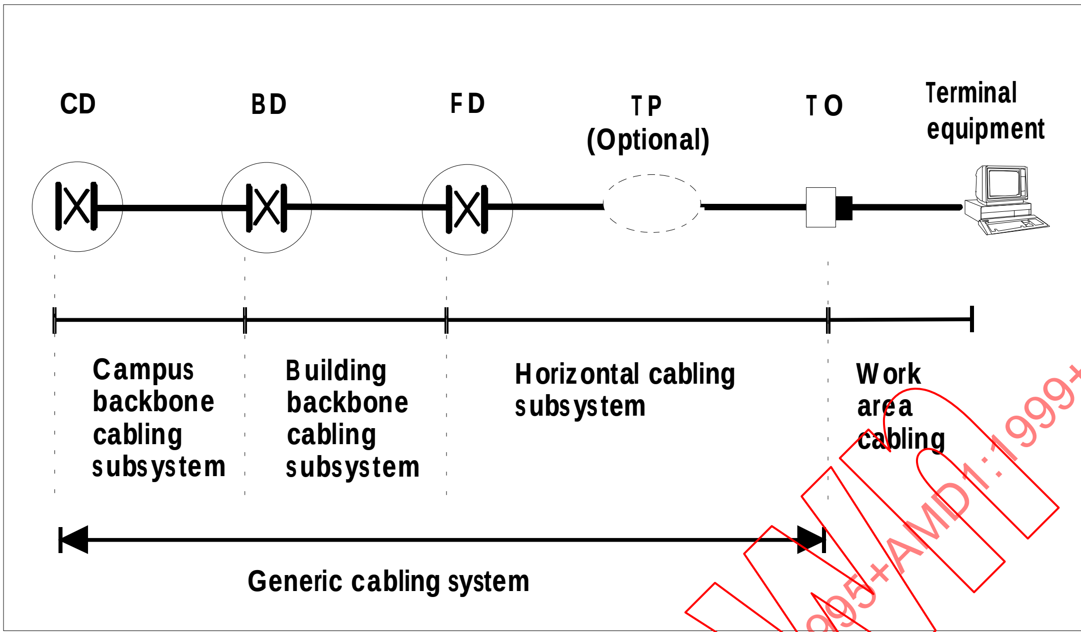

Figure 1 – Structure of generic cabling

5.1.3 Campus backbone cabling subsystem

The campus backbone cabling subsystem extends from the CD to the BD(s) usually located in separate buildings. When present, it includes the campus backbone cables, the mechanical termination of the campus backbone cables (at both the CD and BD(s)) and the cross-connections at the CD. The campus backbone cable may also interconnect BD(s).

5.1.4 Building backbone cabling subsystem

A building backbone cabling subsystem extends from BD(s) to the FD(s). The subsystem includes the building backbone cables, the mechanical termination of the building backbone cables (at both the BD(s) and FD(s)) and the cross-connects at the BD. The building backbone cables shall not contain TPs; copper backbone cables should not contain splices.

5.1.5 Horizontal cabling subsystem

The horizontal cabling subsystem extends from FD(s) to the TO(s). The subsystem includes the horizontal cables, the mechanical termination of the horizontal cables at the FD, the cross-connections at the FD and the TOs.

Horizontal cables should be continuous from the FD to the TOs. If necessary, one TP is permitted between an FD and any TO. The transmission characteristics of the horizontal cabling shall be maintained. The incoming and outgoing pairs and fibres at the TP shall be connected so that a 1:1 correspondence is maintained. All cable elements at the TP shall be mechanically terminated. The TP shall not be used as a point of administration (that is, not used as a cross-connect), and application specific equipment shall not be located there. The TP may only contain passive connecting hardware. Refer to 8.3 for restrictions on the use of multi-unit cables.

5.1.6 Work area cabling

The work area cabling connects the TO to the terminal equipment. It is non-permanent and application specific and therefore lies outside the scope of this International Standard. Assumptions have been made concerning the length and the transmission performance of the work area cable; these assumptions are identified when relevant.

5.2 Overall structure

The generic cabling is a hierarchical star structure which may take the form shown in figure 2. The number and type of subsystems that are included in a generic cabling implementation depends upon the geography and size of the campus or building, and upon the strategy of the user. For example, in a campus having only one building the primary distribution point is the BD, and there is no need for a campus backbone cabling subsystem. On the other hand, one large building may be treated as a campus, with a campus backbone subsystem and several BDs. Further information on the application of the cabling structure is given in D.3 of annex D.

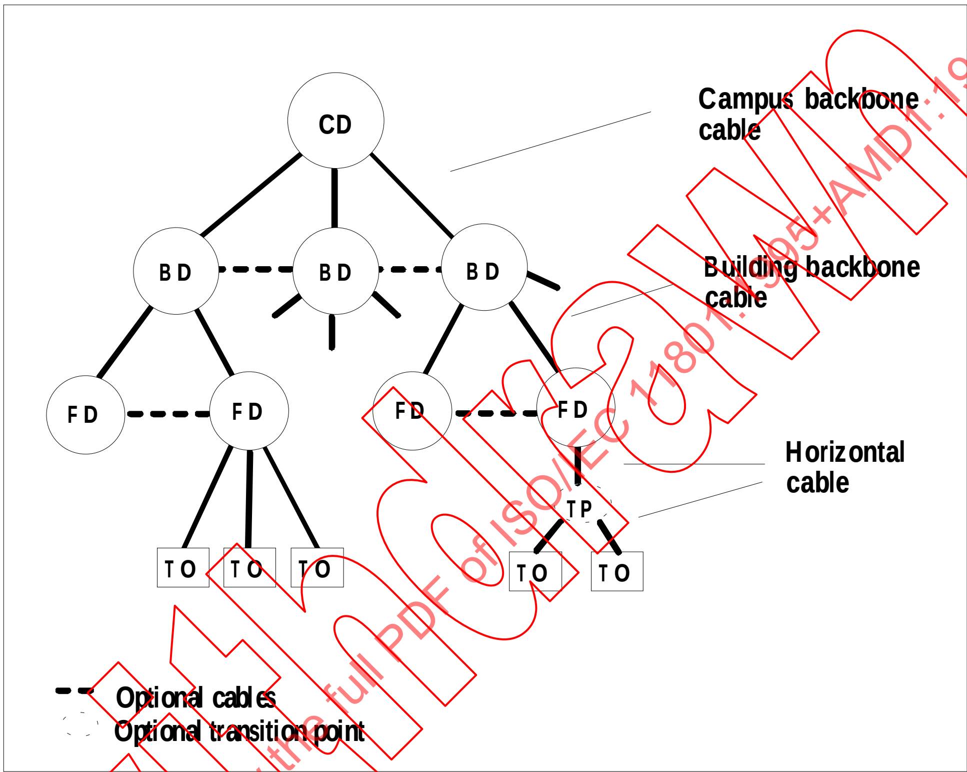

Figure 2 – Inter-relationship of functional elements

Cables shall be installed between adjacent levels in the structure. This forms a hierarchical star as shown in figure 2, and provides the high degree of flexibility needed to accommodate a variety of applications. Annex D details how to configure various networks within the boundaries of the hierarchical star topology. These topologies are established by the inter-connection of the cable elements at cross-connects, and at the application specific equipment.

For some applications, additional direct connections between FDs or BDs are desirable and are permitted. The building backbone cable may also interconnect FDs. However, such connections shall be in addition to those required for the basic hierarchical star topology.

The functions of multiple distributors may be combined. Figure 3 shows an example of generic cabling. The building in the foreground shows each distributor housed separately. The building in the background shows that the functions of the BD and FD have been combined into a single distributor.

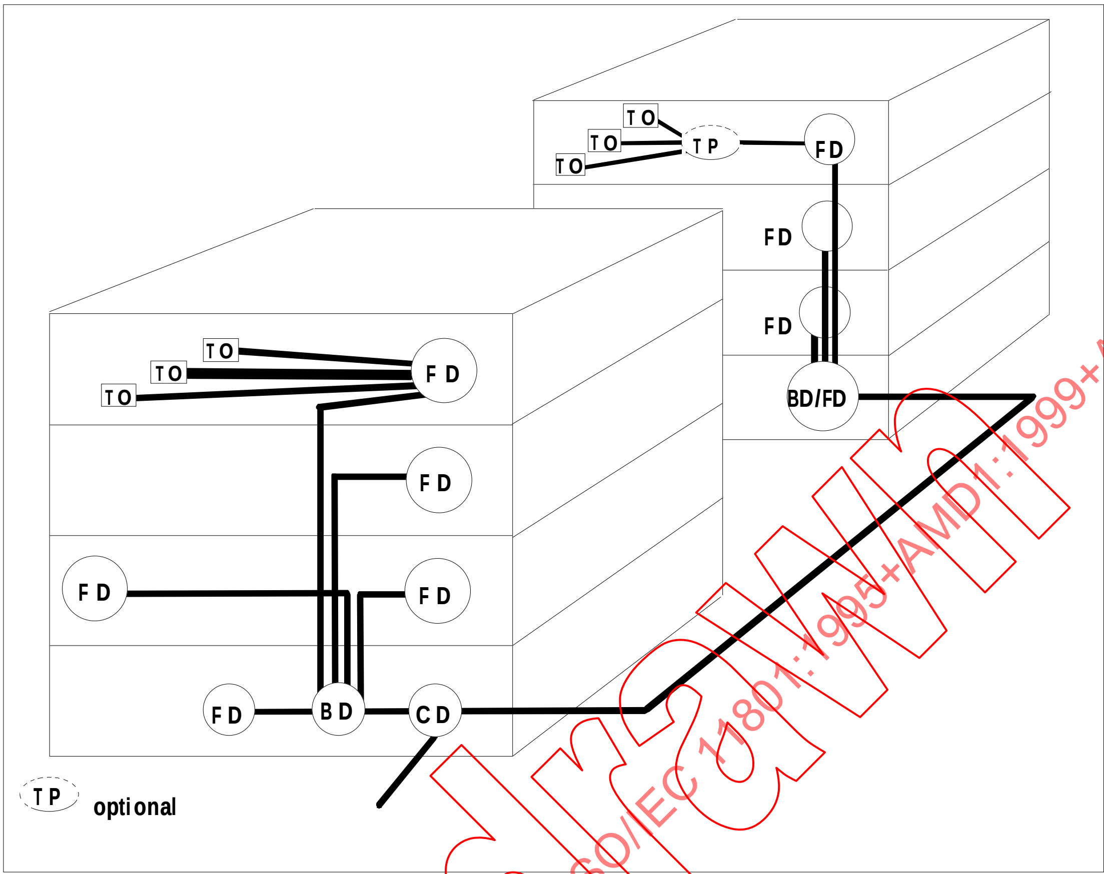

Figure 3 – Example of the generic cabling system

Information about additional cabling for fault tolerance can be found in annex D.

5.3 Location of distributors

Distributors are located in equipment rooms (ER) or telecommunications closets (TC). Figure 4 shows how the functional elements are typically accommodated in a building.

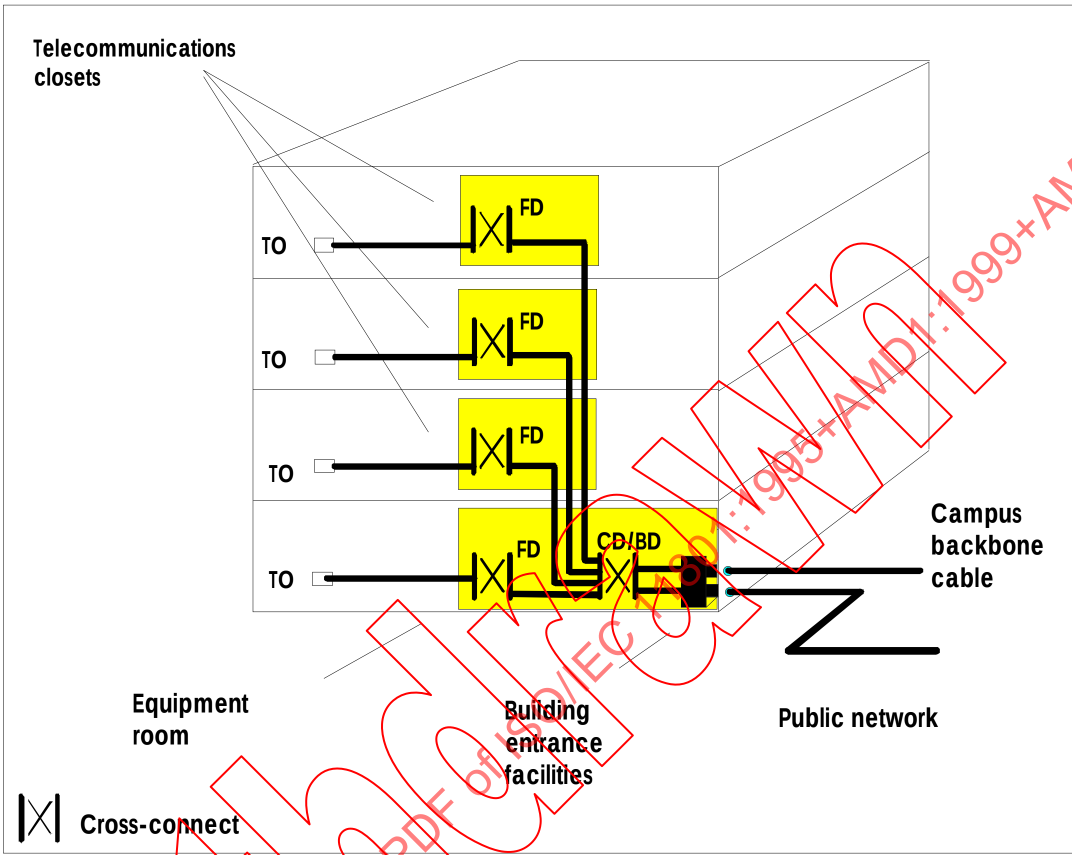

Figure 4 – Typical accommodation of functional elements

Cables are placed in appropriate pathways which may take a variety of forms including ducts, tunnels, cable trays, etc.

5.4 Interfaces to the generic cabling system

Interfaces to generic cabling are located at the ends of each subsystem. Application specific equipment can be connected at these points. Figure 5 shows potential interfaces at the distributors and TO. Any distributor may have an interface to an external services cable, and may use either interconnects or cross-connects.

The distance from external services to the CD can be significant. The performance of the cable between these points should be considered as part of the initial design and implementation of customer applications.

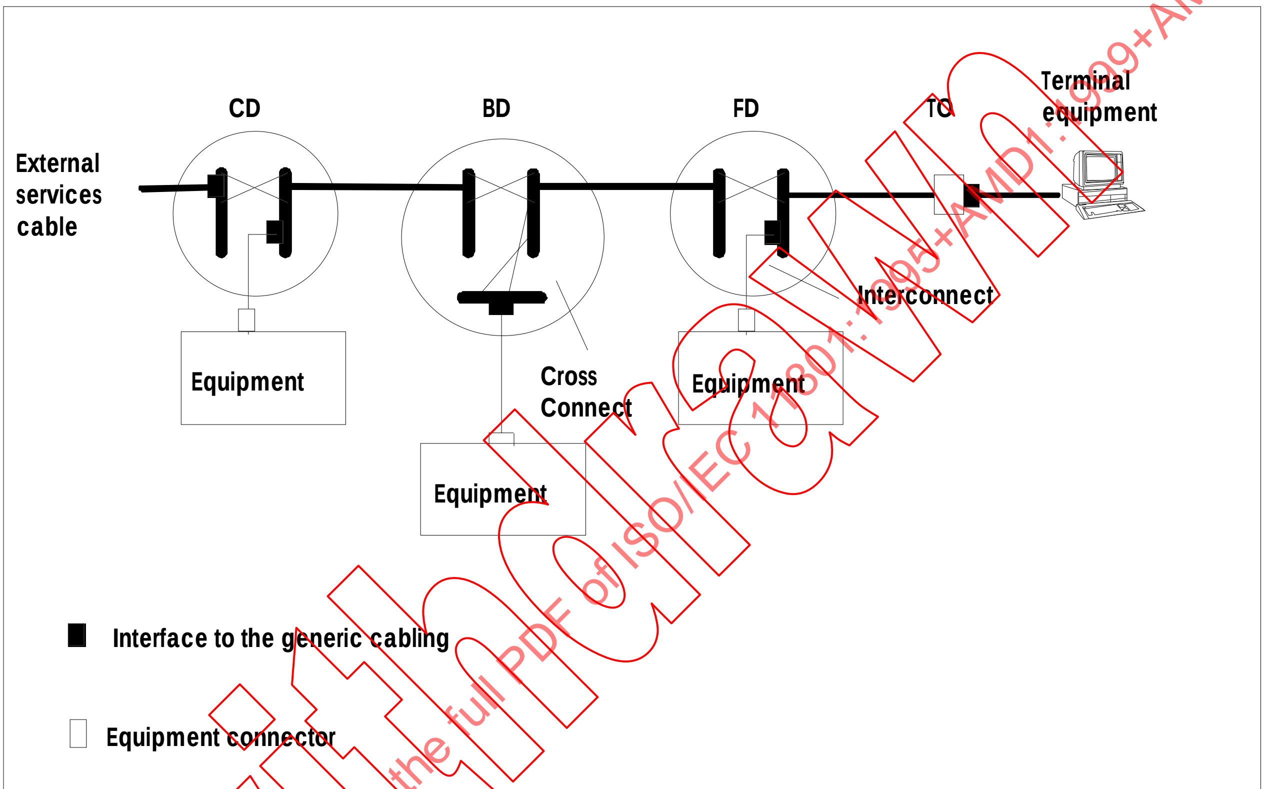

Figure 5 – Potential interfaces to generic cabling

5.4.1 Public network interface

Connections to the public network for the provision of public telecommunications services are made at the public network interface. The location of the public network interface, if present, and the facilities which must be provided may be regulated by national, regional, and local regulations. If the public network interface is not connected directly to a generic cabling interface the performance of the intermediate cabling should be taken into account. The type of cross-connect and the intermediate cable may be governed by national regulations. These regulations should be considered in planning the generic cabling.

5.5 Dimensioning and configuring

5.5.1 Floor distributor

There should be a minimum of one FD for every 1 000 m^2 of floor space reserved for offices. A minimum of one FD should be provided for every floor. If a floor is sparsely populated (for example, a lobby), it is permissible to serve this floor from the FD located on an adjacent floor.

5.5.2 Preferred cable types for pre-cabling and recommended use

Table 1 gives general guidelines regarding the use of different media in a particular subsystem for pre-cabling before applications used are known.

Table 1 – Recommended media for pre-cabling

Subsystem	Media Type	Recommended Use
Horizontal	Balanced cables	Voice and data (see table G.4) [1]
	Optical fibre	Data (see table G.5) [1]
Building backbone	Balanced cables	Voice and low to medium speed data
	Optical fibre	Medium to high speed data
Campus backbone	Optical fibre	For most applications – by using optical fibre – ground potential differences and other sources of interference may be overcome
	Balanced cables	As needed [2]

1) Under certain conditions, (for example, environmental conditions, security concerns, etc.), installation of optical fibre in the horizontal cabling subsystem should be considered.

2) Balanced cables can be used in the campus backbone cabling subsystem in cases when the bandwidth of optical fibre is not required, for example PBX lines.

5.5.3 Telecommunications outlets

TOs are located on the wall, floor, or elsewhere in the work area, depending on the design of the building. The design of generic cabling should provide for TOs to be installed in readily accessible locations throughout the usable floor space. A high density of TOs will enhance the flexibility of the cabling to accommodate changes. In many countries two TOs are provided to serve a maximum of 10 m^2 of usable floor space.

TOs may be presented singly, or in groups, but each work area shall be served by a minimum of two.

A minimum of one TO served by 100 Ω or 120 Ω cable shall be provided at each work area[1] (100 Ω preferred). Other TOs shall be supported by either balanced cable or by fibre optical cable[2]. In the horizontal cabling, at least one TO shall be configured as specified in item b of 6.1.3 (balanced or optical fibre cable) or at least one TO shall be served by either class D or optical class, as identified in 7.1.1. When a TO is supported by balanced cable, 2 pairs[3] or 4 pairs shall be provided at each TO; all pairs shall be terminated. If less than four pairs are provided, the outlet shall be clearly marked[4]. Emerging balanced cable applications may be limited by differential delay of pairs that serve a single telecommunications outlet. See clause 9 for TO specifications that correspond to each of the cables listed above.

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1) When the greatest flexibility is desired, four pair or two quad cable should be used (see annex G).

2) When the largest bandwidth is desired the use of optical fibre is recommended.

3) Installation of 2 pairs not capable of forming class D links may limit the applications supported.

4) See annex G for number and performance of pairs needed for different applications and their pin assignment.

Outlets shall be marked with a permanent label that is visible to the user. Care should be taken that the initial pair assignment, and all subsequent changes, are recorded (see clause 10). Devices such as baluns and impedance matching adapters, if used, shall be external to the outlet. Pair reassignment by means of inserts is allowed.

5.5.4 Telecommunications closets and equipment rooms

A TC should provide all the facilities (space, power, environmental control etc.) for passive components, active devices, and public network interfaces housed within it. Each TC should have direct access to the backbone.

An ER is an area within a building where telecommunications equipment is housed and may or may not contain distributors. ERs are treated differently from TCs because of the nature or complexity of the equipment (e.g. PBXs or extensive computer installations). More than one distributor may be located in an ER. If a telecommunications space houses more than one distributor it should be considered an ER.

5.5.5 Building entrance facilities

Building entrance facilities are required whenever campus backbone, public and private network cables (including antennae) enter buildings and a transition is made to internal cables. It comprises an entrance point at a building wall and the pathway leading to the campus or building distributor. Local regulations may require special facilities where the external cables are terminated. At this termination point, a change from external to internal cable can take place.

5.6 Electromagnetic compatibility

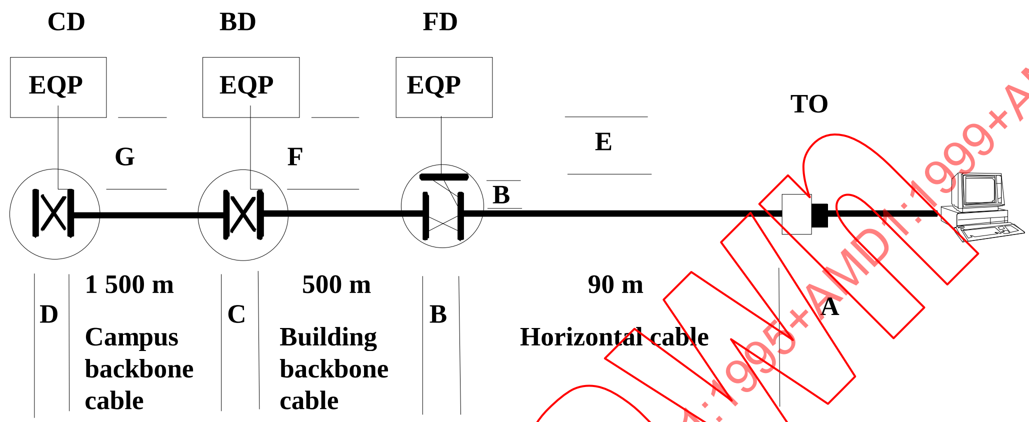
Where applicable, International Standards on electromagnetic emissions and immunity (such as CISPR 22), and local regulations shall be taken into account. Premises cabling is considered as a passive system and cannot be tested for EMC compliance individually. The active equipment which is designed for one specific medium is required to meet relevant EMC standards on this medium.

5.7 Earthing and bonding

Earthing shall meet the requirements mandated by the relevant authorities. Where compatible with required electrical codes, the earthing instructions and requirements of the equipment manufacturers should also be followed.

6 Implementation

This clause specifies a cabling design that, when properly installed, conforms to the requirements of this International Standard. The design should be applicable to the majority of installations. Maximum lengths are defined for the horizontal and backbone cabling subsystems (see figure 6).



A + B + E = < 10 m - combined length of work area cable, equipment cable nd patch cord (or jumper) in the horizontal subsystem
C and D = < 20 m - patch cord (or jumper) in the BD or CD
F and G = < 30 m - equipment cable in the BD or CD

Note that all lengths are mechanical lengths.

EQP = application specific equipment

NOTE 1 See annex C for further information on flexible cables.

NOTE 2 The 10 m (A + B + E) and 30 m (F and G) lengths are strongly recommended, but are of an advisory nature, because they include equipment cables which are outside the scope of this International Standard.

Figure 6 – Maximum cable lengths

The requirements for the cabling components to be used within this clause can be found in clause 8 (for cables) and clause 9 (for connecting hardware). Balanced cables of 100 Ω and 120 Ω characteristic impedance and the connecting hardware for these cables are specified by categories of increasing performance. The transmission characteristics of category 3, 4 and 5 components are specified up to 16 MHz, 20 MHz, and 100 MHz respectively.

Cables and connecting hardware of different categories may be mixed within a subsystem and/or the cabling link, but the transmission of the link will be determined by the category of the least performing component.

Cables of different nominal characteristic impedances shall not be mixed within a cabling link. Optical fibres of different core diameters shall not be mixed within a cabling link.

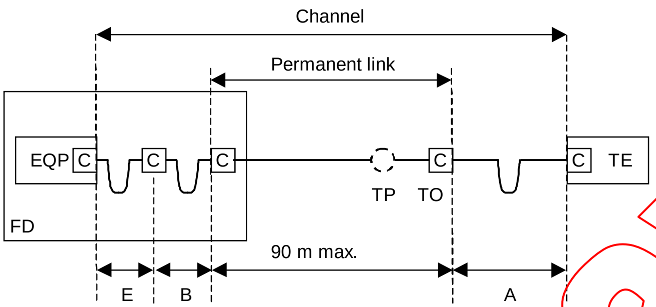
Multiple appearances of the same conductor or conductors continuing past the point of termination (bridged taps) shall not exist as part of the cabling system.

6.1 Horizontal cabling

6.1.1 Horizontal distances

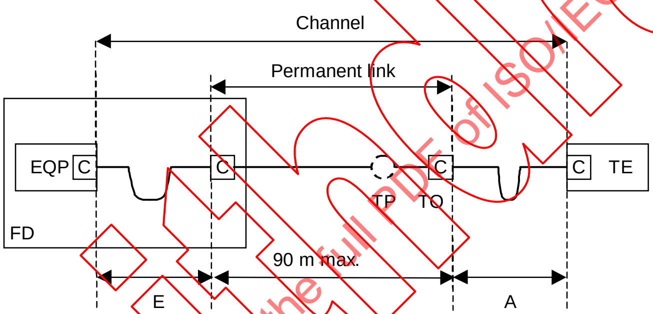
The maximum horizontal cable length shall be 90 m independent of medium (see figure 6). This is the cable length from the mechanical termination of the cable in the floor distributor to the telecommunications outlet in the work area.

In establishing the maximum length of the horizontal channel, the optional use of a crossconnect or an interconnect places different requirements on the total length of the flexible cables used. Figure 7 shows examples of horizontal channel implementations which reflect these differing requirements of maximum cable length.



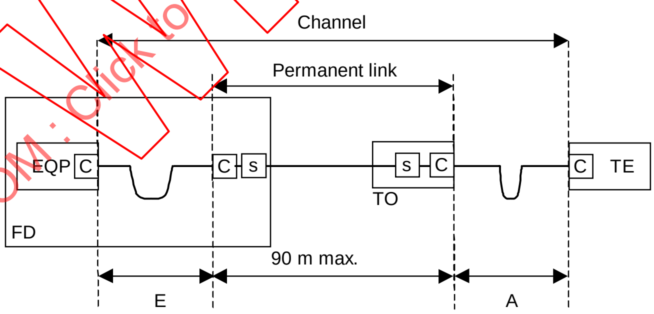
A + B + E = 9 m maximum

Figure 7a – Balanced copper horizontal cabling (with crossconnect)



A + E = 10 m maximum

Figure 7b – Balanced copper horizontal cabling (with interconnect)



A + E = 10 m maximum

Figure 7c – Optical fibre cabling (with interconnect)

Key

C connection (e.g. plug and jack or mated optical connection)

S optical fibre splice

EQP application specific equipment

NOTE 1 All lengths are mechanical lengths.

NOTE 2 See annex C for further information on flexible cables.

Figure 7 – Examples of horizontal channel implementation

In figure 7a, the maximum total length of work area cable, equipment cable and patch cord is 9 m based upon flexible cables with 50 % greater attenuation than the horizontal cable and includes a crossconnect in the floor distributor. In figure 7b, the maximum total length of work area cable and equipment cable is 10 m also based upon flexible cables with 50 % greater attenuation than the horizontal cable and includes an interconnect in the floor distributor. In both cases the transition point is optional. It is required that the performance of the horizontal cabling is not degraded by the inclusion of the transition point.

For optical fibre, the implementation is shown in figure 7c. An optical fibre splice, in accordance with clause 9, is allowed at both ends of the horizontal cable.

See clause 9 and annex C for requirements for patch cords and other flexible cables. In all cases, equipment cables that meet or have better performance characteristics than patch cord requirements are recommended.

6.1.2 Choosing cable types

The following cable types are recommended for use in the horizontal cabling subsystem:

Preferred:

a) 100 Ω balanced cable – (see 8.1).

b) 62,5/125 µm multimode optical fibres – (see 8.4).

Alternative:

a) 120 Ω balanced cable – (see 8.1).

b) 150 Ω balanced cable – (see 8.2).

c) 50/125 µm multimode optical fibres – (see 8.4).

The performance characteristics for the horizontal cable types, associated connecting hardware and cross-connects are described in clauses 8 and 9.

Hybrid and multi-unit cables that meet the requirements of 8.3 may be used in the horizontal cabling subsystem for serving more than one TO.

If shields or grounded metallic parts are present, refer to clause 10.

6.1.3 Configuring TOs

The two TOs in a work area corresponding to the minimum configuration of clause 5 are configured as follows.

a) One telecommunications outlet shall be supported by balanced cable category 3 or higher according to 8.1.

b) A second telecommunications outlet shall be supported either by balanced cable of category 5, according to 8.1, a balanced cable according to 8.2, or an optical fibre cable according to 8.3.

NOTE See 9.2.5, 9.3.5 and 9.4.4 for TO requirements that correspond to each of the cables listed above.

A typical horizontal and work area cabling scenario is represented in figure 8.

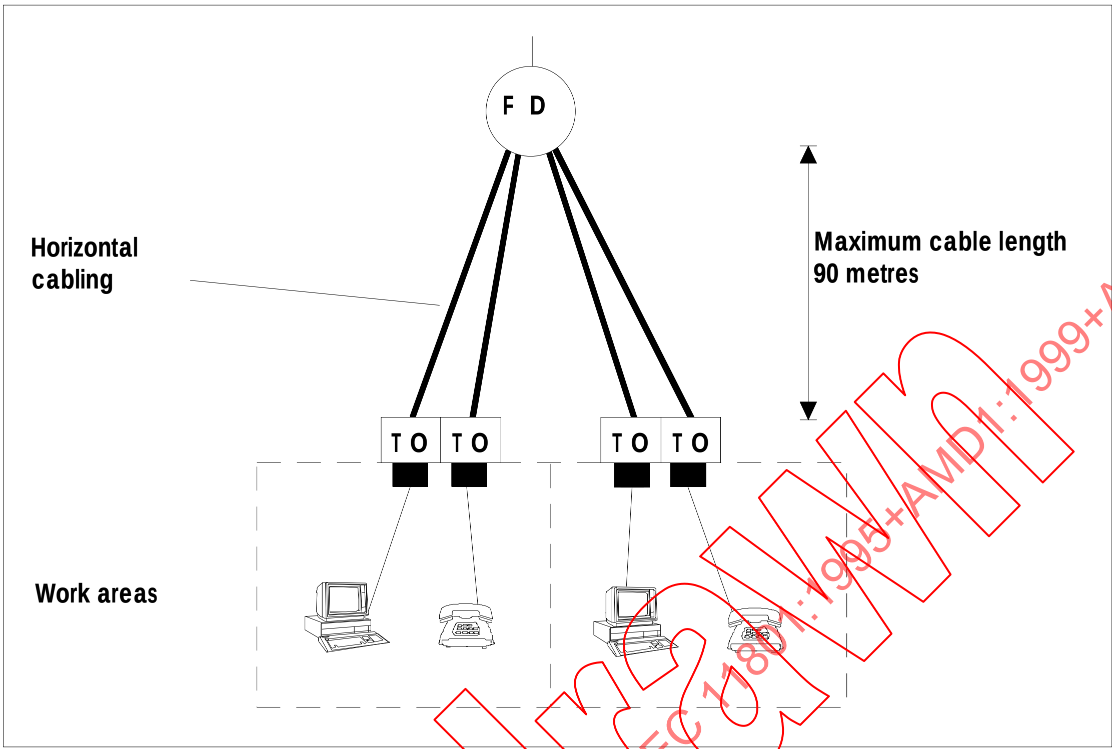


Figure 8 – Typical horizontal and work area cabling

6.2 Backbone cabling

6.2.1 Physical topology

There shall be no more than two hierarchical levels of cross-connects in the backbone cabling to limit signal degradation for passive systems and to simplify administration in keeping track of cables and connections. No more than one cross-connect shall be passed through to reach the CD when starting from a FD.

A single backbone cabling cross-connect may meet the cross-connect needs of the entire backbone subsystem. Backbone cabling cross-connects may be located in telecommunications closets or equipment rooms. See annex D for guidance on accommodating ring, bus, tree, etc. configurations within the hierarchical star.

The star topology is applicable to the cable elements of the transmission medium, such as individual fibres or pairs. Depending on the physical characteristics of a site, cable elements that are terminated at different locations may be part of the same cable over a portion of the distance, or may use individual cables over the entire distance. Hybrid and multi-unit cables that meet the requirements of 8.3 may be used in the backbone cabling subsystem.

An example of the backbone star topology is given in figure 9.

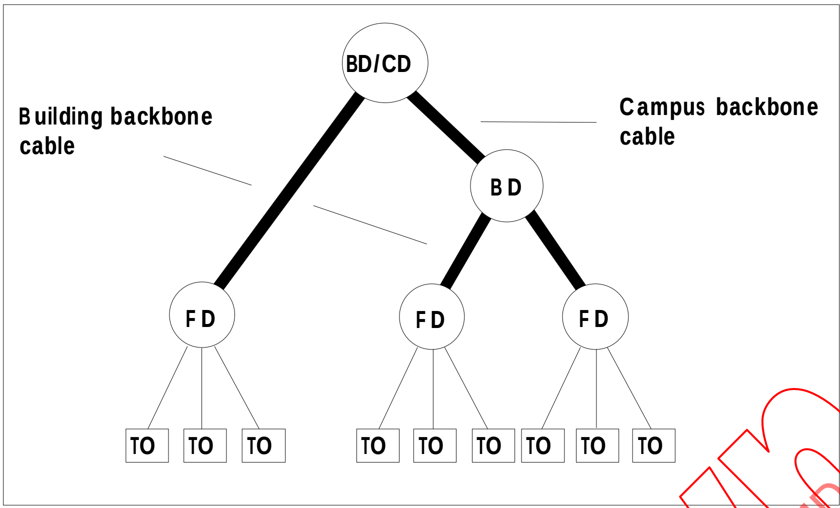


Figure 9 – Backbone star topology

6.2.2 Choosing cable types

This International Standard specifies five transmission media; more than one of these five general types may be present in the backbone cabling. The five media are:

– multimode and singlemode optical fibre cable (see 8.4 and 8.5 respectively). The 62,5/125 µm multimode fibre is preferred;

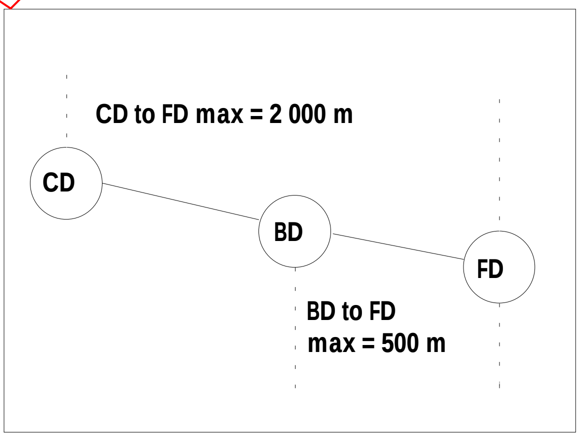
– 100 Ω, 120 Ω or 150 Ω balanced cable (see 8.1 and 8.2 respectively). The 100 Ω cable is preferred. All high speed applications on copper shall be limited to horizontal distances as specified in 6.1.1.

If shields or grounded metallic parts are present, refer to clause 10.

6.2.3 Backbone cabling distances

6.2.3.1 Floor distributor to building/campus distributor

The maximum backbone distance between the CD and the associated distributor in the telecommunications closet shall comply with figure 10. Installations that exceed these distance limits may be divided into areas, each of which can be supported by backbone cabling, thus satisfying the distance requirements of this clause.



NOTE These maximum distances are not applicable for all combinations of cabling media and applications. It is recommended that equipment manufacturers, applications standards, and system providers be consulted before selecting a backbone medium. See also table 2.

Figure 10 – Maximum backbone distances

The distance between the CD and FD shall not exceed 2 000 m. The distance between the BD and FD shall not exceed 500 m. The 2 000 m maximum distance from the CD to the FD may be extended when using singlemode optical fibre cabling. While it is recognized that the capabilities of singlemode fibre may allow for end-to-end distances of up to 60 km, CD to FD distances greater than 3 km are considered beyond the scope of this International Standard. Note, however, that the infrastructure shall conform to the structural requirements in clause 5.

In the BD and CD, jumper and patch cord lengths should not exceed 20 m. Lengths in excess of 20 m shall be deducted from the maximum permissible backbone cable length.

6.2.3.2 External services

External services (for example, broadcast services received by antennae) may enter a campus or building at locations remote from a distributor. The distance between these external service entry points and the distributor to which the services are connected shall be considered in determining maximum cable lengths. Regulatory policies within the jurisdiction which relate to the location of the network interface, if any, will also influence this distance. When applicable, the length and diameter of the media used shall be recorded, and should be made available to the service provider upon request.

6.2.3.3 Connections to telecommunications equipment

Cables that connect telecommunications equipment, such as a PBX, directly to a CD or BD have been assumed not to exceed 30 m in length. If longer cables are used, the backbone distances should be reduced accordingly.

7 Permanent link and channel specifications

7.1 Permanent links and channels

7.1.1 General

This clause defines the permanent link and channel performance requirements of installed generic cabling. The performance of the cabling is specified for individual permanent links and channels and for two different media types (balanced cables and optical fibre). A tutorial on the material in this clause is provided in annex F.

The design rules of clause 6 can be used to create generic cabling links and channels containing components specified in clauses 8 and 9. It is not necessary to measure every parameter specified in this clause as conformance may also be proven by suitable design. The permanent link and channel specifications in this clause allow for the transmission of defined classes of applications over distances other than those of clause 6, and/or using media and components with different transmission performances than those of clauses 8 and 9.

The permanent link and channel performance requirements specified in this clause shall be met at each interface specified for each medium.

The performance requirements described in this clause may be used as verification tests for any implementation of this International Standard, using the test methods defined, or referred to, by this clause. The permanent link requirements are primarily intended to provide a basis for the acceptance testing of installed cabling. The channel requirements are primarily for application developers but are able to be used for troubleshooting where application support is under development.

Permanent link and channel performance specifications shall be met for all temperatures at which the cabling is intended to operate. Performance testing may be carried out at ambient temperature, but there shall be adequate margins to account for temperature dependence of cabling components as per their specifications. The effects of ageing should also be taken into account. In particular, consideration should be given to measuring performance at worst case temperatures, or calculating worst case performance based on measurements made at other temperatures.

Care should be exercised in the interpretation of any results obtained from alternative test methods or practices. When needed, correlation factors should be identified and applied.

7.1.2 Permanent links

The performance of a permanent link is specified at and between interfaces to the link. The permanent link comprises only passive sections of cable and connecting hardware. A transition point may also be included in the horizontal subsystem. Active and passive application specific hardware is not addressed by this International Standard (figure 11).

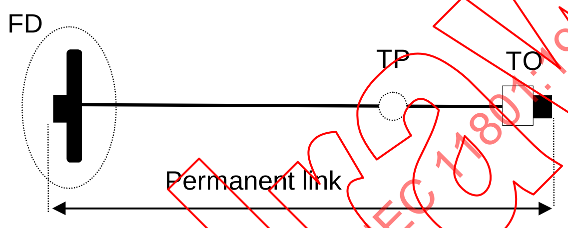


Figure 11 – Permanent link

Figure 12a shows an example of terminal equipment in the work area connected to a host using three links; two optical fibre links and a balanced cable link. The optical fibre and balanced cable links are connected together using an optical fibre to balanced cable converter, a cross-connect and two equipment cables. Interfaces to the cabling are at each end of a permanent link. Interfaces to the cabling are specified at the TO and at any point where application specific equipment is connected to the cabling; the work area and equipment cables are not included in the permanent link.

Interfaces to the cabling are at each end of a permanent link. Interfaces to the cabling are specified at the TO and at any point where application specific equipment is connected to the cabling; the work area and equipment cables are not included in the permanent link.

NOTE For balanced cabling the limits for the permanent link in this clause are calculated on the basis of 90 m of installed cable and two connections.

7.1.3 Channels

The performance of the channel is specified at and between interfaces to the channel. The cabling comprises only passive sections of cable, connecting hardware, work area cords, equipment cords and patch cords.

Figure 12b shows an example of terminal equipment in the work area connected to a host using two channels; an optical fibre channel and a balanced cabling channel. The optical fibre and balanced cabling channels are connected together using an optical fibre to balanced cable converter. There are four channel interfaces; one at each end of the copper channel, and one at each end of the optical fibre channel. Equipment connections are not considered to be part of the channel. All work area, equipment cables and patch cords are included in the channel.

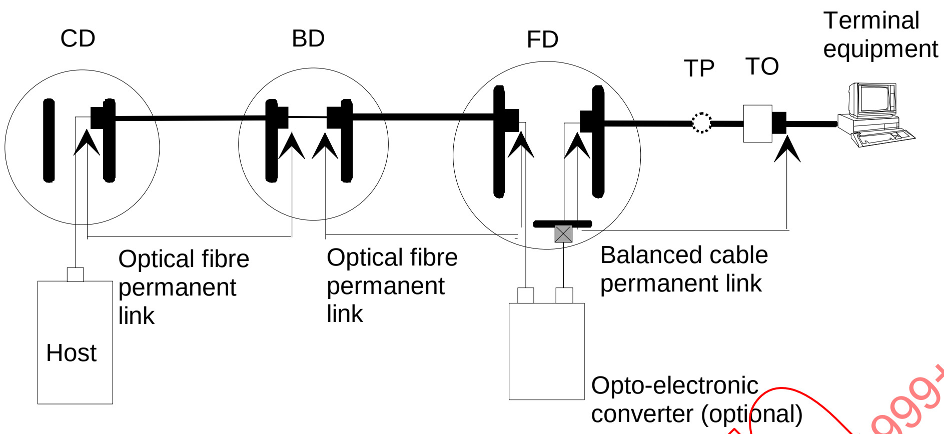


Figure 12a – Location of cabling interfaces and extent of associated permanent links

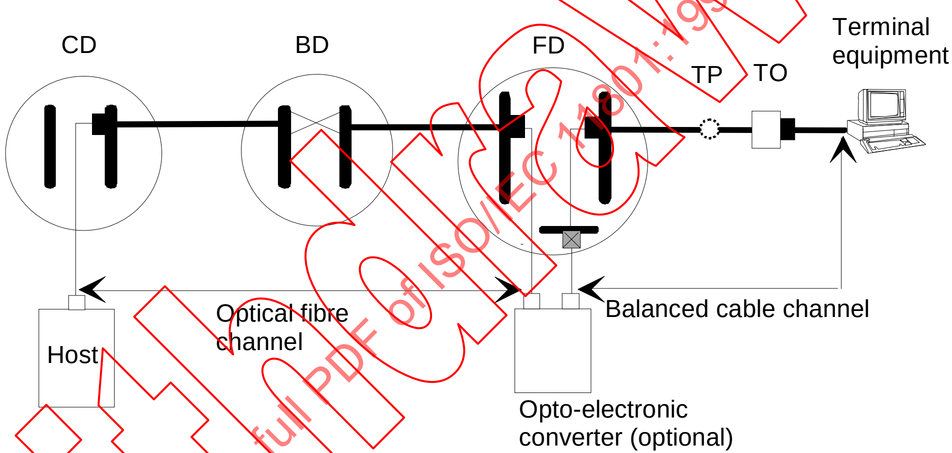
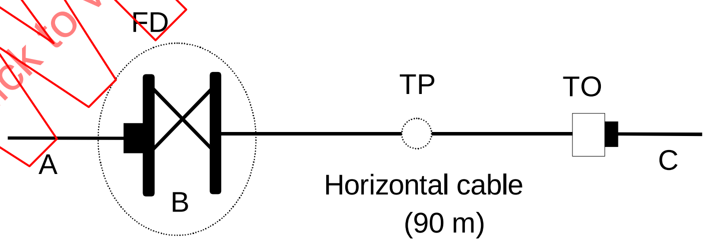


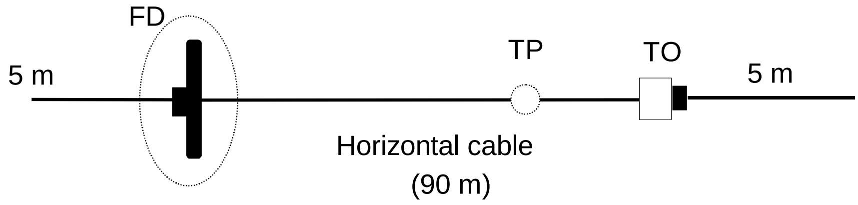
Figure 12b – Location of cabling interfaces and extent of associated channels



A + B + C = 9 m

NOTE For balanced cabling, this example assumes the use of flexible cables with 50 % greater attenuation (dB/m) than the horizontal cable, and a cross-connection in the floor distributor, thus 3 connections. In this case, the maximum length of work area, equipment, and patch cable is 9 m. A longer channel length may be achieved by using flexible cables with better attenuation performance.

Figure 12c – Class D channel implementation (with cross-connection)



NOTE For balanced cabling, this example assumes the use of flexible cables with 50 % greater attenuation (dB/m) than the horizontal cable. In this case, the maximum length of work area and equipment cables is 10 m. This example results in a calculated channel attenuation of 23,9 dB at 100 MHz using category 5 component requirements.

Figure 12d – Class D channel implementation (with interconnection)

Key

■ Interface to the generic cabling

☒ Optional interface when using a crossconnection

Figure 12 – Examples of cabling systems

7.2 Classification of applications, links and channels

7.2.1 Application classification

Five application classes for cabling have been identified for the purposes of this International Standard. This ensures that the limiting requirements of one system do not unduly restrict other systems.

The application classes are:

Class A includes speech band and low-frequency applications. Copper cabling permanent links and channels supporting* Class A applications are referred to as Class A permanent links and Class A channels respectively.

Class B includes medium bit rate data applications. Copper cabling permanent links and channels supporting* Class B applications are referred to as Class B permanent links and Class B channels respectively.

Class C includes high bit rate data applications. Copper cabling permanent links and channels supporting* Class C applications are referred to as Class C permanent links and Class C channels respectively.

Class D includes very high bit rate data applications. Copper cabling permanent links and channels supporting* Class D applications are referred to as Class D permanent links and Class D channels respectively.

Optical Class includes high and very high bit rate data applications. Optical fibre permanent links and channels supporting* Optical Class applications are referred to as Optical Class permanent links and Optical Class channels respectively.

NOTE *Permanent link specifications are provided for field test verification. Channel values provide minimum requirements for application support.

Annex G gives examples of applications that fall within the various classes.

7.2.2 Link and channel classification

Generic cabling, when configured to support particular applications, comprises one or more permanent links and channels. Five permanent link and channel classes are defined, which relate to the application classes as indicated in 7.2.1.

Permanent link/channel class A	specified up to 100 kHz
Permanent link/channel class B	specified up to 1 MHz
Permanent link/channel class C	specified up to 16 MHz
Permanent link/channel class D	specified up to 100 MHz
Optical permanent link/channel class	specified to support applications specified at 10 MHz and above.

For copper cabling, a class A to D permanent link or channel is specified so that channels will provide the minimum transmission performance to support applications of the related application class. Links and channels of a given class will support all applications of a lower class. Permanent link/channel class A is regarded as the lowest class.

Optical parameters are specified for single-mode and multimode optical fibre permanent links and channels.

Class C and D permanent links and channels correspond to full implementations of category 3 and category 5 horizontal cabling subsystems respectively, as specified in 6.1.[1)]

Table 2 relates the permanent link and channel classes to the categories of clauses 8 and 9. This table indicates the channel length over which the various applications may be supported.

The distances presented are based on NEXT loss (for copper cables), bandwidth (for optical fibre cables), and attenuation limits for various classes. Other characteristics of applications, for example propagation delay, may further limit these distances.

Table 2 – Channel lengths achievable with different categories and types of cabling

Medium	Channel length				
	Class A	**Class B**	**Class C**	**Class D**	**Optical class**
Category 3 balanced cable (8.1)	2 km	200 m	100 m [1)]	–	–
Category 4 balanced cable (8.1)	3 km	260 m	150 m [2)]	–	–
Category 5 balanced cable (8.1)	3 km	260 m	160 m [2)]	100 m [1)]	–
150 Ω balanced cable (8.2)	3 km	400 m	250 m [2)]	150 m [2)]	–
Multimode optical fibre (8.4)	N/A	N/A	N/A	N/A	2 km [3)]
Singlemode optical fibre (8.5)	N/A	N/A	N/A	N/A	3 km [4)]

1) The 100 m distance includes a 90 m length permanent link and a maximum allowance of 10 m of flexible cable for patch cords/jumpers, work area and equipment connections.

2) For distances greater than 100 m of balanced cable in the horizontal cabling subsystem, the applicable application standards should be consulted.

3) The minimum bandwidth for a 2 km multimode optical link is specified in 7.4.2. Multimode applications may be limited to distances shorter than 2 km. Consult application standards for limitations.

4) 3 km is a limit defined by the scope of the International Standard and not a medium limitation.

1) The use of link in clause 6 allows for a wider range of configurations than a permanent link in this amendment.

Consideration should be given, when specifying and designing cabling, to the possible future connection of cabling subsystems to form longer links and channels. The performance of these longer links and channels will be lower than that of any of the individual subsystem links and channels from which they are constructed. Measurement of permanent links and channels should be made initially, upon installation of each cabling subsystem. Testing of combined subsystems should be performed as required by the application.

7.3 Balanced cabling permanent links and channels

7.3.1 General

The parameters specified in this subclause apply to permanent links and channels with shielded or unshielded cable elements, with or without an overall shield, unless explicitly stated otherwise. Unless stated otherwise, outline test configurations for all measurements on balanced cabling are given in annex A. Specialised test instruments are required for high frequency field measurements on balanced cabling. The maximum application frequencies are based on required permanent link and channel characteristics, and are not indicated by the maximum specified frequency for the cabling. In the following tables, the requirements for attenuation, NEXT loss, Power Sum NEXT loss, ACR, Power Sum ACR, ELFEXT and Power Sum ELFEXT are given for discrete frequencies only. Transmission requirements shall also be met for all intermediate frequencies. Requirements at intermediate frequencies are derived by linear interpolation between frequencies on a semi-logarithmic (NEXT loss, Power Sum NEXT loss, ACR, Power Sum ACR, ELFEXT and Power Sum ELFEXT) or logarithmic (attenuation) scale.

7.3.2 Nominal impedance

The designed nominal impedance of a permanent link and channel shall be 100 Ω, 120 Ω, or 150 Ω. The nominal impedance of permanent links and channels should be achieved by suitable design, and the appropriate choice of cables and connecting hardware.

The variation of the input impedance of a permanent link and channel is characterised by the return loss. The characteristic impedance of cables used in a permanent link and channel shall be in accordance with the requirements of clause 8.

7.3.3 Return loss

The return loss of a permanent link and channel shall meet or exceed the values shown in tables 3 and 4. The return loss shall be measured according to IEC 61935-1. The return loss shall be measured from both ends to allow a correct evaluation of the permanent link or channel. Terminations that are matched to the nominal impedance of the cable (specifically 100 Ω, 120 Ω, 150 Ω) shall be connected to the cabling elements under test at the remote end of the permanent link or channel.

Table 3 – Minimum return loss for permanent link

Frequency MHz	**Minimum return loss** dB	
	Class C	**Class D**
$1 \leq f < 16$	15	17
$16 \leq f < 20$	N/A	17
$20 \leq f \leq 100$	N/A	17-7 log(f/20)

Table 4 – Minimum return loss for a channel

Frequency MHz	Minimum return loss dB	
	Class C	Class D
1 ≤ *f* < 16	15	17
16 ≤ *f* < 20	N/A	17
20 ≤ *f* ≤ 100	N/A	17-10 log(*f*/20)

7.3.4 Attenuation (insertion loss)

The attenuation of a permanent link and channel shall not exceed the values shown in tables 5 and 6 respectively, and shall be consistent with the design values of cable length and cabling materials used. The attenuation of the permanent link or channel shall be measured according to IEC 61935-1, except that the measured attenuation shall not be scaled to a standard length. Class D permanent links and channels should comprise cables, which closely follow the square root of frequency attenuation characteristic above 1 MHz.

The values in tables 5 and 6 are based on the requirements of the applications listed in annex G.

Table 5 – Maximum attenuation values for a permanent link

Frequency MHz	Maximum attenuation dB			
	Class A	Class B	Class C	Class D
0,1	16,0	5,5	N/A	N/A
1,0	N/A	5,8	3,1	2,1
4,0	N/A	N/A	5,8	4,1
10,0	N/A	N/A	9,6	6,1
16,0	N/A	N/A	12,6	7,8
20,0	N/A	N/A	N/A	8,7
31,25	N/A	N/A	N/A	11,0
62,5	N/A	N/A	N/A	16,0
100,0	N/A	N/A	N/A	20,6

Table 6 – Maximum attenuation values for a channel

Frequency MHz	Maximum attenuation dB			
	Class A	Class B	Class C	Class D
0,1	16,0	5,5	N/A	N/A
1,0	N/A	5,8	4,2	2,5
4,0	N/A	N/A	7,3	4,5
10,0	N/A	N/A	11,5	7,0
16,0	N/A	N/A	14,9	9,2
20,0	N/A	N/A	N/A	10,3
31,25	N/A	N/A	N/A	12,8
62,5	N/A	N/A	N/A	18,5
100,0	N/A	N/A	N/A	24,0

7.3.5 NEXT loss

7.3.5.1 Pair-to-pair NEXT loss

The pair-to-pair NEXT loss of a permanent link and channel shall meet or exceed the values shown in tables 7 and 8 respectively, and shall be consistent with the design values of cable length and cabling materials used. The NEXT loss shall be measured according to IEC 61935-1 except that the measured NEXT loss shall not be adjusted for length. The NEXT loss shall be measured from both ends to allow a correct evaluation of the permanent link or channel. See also A.1.1.

The values in tables 7 and 8 are based on the NEXT loss requirements of the applications listed in annex G.

Table 7 – Minimum NEXT loss for a permanent link

Frequency MHz	Minimum NEXT loss dB			
	Class A	Class B	Class C	Class D
0,1	27,0	40,0	N/A	N/A
1,0	N/A	25,0	40,1	61,2
4,0	N/A	N/A	30,7	51,8
10,0	N/A	N/A	24,3	45,5
16,0	N/A	N/A	21,0	42,3
20,0	N/A	N/A	N/A	40,7
31,25	N/A	N/A	N/A	37,6
62,5	N/A	N/A	N/A	32,7
100,0	N/A	N/A	N/A	29,3

Table 8 – Minimum NEXT loss for a channel

Frequency MHz	Minimum NEXT loss dB			
	Class A	Class B	Class C	Class D
0,1	27,0	40,0	N/A	N/A
1,0	N/A	25,0	39,1	60,3
4,0	N/A	N/A	29,3	50,6
10,0	N/A	N/A	22,7	44,0
16,0	N/A	N/A	19,3	40,6
20,0	N/A	N/A	N/A	39,0
31,25	N/A	N/A	N/A	35,7
62,5	N/A	N/A	N/A	30,6
100,0	N/A	N/A	N/A	27,1

Equipment connectors are not accounted for in table 8 and may contribute to additional crosstalk degradation.

7.3.5.2 Power Sum NEXT loss (PSNEXT)

The PSNEXT parameter is applicable to class D only. The PSNEXT of a class D permanent link and channel shall meet or exceed the values shown in tables 9 and 10 respectively. PSNEXT is computed from pair-to-pair NEXT as follows:

$$PSNEXT = -10\log\left(10^{\frac{-NEXT_{pp,1}}{10}} + 10^{\frac{-NEXT_{pp,2}}{10}} + 10^{\frac{-NEXT_{pp,3}}{10}}\right)$$

Table 9 – Minimum PSNEXT loss for a permanent link

Frequency MHz	**Minimum PSNEXT loss** dB
	Class D
1,0	58,2
4,0	48,8
10,0	42,5
16,0	39,3
20,0	37,7
31,25	34,6
62,5	29,7
100,0	26,3

Table 10 – Minimum PSNEXT loss for a channel

Frequency MHz	**Minimum PSNEXT loss** dB
	Class D
1,0	57,3
4,0	47,6
10,0	41,0
16,0	37,6
20,0	36,0
31,25	32,7
62,5	27,6
100,0	24,1

Power Sum NEXT is met if measured pair-to-pair NEXT values for each pair combination are at least 1,8 dB better than those specified in tables 7 and 8 for permanent links and channels respectively.

7.3.6 Attenuation to crosstalk loss ratio

7.3.6.1 Pair-to-pair ACR

This is the difference between the NEXT loss and the attenuation of the cabling in dB. It is related to, but distinct from, the signal to crosstalk ratio (SCR) which accommodates the transmit and receive signal levels of an application. By applying the requirements of 7.3.3, 7.3.4 and 7.3.5, the transmission requirements of the applications listed in annex G will be met. The ACR of cabling is calculated by:

$$ACR = a_N - a \quad \text{(dB)}$$

where

ACR is the attenuation to crosstalk loss ratio;

a_N is the NEXT loss, measured between any two pairs of the cabling. The NEXT loss shall be measured according to IEC 61935-1, except that the measured NEXT loss shall not be adjusted for length;

a is the attenuation of the cabling when measured according to IEC 61935-1, except that the measured attenuation shall not be scaled to a standard length.

Table 11 – Minimum ACR values for permanent link

Frequency MHz	**Minimum ACR** dB
	Class D
1,0	59,1
4,0	47,7
10,0	39,4
16,0	34,5
20,0	32,0
31,25	26,6
62,5	16,7
100,0	8,7

Table 12 – Minimum ACR values for channels

Frequency MHz	**Minimum ACR** dB
	Class D
1,0	57,8
4,0	46,1
10,0	37,0
16,0	31,4
20,0	28,7
31,25	22,9
62,5	12,1
100,0	3,1

7.3.6.2 Power Sum ACR (PSACR)

The PSACR parameter is applicable to class D only. The PSACR of a class D permanent link and channel shall meet or exceed the values shown in tables 13 and 14 respectively. The Power Sum ACR is computed from Power Sum NEXT and attenuation as follows:

$$PSACR = PSNEXT - a$$

Table 13 – Minimum PSACR values for permanent link

Frequency MHz	Minimum ACR dB Class D
1,0	56,1
4,0	44,7
10,0	36,4
16,0	31,5
20,0	29,0
31,25	23,6
62,5	13,7
100,0	5,7

Table 14 – Minimum PSACR values for channels

Frequency MHz	Minimum ACR dB Class D
1,0	54,8
4,0	43,1
10,0	34,0
16,0	28,4
20,0	25,7
31,25	19,9
62,5	9,1
100,0	0,1

7.3.7 ELFEXT

7.3.7.1 Pair-to-pair ELFEXT

The ELFEXT shall be measured from both ends to allow a correct evaluation of the permanent link or channel.

Table 15 – Minimum ELFEXT values for permanent link

Frequency MHz	Minimum ELFEXT dB Class D
1,0	59,6
4,0	47,6
10,0	39,6
16,0	35,5
20,0	33,6
31,25	29,7
62,5	23,7
100,0	19,6

Table 16 – Minimum ELFEXT values for channels

Frequency MHz	**Minimum ELFEXT** dB
	Class D
1,0	57,0
4,0	45,0
10,0	37,0
16,0	32,9
20,0	31,0
31,25	27,1
62,5	21,1
100,0	17,0

7.3.7.2 Power Sum ELFEXT

The PSELFEXT parameter is applicable to class D only. The PSELFEXT of a class D permanent link and channel shall meet or exceed the values shown in tables 17 and 18 respectively. PSELFEXT is computed from pair-to-pair ELFEXT as follows:

$$PSELFEXT = -10\log\left(10^{\frac{-ELFEXT_{pp,1}}{10}} + 10^{\frac{-ELFEXT_{pp,2}}{10}} + 10^{\frac{-ELFEXT_{pp,3}}{10}}\right)$$

Table 17 – Minimum Power Sum ELFEXT values for permanent link

Frequency MHz	**Minimum PSELFEXT** dB
	Class D
1,0	57,0
4,0	45,0
10,0	37,0
16,0	32,9
20,0	31,0
31,25	27,1
62,5	21,1
100,0	17,0

Table 18 – Minimum Power Sum ELFEXT values for channels

Frequency MHz	Minimum PSELFEXT dB Class D
1,0	54,4
4,0	42,4
10,0	34,4
16,0	30,3
20,0	28,4
31,25	24,5
62,5	18,5
100,0	14,4

Power Sum ELFEXT is met if measured pair-to-pair ELFEXT values for each pair combination are at least 2,2 dB better than those specified in tables 15 and 16 for permanent links and channels respectively.

7.3.8 DC loop resistance

The loop resistance of pairs shall be less than the values given in table 19 for each class of application. These figures are derived from application requirements. The d.c. loop resistance shall be measured according to IEC 61935-1. A short circuit is applied at the remote end of the pair and the loop resistance is measured at the near end. The measured value should be consistent with the length and diameter of the conductors used in the cable.

Table 19 – Maximum d.c. loop resistance

Cabling class	Class A	Class B	Class C	Class D
Maximum loop resistance Ω	560	170	40	40

7.3.9 Propagation delay

The propagation delay, measured according to IEC 61935-1, shall be less than the limits given in tables 20 and 21. These limits are derived from system requirements. Any measured or calculated values should be consistent with the lengths and materials used in the cabling.

Table 20 – Maximum propagation delay for permanent link

Measurement frequency MHz	Class	Delay µs
$1 \leq f \leq 16$	C	$0,486 + 0,036/\sqrt{f}$
$1 \leq f \leq 100$	D	$0,486 + 0,036/\sqrt{f}$

Table 21 – Maximum propagation delay for a channel

Measurement frequency MHz	Class	Delay µs
$1 \leq f \leq 16$	C	$0{,}544 + 0{,}036/\sqrt{f}$
$1 \leq f \leq 100$	D	$0{,}544 + 0{,}036/\sqrt{f}$

The class C and D channel delay requirements ensure that the delay requirements of the applications listed in annex G are fulfilled.

7.3.10 Delay skew

The difference in propagation delay between any two pairs in a cabling channel shall be less than the limits given in tables 22 and 23.

Table 22 – Maximum delay skew for permanent link

Measurement frequency MHz	Class	Delay skew µs
$1 \leq f \leq 16$	C	0,043
$1 \leq f \leq 100$	D	0,043

Table 23 – Maximum delay skew for a channel

Measurement frequency MHz	Class	Delay skew µs
$1 \leq f \leq 16$	C	0,050
$1 \leq f \leq 100$	D	0,050

7.3.11 Longitudinal to differential conversion loss (balance)

The longitudinal conversion loss, measured as LCL and as LCTL according to ITU-T Recommendation G.117, should exceed the values shown in table 24.

Table 24 – Longitudinal to differential conversion loss

Frequency MHz	Minimum longitudinal to differential conversion loss dB			
	Class A	Class B	Class C	Class D
0,1	30	45	45	45
1,0	N/A	20	30	40
4,0	N/A	N/A	f.f.s.	f.f.s.
10,0	N/A	N/A	25	30
16,0	N/A	N/A	f.f.s.	f.f.s.
20,0	N/A	N/A	N/A	f.f.s.
100,0	N/A	N/A	N/A	f.f.s.

The measurement of these values on installed systems is not yet well established. It is sufficient to verify the values by design.

7.3.12 Transfer impedance of shield

This parameter applies to shielded cabling only. The measurement of transfer impedance for installed cabling is not well developed. Connector termination practices may be verified by laboratory measurements of representative samples of short lengths of terminated cable. The transfer impedance requirements for shielded cables and connectors in clauses 8 and 9 should be applied. See clause 10 for guidance on the use of shielded cabling.

7.4 Optical fibre permanent links/channels

7.4.1 General

The performance requirements for optical fibre permanent links/channels assume that each optical fibre permanent link/channel employs a single optical wavelength in one transmission window only. Application standards employing wavelength multiplexing are not yet available for listing in annex G. All application specific hardware for wavelength multiplexing is installed in the equipment area and in the work area, which both are outside the scope of this International Standard. The requirements for the wavelength multiplexing and demultiplexing components will be found in the application standards. There are no special requirements for generic cabling concerning wavelength multiplexing.

The performance requirements of single-mode and multimode optical fibre permanent links/ channels are considered in this subclause.

Unless otherwise stated, test procedures are described in IEC 61280-4.

7.4.2 Optical attenuation

The maximum attenuation (insertion loss) shall not exceed the values specified in table 25 in the wavelength windows specified in tables 26 and 27. The allowable attenuation of optical fibre permanent links/channels is application dependent. Consult the application standards for limitations.

The attenuation values given in table 25 have been calculated for optical fibre permanent links/channels in each cabling subsystem, assuming a worst case installation philosophy of a connector and a splice at each end of each subsystem.

Table 25 – Attenuation of optical fibre cabling subsystems

Cabling subsystem	Link/channel length [1)] m	Attenuation dB			
		Singlemode		Multimode	
		1 310 nm	1 550 nm	850 nm	1 300 nm
Horizontal	100	2,2	2,2	2,5	2,2
Building backbone	500	2,7	2,7	3,9	2,6
Campus backbone	1 500	3,6	3,6	7,4	3,6

[1)] The link/channel lengths and attenuation values given here are achievable using optical fibre components meeting the minimum requirements of 8.4, 8.5 and 9.4.
Different link lengths could be achieved if other optical fibre components were used.

Table 26 – Wavelength windows for multimode optical fibre cabling

Nominal wavelength nm	Lower limit nm	Upper limit nm	Reference test wavelength nm	Maximum spectral width FWHM nm
850	790	910	850	50
1 300	1 285	1 330	1 300	150

Table 27 – Wavelength windows for singlemode optical fibre cabling

Nominal wavelength nm	Lower limit nm	Upper limit nm	Reference test wavelength nm	Maximum spectral width FWHM nm
1 310	1 288	1 339	1 310	10
1 550	1 525	1 575	1 550	10

7.4.3 Multimode modal bandwidth

For multimode optical fibre permanent links/channels the optical modal bandwidth shall exceed the minimum values shown in table 28.

Table 28 – Minimum optical modal bandwidth

Wavelength nm	Minimum bandwidth MHz
850	100
1 300	250

The dispersion of the optical fibre used in the optical link/channel shall be measured in accordance with the test methods described in IEC 60793-1. See table 2 for achievable distances.

7.4.4 Return loss

The optical return loss of any interface of an optical link/channel shall exceed the values shown in table 29.

Table 29 – Minimum optical return loss

Multimode		Singlemode	
850 nm	1 300 nm	1 310 nm	1 550 nm
20 dB	20 dB	26 dB	26 dB

7.4.5 Propagation delay

For some applications, knowledge of the delay of optical fibre permanent links/channels is important to ensure compliance with end-to-end delay requirements of complex networks consisting of multiple cascaded links/channels. For this reason, it is important to know the lengths of optical fibre permanent links/channels. It is possible to calculate propagation delay based on cable performance (see clause 8).

8 Cable requirements

This clause provides the requirements for the cable for the horizontal and backbone cabling subsystems. For additional requirements regarding flexible balanced cables, see annex C.

All cables shall meet the applicable safety requirements as specified by the relevant local authorities. This clause provides essential mechanical and transmission characteristics for each medium. Due to inherent limitations of some telecommunications services, the use of cables described below to support applications other than those listed in annex G may not always result in acceptable service performance. The user is advised to consult standards associated with the planned service or equipment in order to determine any specific limitation.

In the following tables, the requirements for attenuation and NEXT loss are given for discrete frequencies only. They have to be fulfilled, however, for all intermediate frequencies. Requirements at intermediate frequencies are derived by linear interpolation between two specified frequencies on a semi-logarithmic (NEXT loss) or logarithmic (attenuation) scale. Requirements for Power Sum NEXT loss, ELFEXT, and Power Sum ELFEXT are under study.

For multimode and single mode fibre, a conservative conversion value for unit propagation delay of 5,00 ns/m (0,667 c) may be used. This value can be used to calculate channel delay without verification.

The requirements of this clause are provided for the cable as measured by the manufacturer. It is assumed that these characteristics do not change significantly for cables installed according to manufacturer's instructions and operating at 20 °C.

8.1 General requirements for 100 Ω and 120 Ω balanced cable

The mechanical and electrical requirements given in table 30 and table 31 shall be met by both 100 Ω and 120 Ω cables. For additional electrical requirements, see 8.1.1 (100 Ω) and 8.1.2 (120 Ω).

Table 30 – Mechanical characteristics of 100 Ω and 120 Ω balanced cables

Cable characteristics		Units	Subsystem		Test method
1	Mechanical characteristics		Backbone	Horizontal	Subclause
1.1	Diameter of conductor [1)]	mm	0,4 to 0,65		3.4.1 of IEC 61156-1
1.2	Diameter over insulated conductor [2)]	mm	≤1,4		3.4.1 of IEC 61156-1
1.3	Number of conductors in a cable element	per pair/per quad	2/4		
1.4	Shield around cable element [3)]		Optional. Refer to clause 10		
1.5	Number of cable	Pairs	≥4	$2n$ (n = 1, 2, 3, ...)	
	Elements in a unit [4)]	Quads	≥2	n (n = 1, 2, 3, ...)	
1.6	Shield around cable unit [3)]		Optional		
1.7	Number of cable units in a cable		≥1[4)]		
1.8	Shield around cable [3)]		Optional. Refer to clause 9		
1.9	Outer diameter of cable [5)]	mm	≤90	≤20	3.4.1 of IEC 61156-1
1.10	Temperature range without mechanical degradation [6)]	°C	Installation: 0 to +50 Operation: –20 to +60		f.f.s.
1.11	Minimum bending radius for pulling during installation		8 times outer cable diameter		3.4.8 of IEC 61156-1

	Cable characteristics	Units	Subsystem	Test method	
1.12	Minimum bending radius installed		6 (f.f.s.) times outer cable diameter	4 (f.f.s.) times outer cable diameter	f.f.s.
1.13	Pulling strength 7)	N/mm^2 × Cu_{min}	≥50		3.4.9 of IEC 61156-1
1.14	Fire rating		According to IEC 61156 unless otherwise requested by local regulation		As applicable
1.15	Colour coding 8)		As required by local regulations preferably IEC 60708-1		
1.16	Cable marking		As required by local regulations or national specifications		

1) Conductor diameters below 0,5 mm may not be compatible with all connecting hardware.
The two measured values using the IEC method must be averaged and then compared to the limit for compliance verification.

2) Diameters over the insulated conductor up to 1,6 mm may be used if they meet all other performance requirements. These cables may not be compatible with all connecting hardware.

3) If it is intended to use cables with shielding, care shall be taken that the connecting hardware is properly designed to terminate the shielding.

4) Care has to be taken to meet the NEXT loss requirements given in 8.3.

5) Should be minimised to make best use of duct and crossconnect capacity (see clause 9).
In case of under carpet cable the value is not applicable.

6) For certain applications (e.g. precabling buildings in cold climate) a cable with a lower temperature bending performance of –30 °C may be required.

7) This is an indication for cable performance, installation needs are for further study. This results in a maximum pulling force of 50 N/mm^2 times copper conductor cross-section, excluding shields, if present.

8) For cables with fewer cable elements than those specified by IEC 60708, pair colours should be consistent with all pairs or quads specified starting from 1 up to the number of elements in the cable.

The following electrical characteristics are given for 20 °C. They may degrade with changing temperature. Some commonly used insulation materials may result in a non-linearly dependence of electrical characteristics on temperature. Thus, especially for temperatures above 40 °C, special insulation materials may be necessary.

Table 31 – Electrical characteristics of 100 Ω and 120 Ω balanced cables

Cable characteristics				Cable category 3)			Test method 3)
2	Electrical characteristics at 20 °C	Units	MHz	3	4	5	
2.1	Maximum d.c. loop resistance	Ω/100 m	d.c.	19,2 1)	19,2 1)	19,2 1)	3.2.1 of IEC 61156-1
2.2	Nominal phase velocity of propagation		1 10 100	0,4 c 0,6 c N/A	0,6 c 0,6 c N/A	0,65 c 0,65 c 0,65 c	3.3.1 of IEC 61156-1
2.3	Minimum NEXT loss 2)	dB at 100 m cable length	0,772	43	58	64	3.3.4 of IEC 61156-1
			1	41	56	62	
			4	32	47	53	
			10	26	41	47	
			16	23	38	44	
			20	N/A	36	42	
			31,25	N/A	N/A	40	
			62,5	N/A	N/A	35	
			100	N/A	N/A	32	
2.4	Maximum resistance unbalance	%	d.c.	3	3	3	3.2.2 of IEC 61156-1

Cable characteristics				Cable category [3]			Test method [3]
2.5	Minimum longitudinal conversion loss	dB	0,064	45 (f.f.s.)	45 (f.f.s.)	45 (f.f.s.)	ITU-T O.9
2.6	Maximum capacitance unbalance pair to ground	pF/km	0,0008 or 0,001	3 400	3 400	3 400	3.2.6 of IEC 61156-1
2.7	Maximum transfer	mΩ/m	1	50	50	50	3.2.7 of IEC 61156-1
	Impedance		10	100	100	100	
	(only applicable when shields are present)		100	N/A	N/A	f.f.s.	
2.8	Minimum d.c. insulation resistance	MΩ km	d.c.	150	150	150	3.2.4 of IEC 61156-1
2.9	Dielectric strength conductor/conductor and conductor/shield		d.c. or	1 kV, 1 min or 2,5 kV, 2 s			3.2.3 of IEC 61156-1
			a.c.	700 V, 1 min or 1,7 kV, 2 s			
2.10	Minimum structural return loss	dB at 100 m cable length	1 to <10	12 (f.f.s.)	21 (f.f.s.)	23 (f.f.s.)	
			10 to <16	10 (f.f.s.)	19 (f.f.s.)	23 (f.f.s.)	IEC 61156-1
			16 to <20	N/A	18 (f.f.s.)	23 (f.f.s.)	f.f.s.
			20 to 100	N/A	N/A	23-10log (*f*/20) (f.f.s.)	
2.11	Delay skew	ns/100 m	1 to <16	45	45	45	IEC 61935-1
			16 to <20		45	45	
			20 to 100			45	

[1] If all other values are fulfilled, the maximum d.c. loop resistance may be as high as 30 Ω /100 m.

[2] Unless otherwise specified, cable NEXT loss performance shall be characterised using "worst case pair combination" testing. See 8.3 for additional NEXT loss requirements for balanced cables.

[3] The test method shall be as stated in the column "Test method" while the required value shall meet the values stated in the column "Cable category".

8.1.1 Additional requirements for 100 Ω balanced cable

This subclause covers the characteristic impedance and maximum attenuation of 100 Ω cables.

Table 32 – Additional electrical characteristics of 100 Ω balanced cables

Cable characteristics				Cable category			Test method
3	Electrical characteristics at 20 °C	Units	MHz	3	4	5	
3.1	Characteristic impedance	Ω	0,1	75 to 150	75 to 150	75 to 150	IEC 61156-1
			≥1	100 ± 15	100 ± 15	100 ± 15	(U.C.)
3.2	Maximum attenuation	dB/	0,064	0,9	0,8	0,8	3.3.2 of IEC 61156-1
		100 m	0,256	1,3	1,1	1,1	
			0,512	1,8	1,5	1,5	
			0,772	2,2	1,9	1,8	
			1	2,6	2,1	2,1	
			4	5,6	4,3	4,3	
			10	9,8	7,2	6,6	
			16	13,1	8,9	8,2	
			20	N/A	10,2	9,2	
			31,25	N/A	N/A	11,8	
			62,5	N/A	N/A	17,1	
			100	N/A	N/A	22,0	

8.1.2 Additional requirements for 120 Ω balanced cable

This subclause covers the characteristic impedance and maximum attenuation of 120 Ω cables.

Table 33 – Additional electrical characteristics of 120 Ω balanced cables

Cable characteristics				Cable category		Test method
3	Electrical characteristics at 20 °C	Units	MHz	4	5	
3.1	Characteristic Impedance	Ω	0,1	75 to 150	75 to 150	IEC 61156-1
			≥1	120 ± 15	120 ± 15	
3.2	Maximum attenuation	dB/ 100 m	0,064	0,8	0,8	3.3.2 of IEC 61156-1
			0,256	1,1	1,1	
			0,512	1,5	1,5	
			0,772	1,7	1,5	
			1	2,0	1,8	
			4	4,0	3,6	
			10	6,7	5,2	
			16	8,1	6,2	
			20	9,2	7,0	
			31,25	N/A	8,8	
			62,5	N/A	12,5	
			100	N/A	17,0	

8.2 General requirements for 150 Ω balanced cable

This subclause covers the requirements for 150 Ω balanced cables. Table 34 gives the mechanical requirements, and table 35 the electrical requirements for 150 Ω balanced cables.

Table 34 – Mechanical characteristics of 150 Ω balanced cables

Cable characteristics		Units	Requirement	Test method
1	Mechanical characteristics			
1.1	Diameter of conductor [1)]	mm	0,6 – 0,66	3.4.1 of IEC 61156-1
1.2	Diameter over insulated conductor [2)]	mm	≤2,6	3.4.1 of IEC 61156-1
1.3	Number of conductors in a cable element	per pair/ per quad	2/4	
1.4	Shield around cable element		Optional. Refer to clause 10	
1.5	Number of cable elements in a unit	pairs:	2	
		quads:	1	
1.6	Shield around cable unit		Yes, but optional, if 1.4 is fulfilled. Refer to clause 10	
1.7	Number of cable units in a cable		≥1	
1.8	Shield around cable		Optional. Refer to clause 10	
1.9	Outer diameter of cable [3)]	mm	≤11	3.4.1 of IEC 61156-1
1.10	Temperature range without mechanical degradation	°C	Installation: 0 to + 50	f.f.s.
			Operation: –20 to + 60	f.f.s.
1.11	Minimum bending radius for pulling during installation	cm	7,5	3.4.9 of IEC 61156-1

Cable characteristics		Units	Requirement	Test method
1.12	Minimum bending radius installed		f.f.s.	f.f.s.
1.13	One time bend radius	mm	20	
1.14	Pulling strength 4)	N/mm^2 × Cu_{min}	≥50	3.4.8 of IEC 61156-1
1.15	Fire rating		According to IEC 61156-1 unless otherwise requested by local regulation	As applicable
1.16	Colour coding		Preferably IEC 60708 or pair 1: red/green pair 2: orange/black	
1.17	Cable marking		As required by local rules or national specifications	

1) The two measured values using the IEC method must be averaged and then compared to the limit for compliance verification.

2) Values above 1,6 mm may not be compatible with all connecting hardware.

3) Only for cables with one cable unit.

4) This is an indication for cable performance, installation needs are for further study. This results in a maximum pulling force of 50 N/mm^2 times copper conductor cross-section, excluding shields, if present.

Table 35 – Electrical characteristics of 150 Ω balanced cables

Cable characteristics				Requirement	Test method
2	Electrical characteristics at 20 °C	Units	MHz		
2.1	Characteristic impedance	Ω	≥1	150 ± 15	IEC 61156-1
2.2	Maximum d.c.-loop resistance	Ω/100 m	d.c.	12,0	3.2.1 of IEC 61156-1
2.3	Maximum attenuation 1)	dB/100 m	1	1,1	3.3.2 of IEC 61156-1
			4	2,2	
			10	3,6	
			16	4,4	
			20	4,9	
			31,25	6,9	
			62,50	9,8	
			100	12,3	
2.4	Minimum phase velocity of propagation	m/s	1-100	0,6 c	3.3.1 of IEC 61156-1
2.5	Minimum NEXT loss	dB at 100 m cable length	1	68	3.3.4 of IEC 61156-1
			4	58	
			10	53	
			16	50	
			20	49	
			31,25	46	
			62,50	41	
			100	38	
2.6	Maximum resistance unbalance	%	d.c.	4	3.2.2 of IEC 61156-1 2)
2.7	Minimum longitudinal conversion loss	dB	0,064	f.f.s.	ITU-T 0.9
2.8	Maximum capacitance unbalance pair to ground	pF/100 m	0,001	100	3.2.6 of IEC 61156-1
2.9	Maximum transfer impedance	mΩ/m	1	50	3.2.7 of IEC 61156-1
			10	100	

Cable characteristics				Requirement	Test method
2.10	Minimum d.c. insulation resistance	GΩ km	d.c.	1	3.2.4 of IEC 61156-1
2.11	Dielectric strength		d.c. or	1 kV, 1 min or 2,5 kV, 2 s	3.2.3 of IEC 61156-1
			a.c.	700 V, 1 min or 1,7 kV, 2 s	
2.12	Minimum structural return loss	dB at 100 m cable length	3 to <20	24 (f.f.s.)	f.f.s.
			20 to 100	24-10 log (*f*/20) (f.f.s.)	
2.13	Delay skew	ns/100 m	1 to 100	45	

1) The attenuation variation with temperature follows the curve described by the equation $\alpha = 0{,}03 \times (T\text{-}23) \times \sqrt{f}$ in dB, where T is the temperature in °C and f is the frequency in MHz for f in the range of 4 MHz to 100 MHz (f.f.s.).

2) The test method shall be as stated in the IEC reference while the required value shall meet the values stated above.

8.3 Additional crosstalk considerations for balanced cables

This subclause covers cabling system implementations that may lead to the presence of multiple signals on the same cable.

In the backbone cabling subsystem, cables that contain more than two pairs or one quad shall meet the requirements of 8.3.1.

In the horizontal cabling subsystem, when multiple telecommunications outlets are 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 8.3.2. The requirements of 8.3.2 also apply between units of hybrid and multi-unit cables used in either the horizontal or backbone subsystems.

8.3.1 Power summation

Examples of the types of cables covered by this clause include cables with two or more elements within a cable unit that are used for backbone subsystems. Cables required to meet this clause shall also meet the transmission and colour-code requirements for the corresponding cable type given in 8.1 and 8.2.

For cables required to meet this clause, worst pair NEXT loss performance values specified in 8.1 or 8.2 shall be met using power summation to determine total crosstalk energy. The power sum crosstalk for uncorrelated disturbing pairs is calculated from the individual pair-to-pair crosstalk measurements at a given frequency.

8.3.2 Hybrid and multi-unit cables and cables connected to multiple TOs

Examples of the types of cables that are covered by this clause include hybrid cables and multi-unit cables and cables that are connected to multiple TOs through a transition point or other means. The units may be of the same type or of different types, and of the same category or of different categories. Cables required to meet this clause shall also meet the transmission and colour-code requirements for the corresponding cable type given in 8.1 and 8.2.

For cables required to meet this clause, NEXT loss between any balanced cable unit or element shall be at least better by ΔNEXT loss than the specified NEXT loss of 8.1 (same category) or 8.2, where

$$\Delta NEXT = 6\,\text{dB} + 10 \times \log(n+1)\,\text{dB},$$

where n is the number of adjacent non-fibre units within the cable.

NOTE The above equation is intended to minimize potential for sheath sharing incompatibilities. In that case, a maximum power budget between maximum power of the different supported applications of 6 dB is taken into account. Cables that meet the power summation requirement for NEXT loss may not support services with different schemes. The use of different applications, supported by metallic cabling, with a maximum power budget exceeding 6 dB is not assured within a common sheath.

8.4 Multimode optical fibre cables

The three parts to the requirement for optical fibre cables are the optical fibre requirements, the cable transmission performance requirements and the physical cable requirements.

a) Optical fibre requirements

The fibre shall be multimode, graded-index optical fibre waveguide with nominal 62,5/125 µm or 50/125 µm core/cladding diameter complying with A1b or A1a fibre respectively of IEC 60793-2.

b) Cable transmission performance requirements

Each fibre in the cable shall meet the graded performance requirements of table 36. Attenuation shall be measured in accordance with IEC 60793-1. Modal bandwidth-distance product shall be measured in accordance with IEC 60793-1.

c) Physical cable requirements

The mechanical and environmental requirements for indoor and outdoor fibre optic cable are defined in accordance with IEC 60794-1 and IEC 60794-2.

Table 36 – Cable transmission performance parameters

Wavelength µm	**Maximum attenuation** dB/km at 20 °C	**Minimum modal bandwidth** MHz·km at 20 °C
0,85	3,5	200 1)
1,3	1,0	500
1) When using fibre with a modal bandwidth of 160 MHz·km the minimum requirements of table 13 in clause 7 can only be met for links up to 1,6 km.		

8.5 Singlemode optical fibre cables

The three parts to the requirement for optical fibre cable are the optical fibre requirements, the cable transmission performance and the physical cable requirements.

a) Optical fibre requirements

the fibre shall comply with IEC 60793-2 type B1 and ITU-T G.652.

b) Cable transmission performance requirement:

1) Attenuation:

each fibre in the cable shall have an attenuation of less than 1 dB/km at wavelength of 1 310 nm and 1 550 nm. Attenuation shall be measured in accordance with IEC 60793-1.

2) Cut-off wavelength:

the cut-off wavelength of cabled singlemode fibre shall be <1 280 nm when measured in accordance with IEC 60793-1.

c) Physical cable requirements:

the mechanical and environmental requirements for indoor and outdoor fibre optic cable are defined in accordance with IEC 60794-2 and IEC 60794-1.

9 Connecting hardware requirements

9.1 General requirements

This clause provides guidelines and requirements for connecting hardware used with generic cabling. For the purposes of this clause, a connector (sometimes referred to as a connection) is considered to consist of a device or a combination of devices used to connect two cables or cable elements. Unless otherwise specified, all connectors shall be tested in a mated state. It should be noted that this clause does not address requirements for media adapters, or other devices with passive or active electronic circuitry (for example, impedance matching transformers, terminating resistors, LAN equipment, filters and protection devices) whose main purpose is to serve a specific application, or to provide compliance with other rules and regulations. When required, such devices are not considered to be part of the cabling, and may have significant detrimental effects on network performance. Therefore, it is important that their compatibility with the cabling system and active equipment be considered before use. These requirements apply only to individual connectors and connector assemblies which include, but are not limited to, telecommunications outlets, patch panels, transition connectors, and cross-connect blocks. Transmission characterisation of these components does not include the effects of cross-connect jumpers or patch cables.

In the following tables, requirements for attenuation and NEXT loss are given for discrete frequencies only. Requirements at intermediate frequencies shall be derived by linear interpolation between two specified frequencies on a semi-logarithmic (NEXT loss) or logarithmic (attenuation) scale.

NOTE 1 It is intended to supplement the performance and functional requirements in this clause by reference to International Standards as they become available. Since the sectional specifications referenced herein only guarantee mechanical compatibility, the transmission specifications of this clause are needed until detailed specifications are available.

NOTE 2 The requirements of this clause are provided for connecting hardware as measured by the manufacturer. It is assumed that these characteristics do not change significantly for connecting hardware installed according to the manufacturer's instructions and operating at 20 °C. Unless otherwise specified, the measuring atmosphere should be room climate in accordance with 5.3.1 of IEC 60068-1.

9.1.1 Location

Connecting hardware is installed:

a) in a CD permitting connections to Building Backbone and Campus Backbone cabling and active equipment;

b) in a BD permitting connections to the Building Backbone cabling and active equipment;

c) in an FD providing the cross-connections between backbone and horizontal cabling and permitting connections to active equipment;

d) at the horizontal cabling transition point (if provided);

e) at the TO.

9.1.2 Design

The connecting hardware should be designed to provide:

a) means to interconnect cabling with cross-connect jumpers, patching or applications dependent equipment;

b) means to identify cabling for installation and administration as described in clause 11;

c) means to permit orderly cable management;

d) means of access to monitor or test cabling and active equipment;

e) reasonable protection against physical damage and ingress of contaminants that may affect continuity;

f) a termination density that is space efficient, but that also provides ease of cable management and ongoing administration of the cabling system;

g) means to accommodate shielding and bonding requirements, when applicable.

When connections of the same mechanical type used at the TO are used at the CD, BD or FD, they shall meet the same requirements as those specified for the TO connector.

9.1.3 Operating environment

The connecting hardware shall be designed to operate reliably for temperatures ranging from –10 °C to 60 °C. Connecting hardware shall be protected from physical damage and from direct exposure to moisture and other corrosive elements. This protection may be accomplished by installation indoors or in an appropriate enclosure for the environment.

9.1.4 Mounting

Connecting hardware should be designed to provide flexibility for mounting (for example, on walls, in walls, in racks, or on other types of distribution frames and mounting fixtures).

9.1.5 Cross-connect jumpers and patch cords

General limitations for total lengths of cross-connect jumpers, patch cords and cables used to connect application specific equipment are provided in clause 6.

Cables used for cross-connect jumpers and patch cords in the CD, BD and FD are subject to the performance requirements in 9.4.6 and annex C. Compatibility between cables used in the same link shall be maintained throughout the cabling system. (For example, connections between cables with different nominal characteristic impedance values shall not be made.)

9.1.6 Installation practices

The manner and care with which the cabling is implemented are a significant factor in the performance and ease of administration of installed cabling systems. Installation and cable management precautions that should be observed 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 shield effectiveness (where shielded cabling is used) by proper cable preparation, termination practices (in accordance with manufacturer's guidelines) and well organised cable management;

b) room for mounting telecommunications equipment associated with the cabling system. Racks should have adequate clearances for access and cable dressing space.

In cabling pathways and in the vicinity of connecting hardware, the cable shall meet the bend radius requirement of clause 8.

NOTE 1 Pathways should be designed and installed to accommodate the cable bend radius requirements in clause 8.

NOTE 2 Some connections are used to perform a cross-over function between two elements in order to properly configure cabling links for transmit and receive connections.

NOTE 3 Besides signal degradation, improper termination practices of balanced cable elements, shields or both may also create loop antenna effects resulting in levels of signal radiation that may exceed regulatory requirements.

9.1.7 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 (for example, different performance categories, 100 Ω and 120 Ω balanced cables, or 62,5 µm and 50 µm optical fibres), they shall be marked in such a way as to allow each cabling type to be clearly identified. See clause 11.

9.2 Connecting hardware for 100 Ω and 120 Ω cabling

9.2.1 General requirements

The following requirements apply to all connecting hardware used to provide electrical connections for the balanced cables specified in 8.1 (100 Ω and 120 Ω cables). It is desirable that hardware used to directly terminate 100 Ω and 120 Ω cable elements be of the insulation displacement connection (IDC) type. In addition to the requirements of this subclause, connecting hardware used with shielded cabling shall be in full compliance with the applicable requirements of clause 10.

9.2.2 Performance marking

Connecting hardware intended for use with 100 Ω or 120 Ω cabling should be marked to designate transmission performance at the discretion of the manufacturer. The markings, if any, shall be visible during installation.

NOTE Performance markings are in addition to, and do not replace, other markings specified in 9.1.7, clause 11, or those required by local codes or regulations.

9.2.3 Mechanical characteristics

Connecting hardware intended for use with 100 Ω or 120 Ω cabling shall meet the requirements specified in table 37.

Table 37 – Mechanical characteristics of connecting hardware intended for use with 100 Ω or 120 Ω cabling

1	Mechanical characteristics		Units	Requirement	Component or test standard
1.1	Physical dimensions only at TO interface	Unshielded		3 and 5 of IEC 60603-7, mating dimensions and gauging	IEC 60603-7[1]
		Shielded			IEC 60603-7[1, 2]
1.2	Cable termination compatibility				
1.2.1	Nominal conductor diameter		mm	0,5 – 0,65 [3]	–
1.2.2	Conductor type	Patching/ Jumpers		Stranded or solid conductors	–
		Other		Solid conductors	
1.2.3	Nominal diameter of insulated conductor		mm	0,7 – 1,4 [4, 5]	8.3 of IEC 60811-1-1
1.2.4	Number of conductors	TO		8	–
		Other		≥2n (n = 1,2,3,...)	
1.2.5	Cable outer diameter	TO	mm	≤20[6]	8.3 of IEC 60811-1-1
		Other		N/A	
1.2.6	Means to connect shield			See table 38, row 2.3 [7]	–
1.3	Mechanical operation (Durability)				
1.3.1	Conductor termination		cycles	≥200 [8]	Annex B
1.3.2	Plug interface		cycles	≥750 (Level A of IEC 60603-7)	6 and 7 of IEC 60603-7

1) The scope of IEC 60603-7:1990 is limited to frequencies of up to 3 MHz. Until IEC 60603-7 is revised, connectors may be qualified for use at higher frequencies when tested and proved to be in compliance with the performance requirements specified in table 38.

2) IEC 60603-7:1990 does not have provision for an overall shield.

3) Because it is not required that connecting hardware be compatible with cables outside this range, special care shall be taken to ensure compatibility between cables with conductor diameters as low as 0,4 mm (when used) and the connecting hardware with which they are used.

4) Use of the modular plug connector specified in IEC 60603-7 is typically limited to cables having insulated conductor diameters in the range of 0,8 mm to 1,0 mm.

5) Because it is not required for connecting hardware to be compatible with cables outside this range, special care shall be taken to ensure compatibility between cables with insulated conductor diameters as high as 1,6 mm (when used) and the connecting hardware they are used with.

6) Use of the modular plug connector specified in IEC 60603-7 is typically limited to cables having outside diameters in the range of 4 mm to 6 mm. Flat/oval cables with equivalent cross-sectional area are acceptable.

7) If it is intended to use shielded cabling, care should be taken that the cross-connect is designed to terminate the shielding.

Note that there may be a difference between cross-connects designed to terminate balanced cables with overall shields only, as opposed to cables having both individually shielded elements and an overall shield.

8) The durability requirement of 1.3.1 is only applicable to connections designed for more than a single termination operation (for example, those that are used to administer cabling system changes).

9.2.4 Electrical characteristics

Connecting hardware intended for use with 100 Ω or 120 Ω cabling of a given category shall meet the corresponding performance requirements of table 38.

Connecting hardware shall be tested with each cable impedance that it is intended to support.

Table 38 – Electrical characteristics of connecting hardware intended for use with 100 Ω or 120 Ω cabling

2	**Electrical characteristics at 20 °C**		**Units**	**Frequency** MHz	**Requirements**			**Component or test standard**
2.1	Contact reliability	TO			Clause 7 of IEC 60603-7			IEC 60603-7
		Other			Annex B			Annex B
2.2	Transmission performance				Connector category			
					3	4	5	
2.2.1	Maximum attenuation [1]		dB	1	0,4 [2]	0,1	0,1	Annex A, A.2.3.1
				4,0	0,4 [2]	0,1	0,1	
				10,0	0,4 [2]	0,1	0,1	
				16,0	0,4 [2]	0,2	0,2	
				20,0	–	0,2	0,2	
				31,25	–	–	0,2	
				62,5	–	–	0,3	
				100	–	–	0,4	
2.2.2	Minimum NEXT loss [1]		dB	1	58	>65	>65	Annex A, A.2.3.2
				4,0	46	58	>65	
				10,0	38	50	60	
				16,0	34	46	56	
				20,0	–	44	54	
				31,25	–	–	50	
				62,5	–	–	44	
				100	–	–	40	
2.2.3	Minimum return loss		dB	$1 \le f \le 20$	–	23	26	Annex A, A.2.3.3
				$20 \le f \le 100$	–	–	26-20* log (f/20)	
2.2.4	Input to output resistance [1], [3]		mΩ	d.c.	300			IEC 60512-2
2.3	Maximum transfer impedance [1] (Applicable only when an overall shield is present)		mΩ	1	100 (f.f.s.)			f.f.s.
				10	200 (f.f.s.)			
				100	f.f.s.			

1) For connecting devices that provide cross-connections without patch cords or cross-connect jumpers (for example, those with internal switching), attenuation, input to output resistance, and transfer impedance shall not exceed the equivalent of two connectors and 5 m of patch cord of the same category. Also, NEXT loss of such devices shall not exceed 6 dB worse than the values in 2.2.2.

2) Installed category 3 connectors should exhibit an average attenuation of equal to or less than 0,2 dB up to 16 MHz per random connection.

3) DC resistance is a separate measurement from the contact resistance measurements required in normative annex B. Whereas d.c. resistance is measured to determine the connector's ability to transmit direct current and low-frequency signals, contact resistance measurements are used to determine the reliability and stability of individual electrical connections.

9.2.5 Telecommunications outlet requirements

Each 100 Ω and 120 Ω horizontal cable shall be terminated at the TO with an unkeyed jack that meets 9.2.3 and 9.2.4. Pin and pair grouping assignments shall be as shown in figure 13.

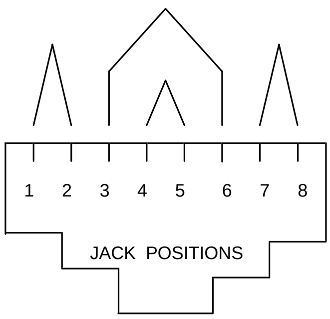


Figure 13 – Eight position jack pin and pair grouping assignments
(This illustration is a front view of the connector.)

If two pairs are provided at the TO, the default pair assignment shall be pins 4-5 and 3-6 with consistent pair groupings to those of figure 13.

Pair re-arrangement at the TO should not involve modification of the horizontal cable terminations. If pair re-arrangement is used at the TO, the configuration of the outlet terminations shall be clearly marked.

NOTE 1 When two physically similar cabling links are used in the same installation (for example, different performance categories and cables with different nominal impedance), special precautions are required to ensure that they are properly identified (see clause 11).

NOTE 2 To ensure proper connectivity, care is needed to ensure that pairs are terminated consistently at the TO and FD. If pairs are terminated on different positions at the two ends of a link, through connectivity will be lost. See clause 11 for cabling system administration.

9.2.6 Installation practices

The untwisted length in a cable element as a result of termination to connecting hardware should be as short as possible. It is recommended that only the length of cable jacket required for termination and trimming should be removed or stripped back. Also, it is recommended that, for links with category 4 components, pair twisting should be maintained to within 25 mm of the termination and that, for links with category 5 components, pair twisting should be maintained to within 13 mm of the termination. The use of quad cables may require that each side circuit of the quad be twisted separately. These recommendations are provided to minimise the impact of terminations on transmission characteristics and are not intended to constrain twist length for cable or jumper construction.

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

Grounding requirements and shield continuity considerations for cables with an overall shield are specified in clause 10.

9.3 Connecting hardware for 150 Ω cabling

9.3.1 General requirements

The following requirements apply to all connecting hardware used to provide electrical connections between the 150 Ω shielded balanced cables specified in 8.2. It is desirable that hardware used to directly terminate 150 Ω cable elements be of the insulation displacement connection (IDC) type.

9.3.2 Performance marking

Connecting hardware intended for use with 150 Ω cabling should be marked to designate transmission performance at the discretion of the manufacturer. The markings, if any, shall be visible during installation.

NOTE Performance markings are in addition to, and do not replace, other markings specified in 9.1.7, clause 11 or those required by local codes or regulations.

9.3.3 Mechanical characteristics

Connecting hardware intended for use with 150 Ω cabling shall meet the requirements specified in table 39.

Table 39 – Mechanical characteristics of connecting hardware intended for use with 150 Ω cabling

1	Mechanical characteristics		Units	Requirements	Component or test standard
1.1	Physical dimensions only at TO interface			IEC 60807-8, Mating dimensions and gauging	IEC 60807-8
1.2	Cable termination compatibility				
1.2.1	Nominal conductor diameter		mm	0,5 to 0,65 [1)]	–
1.2.2	Conductor type	Patching/ jumpers		Stranded or solid conductor	–
		Other		Solid conductor	
1.2.3	Nominal diameter of insulate conductor		mm	1,1 to 1,9 [2)]	8.3 of IEC 60811-1-1
1.2.4	Number of conductors	TO		4	–
		Other		≥2n (n = 1, 2, 3, ...)	
1.2.5	Cable outer diameter	TO	mm	≤20 [3)]	8.3 of IEC 60811-1-1
		Other		N/A	
1.2.6	Shield performance			See table 38, row 2.3 [4)]	–
1.3	Mechanical operation (Durability)				
1.3.1	Conductor termination		cycles	≥200 [5)]	Annex A
1.3.2	Plug interface		cycles	≥1 000	IEC 60807-8

1) Because it is not required that connecting hardware be compatible with cables outside this range, special care shall be taken to ensure compatibility between cables with conductor diameters as low as 0,4 mm (when used) and the connecting hardware they are used with.

2) Because it is not required for connecting hardware to be compatible with cables outside this range, special care shall be taken to ensure compatibility between cables with insulated conductor diameters as high as 2,4 mm (when used) and the connecting hardware they are used with.

3) Use of the connector specified in IEC 60807-8 is typically limited to cables having outside diameters of 9,5 mm or less. Flat/oval cables with equivalent cross-sectional area are acceptable.

4) For shielded cables, care should be taken that the cross-connect is properly designed to terminate the shielding. Note that there may be a difference between cross-connects designed to terminate 150 Ω balanced cables with overall shields only, as opposed to cables having both individually shielded elements and an overall shield.

5) The durability requirement of 1.3.1 is only applicable to connections designed for more than a single termination operation (such as those that are used to administer cabling system changes).

9.3.4 Electrical characteristics

Connecting hardware intended for use with 150 Ω cabling shall meet the requirements specified in table 40.

Table 40 – Electrical characteristics of connecting hardware intended for use with 150 Ω cabling

2	Electrical characteristics		Units	Frequency MHz	Requirement	Component or test standard
2.1	Contact reliability	TO			Clause 7 of IEC 60807-8	IEC 60807-8
		Other			Annex B	Annex B
2.2	Transmission performance					
2.2.1	Maximum attenuation 1)		dB	1,0	0,05	Annex A, A.2.3.1
				4,0	0,05	
				10,0	0,10	
				16,0	0,15	
				20,0	0,15	
				31,25	0,15	
				62,5	0,20	
				100	0,25	
2.2.2	Minimum NEXT loss 1)		dB	1,0	>65	Annex A, A.2.3.2
				4,0	>65	
				10,0	>65	
				16,0	62,4	
				20,0	60,5	
				31,25	56,6	
				62,5	50,6	
				100	46,5	
2.2.3	Minimum return loss		dB	≥1 MHz	36 4)	Annex A, A.2.3.3
				<16 MHz	36 4)	
				≥16 MHz	36-20 log (*f*/16) 4)	
				≤100 MHz	36-20 log (*f*/16) 4)	
2.2.4	Input to output resistance 1), 2)		mΩ	d.c.	f.f.s.	IEC 60512-2
2.3	Maximum transfer impedance 1) (Applicable only when an overall shield is present)		mΩ	1	100 (f.f.s.)	f.f.s. 3)
				10	200 (f.f.s.)	
				100	f.f.s	

NOTE Requirements for FEXT loss are under study.

1) For connecting devices that provide cross-connections without patch cords or cross-connect jumpers, (for example, those with internal switching), attenuation, input to output resistance, and transfer impedance shall not exceed the equivalent of two connectors and 5 m of patch cord of the same category. Also, NEXT loss of such devices shall not exceed 9 dB (f.f.s.) worse than the values in 2.2.2 above.

2) DC resistance is a separate measurement from the contact resistance measurements required in normative annex B. Whereas d.c. resistance is measured to determine the connector's ability to transmit direct current and low-frequency signals, contact resistance measurements are used to determine the reliability and stability of individual electrical connections.

3) Although the IEC 60096-1 test method is intended for coaxial cables, it may be applied to measurements on connectors used to terminate balanced cables with an overall shield, when signal carriers are excited in a common mode.

4) Values above 26 dB need not be tested for conformance.

9.3.5 Telecommunications outlet requirements

Each 150 Ω horizontal cable shall be terminated at the TO with an interface connector that meets 9.3.2 and 9.3.3, and pair assignments specified by ISO/IEC 8802-5.

9.3.6 Installation practices

The untwisted length in a cable element as a result of termination to connecting hardware should be as short as possible. Only the length of cable jacket required for termination and trimming should be removed or stripped back. Also, it is recommended that pair twisting be maintained to within 13 mm of the termination. The use of quad cable may require that each side circuit of the quad be twisted separately. This recommendation is provided to minimise the impact of terminations on transmission characteristics, and is not intended to constrain twist length for cable or jumper construction.

Grounding requirements and shield continuity considerations for cables with an overall shield are specified in clause 10.

9.4 Optical fibre connecting hardware

9.4.1 General requirements

The requirements of 9.4.2 to 9.4.6 apply to all connecting hardware used to provide connections between optical fibre cables specified in clause 8 with the following exception. The requirements of section 9.4.4 and table 41, item 1.1 apply to the TO only.

9.4.2 Marking and colour coding

Correct coding of connectors and adapters, for example by colour, should be used to ensure that mating of different fibre types does not occur. Also, keying and the identification of fibre positions may be used to ensure that correct polarity is maintained for duplex links. See annex H.

NOTE These markings are in addition to, and do not replace, other markings specified in clause 11, or those required by local codes or regulations.

9.4.3 Mechanical and optical characteristics

Optical fibre connecting hardware shall meet the requirements specified in table 41.

Table 41 – Mechanical and optical characteristics of optical fibre connecting hardware

1	**Mechanical and optical characteristics**		**Units**	**Requirements**	**Component or test standard**
1.1	Physical dimensions only at TO interface			IEC 60874-19, Mating dimensions and gauging	IEC 60874-19 (SC-D) 1)
1.2	Cable termination compatibility				
1.2.1	Nominal cladding diameter		µm	125	5 (A1a, A1b) and 32.2 (B.1) of IEC 60793-2
1.2.2	Nominal buffer diameter		mm	–	6.1 of IEC 60794-2
1.2.3	Cable outer diameter		mm	–	6.1 of IEC 60794-2
1.3	Mechanical operation (Durability)				
1.3.1	Plug interface		cycles	≥500	4.5.32 of IEC 60874-1
1.4	Transmission performance				
1.4.1	Maximum attenuation 3)	Other	dB	0,5 2)	27.1 of IEC 60874-1 (Method 7)
		Splice		0,3	IEC 61073-1
1.4.2	Minimum return loss	Multimode	dB	20	27.4 of IEC 60874-1
		Singlemode		26	

1) See 9.4.4.

2) Attenuation of installed connections will reflect optical fibre tolerances and may exhibit an average attenuation equal to or less than 0,5 dB per random connection. Absolute maximum attenuation shall be 0,75 dB. This value is based on maximum backbone length as defined in clause 6 and assumes active components in the FD and CD. Expansion into the horizontal cabling may be achieved with shorter backbone lengths or by connections, each with an absolute maximum attenuation of 0,5 dB.

3) Attenuation values of connectors and splices as specified, shall be met with the referenced test method where the optical source produces an overfilled launch condition (e.g. an LED source). However, measurements with an optical source that produces an underfilled launch condition (e.g. a laser source) will always produce lower attenuation values.

9.4.4 Telecommunications outlet requirements

For new installations and installations without installed optical fibre connectors, the optical fibre cables in the work area shall be connected to the horizontal cabling with a duplex SC connector, (SC-D), that complies with sectional specification IEC 60874-14.

Networks, having an installed base of IEC 60874-10 (BFOC/2,5) connectors and adapters, may remain with the BFOC/2,5 connector and adapter for both existing and future additions to their fibre network.

The optical fibre connector used shall meet the requirements of 9.4.3.

9.4.5 Cross-connect jumpers and patch cords

Cables used for cross-connect jumpers and patch cords in the CD, BD and FD shall meet the performance requirements described in clause 8. See also annex H.

9.4.6 Optical fibre connectivity

All connectivity options shall use colour coding and labelling to distinguish between the optical fibre types of clause 8.

NOTE It is recommended that the connectors and adapters should be coloured in such a way as to distinguish between single mode and multimode optical fibres. Additional colours or labels will be required to distinguish between the multimode optical fibre types.

Consistent polarisation of duplex optical fibre connections shall be maintained throughout the cabling system by means of physical keying, administration (for example labelling), or both. Polarisation assignments should be as shown in annex H (figures H.1 to H.3).

Guidelines on recommended optical fibre connectivity practice are provided in informative annex H.

10 Shielding practices

This clause applies when shielded cables or cables with shielded elements or units are used. Only basic guidance is provided. The procedures necessary to provide adequate grounding for both electrical safety and EMC performance are subject to national and local regulations, are dependent on proper workmanship, and are at times only accomplished with installation specific engineering. Note that improper handling of shields may degrade performance and safety.

10.1 EMC

Shields are intended to improve EMC performance. To achieve this effect they have to be properly bonded. Shielding, to be effective, requires that all cabling components are shielded and meet requirements for transfer impedance [1)] given in clauses 8 and 9. Shielding has to be continuous for the complete channel. This means that work area, equipment cables and the equipment attachment, while not part of the generic cabling, must also satisfy the continuity requirement. Cabling components (including work area and equipment cables) should be carefully chosen, properly installed and inter-connected. Particular attention should be paid to connecting hardware and termination practices.

NOTE 1 The 1990 edition of International Standard IEC 60603-7 does not address termination of shields. The revision of this International Standard will include specification of shielding.

NOTE 2 By installing components with shields, EMC regulations are not necessarily fulfilled.

[1)] Low transfer impedance of cables and connecting hardware alone is not sufficient. Cables have to be terminated in the connecting hardware in such a way that shielding effectiveness is maintained. The termination methods are dependent on the type and design of the cable and connecting hardware. Supplier's instructions should provide the information necessary to meet this requirement. Methods to determine shielding effectiveness for class B and better are under study.

10.2 Grounding

Warning: The recommendations in this subclause are based on operational considerations only. There are significant safety considerations associated with bonding cable shields and other metallic parts (for example moisture barriers) to ground which need to be taken into account. Local regulations shall apply and safety practices should be followed.

Bonding shall be in accordance with applicable electrical codes.

All shields of the cables should be bonded at each TC. Normally, the shields are bonded to the equipment racks, which are, in turn, bonded to building ground.

The bond shall be designed to ensure that

a) the path to ground shall be permanent and continuous. It is recommended that each equipment rack is individually bonded, at the local distribution, in order to assure the continuity of the ground path,

b) the cable shields provide a continuous ground path to all parts of a cabling system that are interconnected by it.

This bonding ensures that voltages that are induced into cabling (by lifts or other disturbances) are directed to building ground, and so do not cause interference of the transmitted signals. All grounding electrodes of different systems in the building shall be bonded together to reduce effects of differences in ground potential. The building grounding system should meet the ground potential difference limits of 1 V r.m.s. and a low resistance between any two grounds on the network. It is recommended that metallic conduits used to house grounding conductor, should be bonded to the ground conductor at both ends.

If the 1 V r.m.s. requirement cannot be met, then optical fibre cable should be used to eliminate the risk of high ground currents.

For recommendations on grounding of cable shields for performance considerations, see IEC 61000-5-2 (under consideration) [2].

11 Administration

Administration is an essential aspect of generic cabling. The flexibility of generic cabling can be fully exploited only if the cabling is properly administered. Administration involves accurate identification and record keeping of all the components which comprise the cabling system as well as the pathways, telecommunications closets and other spaces in which it is installed. All changes to the cabling should be recorded as and when they are carried out; this is essential to maintaining its flexibility. Computer based administration of records is strongly recommended.

11.1 Scope of administration

The requirements for administration described in this clause apply to generic cabling, and to the pathways and spaces in which it is installed. It is strongly recommended that the principles of administration described in this clause are also applied to any application specific cabling and equipment installed.

11.2 Identifiers

Every element of generic cabling, and the pathways and spaces in which it is installed, should be readily identifiable. A unique identifier (such as name, colour, number, and/or string of characters) shall be assigned to every cable, distributor, and termination point in the cabling.

[2] See annex J, Bibliographical references

Each TO should be labelled to reference the following information regarding the choice and implementation of installed cabling.

a) TO: IEC 60603-7 Cable impedance, category of cabling components and pair count at the TO.

b) TO: optical fibre Optical fibre design.

Suitable identifiers shall also be applied to the pathways and spaces in which the cabling is installed.

The elements to which the identifiers are assigned shall be clearly marked in some way. Cables should be marked at both ends.

11.3 Records

Records of the administration of the generic cabling shall be maintained. A reference to the results of acceptance tests, if made, should also be kept.

Although not a requirement of this International Standard, it is also advisable to associate with the records of the system configuration, a list of applications that are being supported. This will facilitate troubleshooting in case of problems.

11.3.1 Documentation

Good control of all of the records kept (such as: as built drawings showing cable routes, TO locations and identification, distributor construction and layout, test and acceptance results, as well as connectivity mapping) is vital to the administration process. It is also important to ensure that suitable procedures are implemented and followed for the timely updating of documentation with changes to the configuration of the cabling.

NOTE A technical report dealing with detailed administration requirements will be developed by ISO/IEC JTC 1/SC 25.

Annex A
(normative)

Test procedures

This annex on test procedures is divided into three parts. A.1 applies to the cabling, A.2 applies to individual components of the cabling and A.3 illustrates how to make measurements on the components. The number of samples to be tested is not necessarily 100 % but depends on the quality assurance level that is specified in the context of a specific installation.

It is intended to replace all of the specifications in this annex by reference to international specifications as they become available.

A.1 Link performance testing

The test procedures described in this section are defined in general terms and are intended to add clarity to the parameters specified in clause 7 of this International Standard. It is the intention to describe *what* has to be measured rather than *how* to make the measurements. Making measurements at high frequencies requires some knowledge and expertise, and often specialised test equipment.

Care should be exercised in the interpretation and the significance of any results obtained from detailed test methods or practices other than those shown here. Correlation factors should be identified and applied when needed.

A.1.1 Testing balanced cabling links

Attenuation shall be measured from 1 MHz to the highest referenced frequency for a given category using a step size no greater than 1 MHz. NEXT loss shall be measured from 1 MHz to the highest referenced frequency for a given category using a step size no greater than 0,15 MHz in the 1 to 31,25 MHz range and no greater than 0,25 MHz in the region above 31,25 MHz.

When a shield is present in the cabling, it shall be connected to the measurement (instrument) ground throughout the measurements, unless otherwise stated.

A.1.1.1 Terminations

The electrical performance of the links can be measured by connecting the source and load circuits in the measurement configuration shown in figure A.1. The voltage sources are assumed to have negligible source impedance, but they can contain part or all of the series resistances R_1, R_2. Sources V_1 and V_2 need not be applied simultaneously. R_1 equals 50 Ω. R_2 and R_3 are half the nominal differential characteristic impedance at the measurement frequency *(Z_C/2).*

Near end crosstalk (V_7 and V_8) is measured at any interface not directly connected to the pair connected to the source.

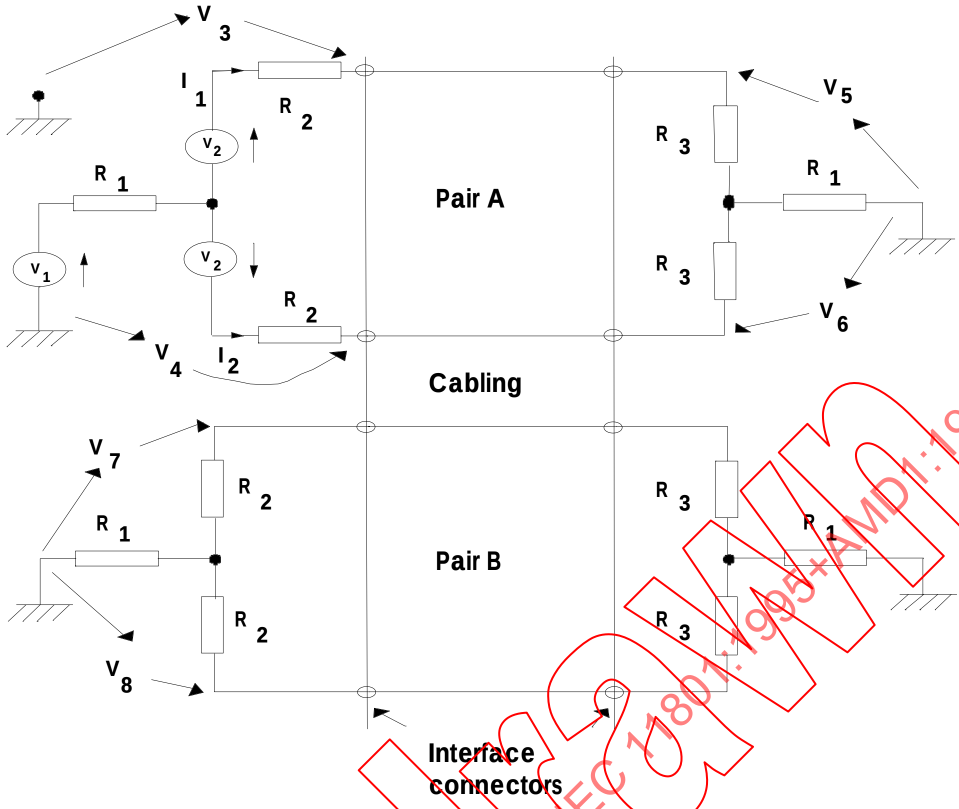


Figure A.1 – Measurement configuration

A.1.1.2 Calibration

Where the voltage sources cannot be measured directly, their effective values can be deduced using the calibration configuration shown in figure A.2. The effective value of V_1 then equals the sum of the measured values of V_3 and V_4 with V_2 set to zero. The effective value of V_2 equals the difference between the measured values of V_3 and V_4 with V_1 set to zero. This method has the advantage of correcting for gain variation in the measurement devices and other parts of the test system.

The balance of the test system should be such that the ratio of the sum of V_3 and V_4 to V_2, with V_1 set to zero, and the ratio of the difference between V_3 and V_4 to V_1, with V_2 set to zero, should be at least 10 dB smaller than the cabling balance performance requirement at each frequency. This condition should be met in the calibration configuration with either polarity of connection between the source network and the load network.

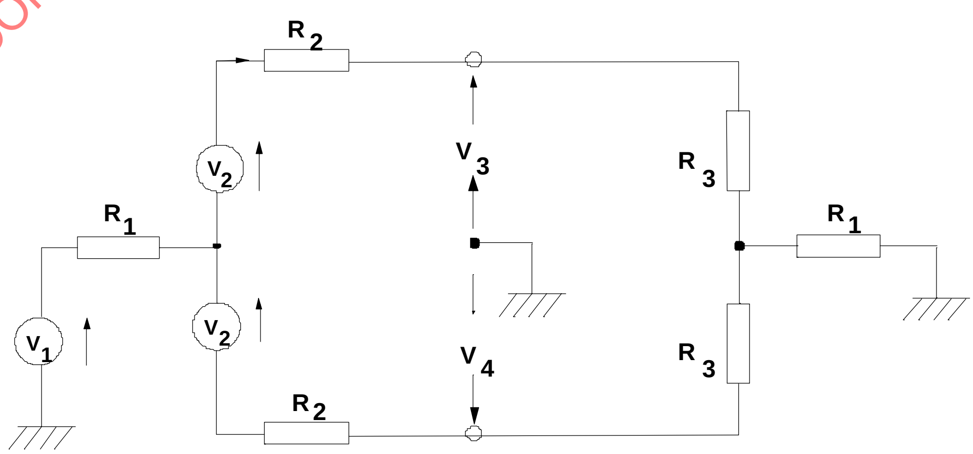


Figure A.2 – Calibration configuration

A.1.1.3 Longitudinal conversion loss

Measurement shall be based upon ITU-T Rec. O.9.

Longitudinal conversion loss is measured with V_2 set to zero.

a) Measured at a single port (LCL) balance = $-20\log_{10}\dfrac{|V_3(f) - V_4(f)|}{V_1(f)}$ in dB

b) Transmission unbalance (LCTL) = $-20\log_{10}\dfrac{|V_5(f) - V_6(f)|}{V_1(f)}$ in dB

The validity of measurements of LCL and LCTL on installed cabling requires further study. Until the measurement is validated, conformance to this International Standard can be achieved by design.

A.1.1.4 Return loss and propagation delay

A voltage V_2 is applied. V_1 is set to zero, $R_2 = Z_C/2$.

a) Return loss = $-20\ \log_{10}\left(1 - \dfrac{|V_3(f) - V_4(f)|}{V_2(f)}\right)$ in dB

b) Propagation delay is measured by applying a step voltage V_2 with $V_1 = 0$, $R_2 = Z_C/2$ and R_3 = Open circuit and/or short circuit. A timer is started in synchronization with the applied step.

The value $V_0(t) = V_3(t) - V_4(t)$ is measured.

The propagation delay T_p is given by $t_S/2$ where t_S is the time at the point at which the slope of $V_0(t)$ changes sign when the open and short circuits for R_3 are swapped. This can be seen more clearly if the open and short circuit responses are subtracted from each other.

The propagation delay is frequency dependent; for example measurements at 10 MHz can be up to 10 % lower than at 1 MHz. If the propagation delay indicated by the above test procedure is within 10 % of the delay requirements for the selected application, then further tests should be performed at the frequency of the application to guarantee its correct operation.

A.1.1.5 Transfer impedance

The test procedures for measuring the transfer impedance of shielded cables are specified in IEC 60096-1, clause 18. The test procedures for measuring shielded cabling are for further study. Until the tests are developed, conformance with the requirements of this International Standard can be achieved by design.

A.1.2 Testing optical fibre cabling links

The test procedures for optical cable installations are based on the test methods described in CCITT (ITU-T) Recommendations G.650 and G.651. Later IEC standards apply when available. The test methods can be applied to optical cables irrespective of dimensions.

A.1.2.1 Requirements of the test equipment

Measurements should be made at one or more wavelengths in the ranges shown in tables 11 and 12.

The characteristics of the optical source for all of the test measurements described below shall comply with the requirements of IEC 60793-1. The source may or may not be modulated, depending upon the measurement being made. The launching system may include components such as cladding mode strippers, mode filters, optics, mode scramblers or others as appropriate.

The characteristics of the optical receiver for all of the test measurements below shall comply with the requirements of IEC 60793-1.

Field measurement of multimode optical bandwidth needs only to be considered for measurement when the optical bandwidth of the input fibre is unknown. Additionally, most field bandwidth measurement equipment requires a minimum of 1 000 m of fibre to perform an accurate and repeatable test.

A.1.2.2 Attenuation measurements

The initial measurement set-up is configurated as shown in figure A.3.

The received optical power P_1 is measured and recorded.

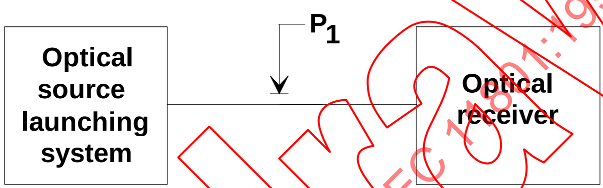


Figure A.3 – Calibration

The calibrated source and receiver are then connected to the optical link under test, as shown in figure A.4.

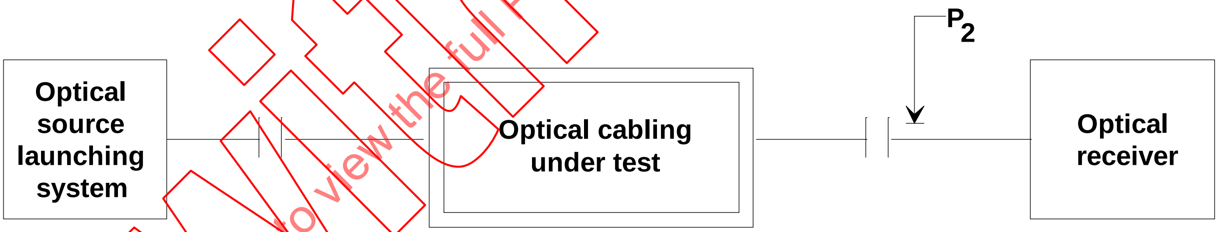


Figure A.4 – Test set-up

The link under test is than connected as shown in figure A.4, and the received optical power, P_2, is measured and recorded. The attenuation of the cabling is then defined by:

$$A = 10 \log_{10}\left(\frac{P_1}{P_2}\right) \text{in dB}$$

A.1.2.3 Propagation delay measurements

(f.f.s.)

A.1.2.4 Optical return loss measurements

(f.f.s.)

A.1.3 Link tests

Cabling link tests can be used in a number of ways:

a) Acceptance testing

As a means of validating installed cabling which is known to meet the requirements of clauses 6, 8 and 9, or which has been previously verified by the tests referred to in c) below.

b) Troubleshooting

As a means of troubleshooting installed cabling. Appropriate tests should be selected from those indicated.

c) Compliance testing

As a means of testing installed cabling, comprising known or unknown components, for compliance with the requirements of clause 7.

In Table A.1, the type of test likely to be carried out for each link is indicated by an "X".

Table A.1 – Parameters for testing cabling links

Balanced cabling link tests	Acceptance	Troubleshooting	Compliance
Characteristic impedance			(X)
Propagation delay			X
DC resistance			X
Near-end crosstalk loss		X	X
Attenuation		X	X
Return loss		X	X
Shield d.c. resistance		X	
Echo response		X	
Continuity of conductors, shields (if applicable), short and open circuits	X	X	
Optical fibre link tests			
Multimode modal bandwidth			X
Propagation delay		X	X
Optical attenuation	X	X	X
Return loss	X	X	X

The values of the parameters measured should meet the requirements of clause 7, and be consistent with the length of the installed cabling.

A.2 Transmission testing of connecting hardware for balanced cabling

As LAN speeds increase and users invest in high performance balanced cabling, it is important to specify connecting hardware that has compatible transmission characteristics with the various grades of cable presently available. Careful selection of connecting hardware will help to assure that the impact of connectors on channel performance is minimised. This annex outlines test parameters, methods and apparatus, as they relate to the minimum transmission requirements given in clause 9.

Categories of connecting hardware specified in clause 9 correspond with cable types and categories found in clause 8, so that cables used with connectors of the same category will experience minimum performance degradation when properly installed. The types and categories of balanced cabling systems are described in clause 6.

NOTE Test reports on connecting hardware transmission performance should reference the nominal impedance of the test set-up (that is, test leads, test baluns and impedance matching terminations used).

A.2.1 Purpose and scope

The purpose of this annex is to specify transmission performance requirements for connecting hardware that are consistent with the balanced cables requirements given in clause 7. This annex contains the minimum set of transmission parameters and test methods necessary to assure that properly installed connectors will have minimal effects on cable performance. These requirements apply to only individual connectors which include, but are not limited to TOs, patch panels, transition connectors and cross-connects. Transmission characterisation of these components does not include the effects of cross-connect jumpers or patch cables.

While the intent of this annex is to minimise the effects of connectors on end-to-end system performance, it should be noted that requirements for connectors of a given type or category are not sufficient in themselves to ensure required system performance. Link performance also depends on cable characteristics (including cross-connect jumpers and patch cords), the total number of connections, and the care with which they are installed and maintained. For guidance and requirements on connector termination practices, cable management and the use of cross-connect jumpers/patch cords, see clause 9 and annex C.

A.2.2 Applicability

The transmission requirements specified herein are applicable to connecting hardware for use with balanced cables, the requirements for which are given in clause 8. This annex relates to connecting hardware performance with respect to balanced cable of a given nominal impedance only. Product compliance with this specification when tested with a specific cable type does not imply compatibility with other cable types or cables with nominal impedance values other than those used for qualification testing.

Although the test methods and apparatus described herein apply to two or more cable elements, the nature of these tests is such that, when conducted properly, worst case transmission performance may be determined for pair groupings of a specific connector, independent of the quantity of cable elements that it is capable of terminating. For example, it may be necessary to sample groupings of adjacent pairs on cross-connect blocks designed for use in 10 or 25 pair increments to determine worst case crosstalk performance variations.

Test results on connecting hardware shall be based on products terminated per manufacturer's guidelines and recommended installation methods. For connecting hardware with modular interface components (such as plug and jack connectors), transmission tests shall be performed with both components in a mated state. For qualification testing, both plug and jack components shall be identified. Product compliance shall be determined using worst case measured values based upon a minimum of ten (10) randomly selected production samples, consisting of a minimum of at least one of each unique circuit design or layout. For example, a multiple port circuit assembly is tested with a minimum of 10 of each port having a unique circuit design or layout. For connecting hardware having multiple ports on the same assembly (such as a patch panel), the samples shall be tested from a minimum of two separate finished assemblies.

For mateable connectors where one component is intended to be fixed (rigidly mounted, such as modular sockets) and the other is free (such as modular plugs), product compliance shall be determined using worst case measured values based upon a minimum of ten (10) of each fixed component and a minimum of five (5) of each free component (that is 10 sockets and five plugs) tested in a minimum of ten (10) combinations total. There shall be no more than two socket samples tested with the same plug. All test specimens shall be randomly selected from production samples. For IEC 60603-7 connectors, additional test plug requirements are specified in A.3.2.

A.2.3 Test parameters

A.2.3.1 Attenuation

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

Tables 24 and 26 in clause 9 specify worst case attenuation of any pair within a connector for the applicable balanced cable type and performance category.

A.2.3.2 Near-end crosstalk (NEXT) loss

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

Tables 24 and 26 in clause 9 specify worst case NEXT loss of any pair combination within a connector for the applicable balanced cable type and performance category.

A.2.3.3 Return loss

Connector return loss is a measure of the degree of impedance matching between the cable and connector, and is derived from swept frequency voltage measurements on short lengths of test leads with the appropriate characteristic impedance before and after inserting the connector under test. A balanced input signal is applied to a connector pair, while signals that are reflected back due to impedance discontinuities are measured at the same port from which the signal is applied. Tables 24 and 26 in clause 9 specify worst case return loss at specific frequencies for the applicable balanced cable type and performance category. The same set-up that is used for NEXT loss measurements is also used for return loss, except that only a single connection is made to the network analyser.

A.2.4 Transmission testing of connecting hardware for balanced cables

A.2.4.1 General

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

NOTE Because the transmission performance of modular jack and plug connectors is determined in a mated state, and because cables used for modular patch cords are subject to the requirements of annex C, the performance category of modular plugended patch cords is determined by the performance capability of the plugs and cables tested separately, and not by the performance of the finished cable assembly. Although this annex provides requirements on connections to test plugs for proper performance characterisation of modular jack and plug connections, termination practices and qualification guidelines for factory and field administered modular plug and cable terminations are a subject of future study.

A.2.4.2 Test set-up and apparatus

Balanced test leads are used for connections to and from the test sample. Test leads shall be taken from cables that meet or exceed requirements for the highest performance 100 Ω, 120 Ω or 150 Ω cable given in clause 8 or annex C. The balanced test leads shall be limited to a length of 65 mm between each balun and the connector under test. If used, coaxial cable assemblies extending to and from test equipment should be as short as possible. It is recommended that they do not exceed 0,6 m each. If a balun ground plane is used, a separation of at least 10 mm shall exist between it and the balanced test leads at the point they are connected to the baluns. In addition, separation between the active conductors of the product under test and the balun ground plane (if present) shall be at least 50 mm. If the balanced test leads are shielded, the shield shall be connected in common with the balun casing on at least one end.

Impedance matching terminations for the balanced test leads and the product under test shall be matched to the nominal impedance of the test leads (in particular 100 Ω, 120 Ω or 150 Ω) with a tolerance not to exceed ±3 % (±1 % precision metal film or precise low inductance resistors are recommended), throughout the frequency range from 1 MHz to 100 MHz.

Unless the network analyser is equipped with balanced outputs, baluns are required to provide transmission continuity to the balanced test leads. Test baluns shall be RFI (Radio Frequency Interference) shielded and shall comply with the specifications listed in table A.2.

Table A.2 – Test balun performance characteristics (1 MHz – 100 MHz)

Parameter	Value
Impedance, primary [1]	50 Ω (unbalanced)
Impedance, secondary [2]	100 Ω, 120 Ω or 150 Ω (balanced)
Attenuation	1,2 dB max.
Return loss, bi-directional	20 dB min.
Power rating	0,1 min.
Longitudinal balance [3]	50 dB min.

[1] Primary impedance may differ, if necessary to accommodate analyser outputs other than 50 Ω.

[2] Balanced outputs of the test baluns shall be matched to the nominal impedance of the test leads (100 Ω, 120 Ω or 150 Ω).

[3] Measured per ITU-T Recommendations G.117 and O.9

For crosstalk measurements, near-end of the transmission test setup corresponds to the end from which test signals are applied. Far-end is defined as the end of the product under test that is not directly connected to measurement equipment. For NEXT loss and return loss measurements, pairs at the far-end are terminated with impedance matching terminations.

For pairs not under test, impedance matching terminations are not required on the near-end. Product orientation, with respect to near-end and far-end, may affect measurement results. Due to these effects, the connector shall be tested in the orientation that best reflects installed field use. Products that are intended to receive near-end signals from either orientation (for example, those that may be used as TOs as well as in telecommunications closets for patching) shall be tested in both orientations for NEXT loss, attenuation, and return loss.

A.2.4.3 Test method

Transmission performance of connecting hardware is determined by evaluating its impact upon measurements of attenuation, NEXT loss and return loss with respect to the appropriate balanced test leads. Calibration and/or reference data sweeps are collected with balanced test leads in place to assure a minimum noise floor of 80 dB for attenuation and NEXT loss measurements. For return loss measurements, the set-up return loss shall be greater than, or equal to, 50 dB when calibrated with the specified impedance matching terminations.

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

See figure A.11 for an example of a set-up implementation that yields accurate and repeatable near-end crosstalk performance data for connecting hardware with modular jack and plug connectors.

A.2.4.4 Measurement precautions

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

a) That consistent and stable balun and resistor terminations are used for each pair throughout the test sequence. In order to reduce variability, terminating resistors should be connected directly to the far-end of the connector under test. Balun terminations may be used, provided they are shown to yield equivalent results.

b) That cable and test lead discontinuities, as introduced by physical flexing, sharp bends and restraints, be avoided before, during, and after connector termination.

c) That, throughout the test sequence, the relative spacing of the test leads be preserved to the greatest extent possible.

d) That the test leads and connector under test be separated from metallic surfaces, such as ground planes, and isolated from sources of electromagnetic interference.

e) That the balance of the test leads be maintained by consistent wire lengths and twisting to the point of termination.

f) That coaxial and balanced lead lengths be kept as short as possible so that resonance and parasitic effects are minimised. If resonance or deviations from linear slope are observed during NEXT loss measurements, balun grounding and length reduction of coaxial leads may improve measurement accuracy.

g) That connections between the connector under test and measurement baluns be made so that wire movement resulting from connection of different pairs to the network analyser will produce minimal variability for repeated measurements on the same product (±0,5 dB or less is acceptable). Where practical, a rigid test fixture is recommended.

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

A.2.4.5 Set-up validation

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

The measured attenuation of the combined baluns and test leads shall not exceed 3 dB from 1 MHz to 100 MHz (figure A.5).

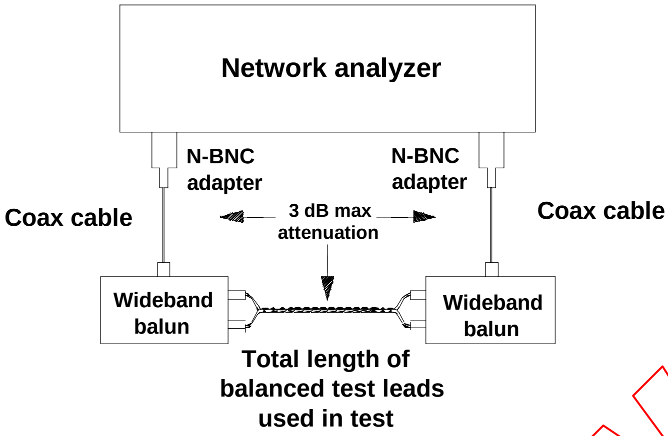


Figure A.5 – Balun and test lead attenuation measurement

With the network analyser calibrated to factor out the combined attenuation of the baluns and test leads, the addition of impedance matching resistors connected across each of the two balanced outputs of the test baluns (one 100 Ω, 120 Ω or 150 Ω resistor connected in parallel with, and on each end of the balanced test leads) shall result in an attenuation of 6 dB ± 1,5 dB from 1 MHz to 100 MHz (figure A.6). In order to minimise inductive effects, the resistor leads should be kept as short as possible (5 mm or less per side).

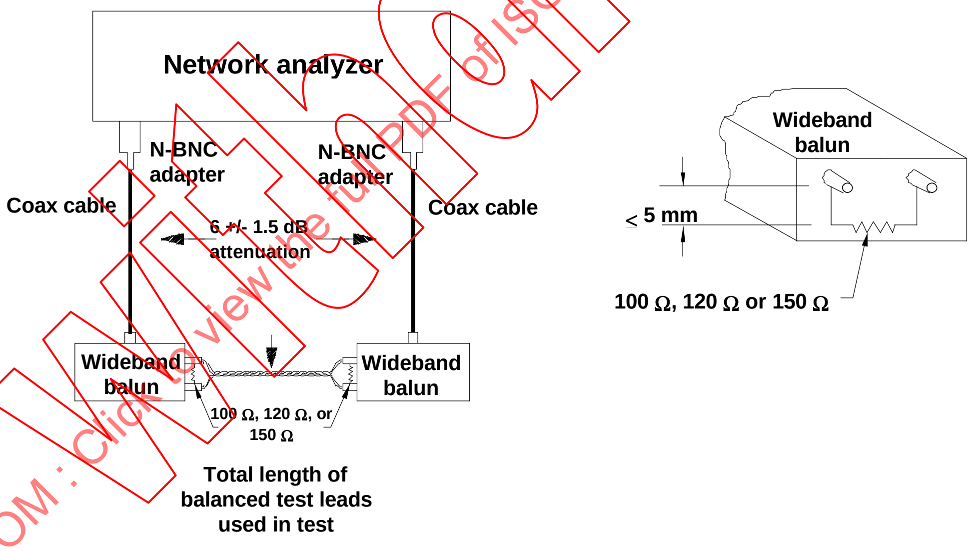


Figure A.6 – Attenuation measurement using resistors

A.3 Termination procedure and set-up verification for modular jack and plug testing

Because of variations that are inherent to the termination of balanced cables to modular plugs (and to a lesser extent, modular jacks) of the type specified in IEC 60603-7, the following requirements and guidelines have been developed. When implemented properly, these guidelines assure that accurate and repeatable transmission test measurements will be performed with minimal variations between test facilities and personnel. These specifications are not intended to replace other requirements and guidelines in this annex, and are not applicable to connecting hardware other than those with the modular interface specified by the IEC 60603-7.

Because the IEC 60603-7 connector is specified as the TO interface for 100 Ω and 120 Ω balanced cabling only, these guidelines are provided for connecting hardware testing with respect to 100 Ω or 120 Ω test leads.

A.3.1 Test plug termination

Connections between the balanced test leads and the modular test plug should be made using the following procedure. It should be noted that the termination procedure described below will not always result in test plugs that meet the requirements of A.3.3. Familiarity with these guidelines through repeated use have been observed to yield improved consistency between terminations.

a) Strip or position the jacket so that the twisted conductors extend a distance of 20 mm beyond it. The jacket itself should be at least 13 mm long.

b) Position the cable pairs so that they are sequenced 1 and 2, 3 and 6, 4 and 5, 7 and 8 respectively (figure A.7). To prevent physical invasion between pairs under the jacket when the plug is crimped, the side-by-side orientation of the test leads shall extend into the jacket a distance of at least 8 mm, creating a flat portion. The flat, jacketed portion of the test leads will appear to be oblong in cross-section.

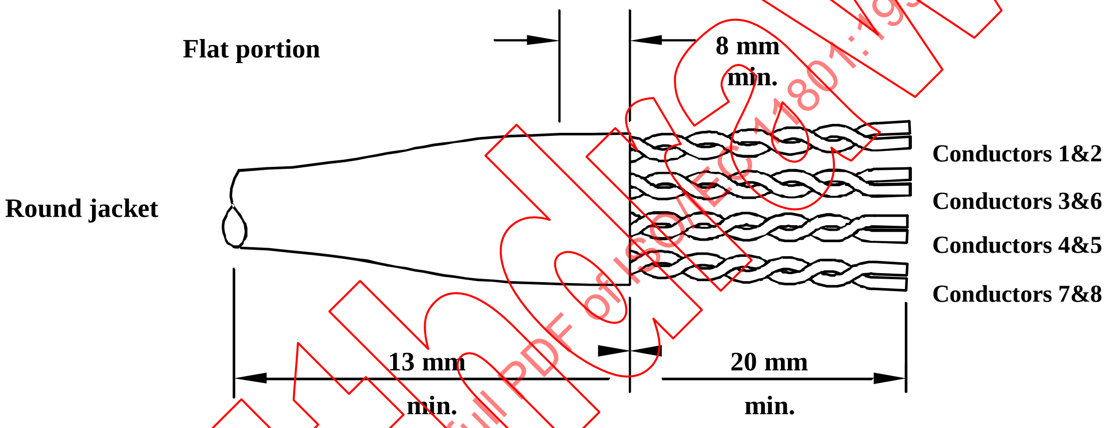


Figure A.7 – Balanced test leads and jacket prior to untwisting

c) Untwist the insulated conductors and orient them in the correct order for termination so that they are parallel, and conductor 6 is made to cross over conductors 4 and 5. There shall be no untwisting of the conductors inside the jacket.

d) The trimmed length of conductors should be about 14 mm, measured from the jacket. There shall be no physical crossings between conductors for a length of at least (10 ± 1) mm from the wire tips (figure A.8). The distance from the jacket where conductor 6 crosses over conductors 4 and 5 shall not exceed 4 mm.

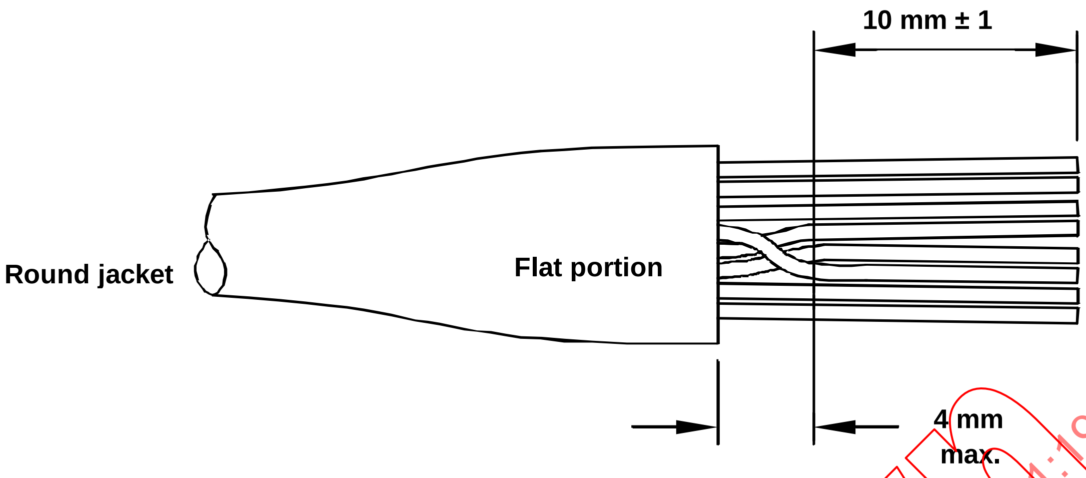


Figure A.8 – Balanced test leads and jacket prior to plug termination

e) Insert the plug over the prepared test leads. The conductors shall be "bottomed-out" in the front of the plug and the flattened portion of the jacketed test leads shall extend from the back of the plug to beyond the primary strain relief (figure A.9). The jacket shall protrude beyond the back of the plug by at least 6 mm.

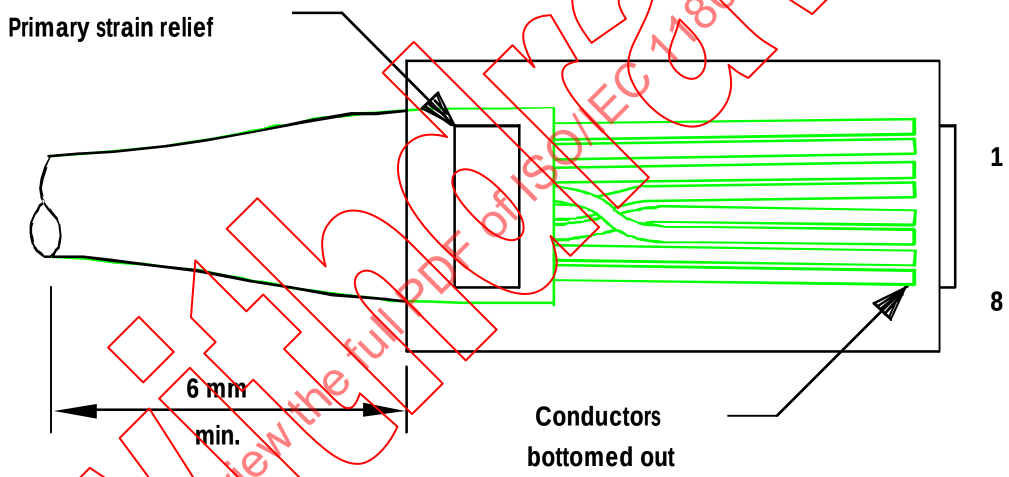


Figure A.9 – Completed test plug

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

A.3.2 Balun and test plug qualification

Once the test plug is terminated (see A.3.1), its characteristics shall be verified by measuring its crosstalk loss in an unmated state, with impedance matching resistors connected in parallel with the 100 Ω or 120 Ω test leads where they connect to the baluns.

For each of the six test plug pair combinations, connect a 100 Ω or 120 Ω impedance matching termination (see A.2.4.2) in parallel with the test leads (where they connect to the baluns), and measure NEXT (figure A.10). In order to minimise inductive effects, the resistor leads should be kept as short as possible (5 mm or less per side). For each of the six pair combinations, the measured NEXT loss of the open circuit plug, with 100 Ω or 120 Ω resistors connected in parallel with the balanced test leads, shall measure in the range shown in table A.3. This measurement is sometimes referred to as "terminated open circuit" or TOC test. For qualification of baluns and setup, the logarithmic recording of NEXT loss versus frequency is a straight line. Therefore, the difference between the NEXT loss measured at 100 MHz and the NEXT loss measured at 10 MHz for the baluns and setup shall be 20 dB ± 0,5 dB.

Table A.3 – Test plug NEXT loss requirements

Pin combination	Test plug NEXT loss at 100 MHz
4 and 5 – 3 and 6	≥ 40 dB
3 and 6 – 1 and 2	≥ 45 dB
3 and 6 – 7 and 8	≥ 45 dB
4 and 5 – 1 and 2	≥ 55 dB
4 and 5 – 7 and 8	≥ 55 dB
1 and 2 – 7 and 8	≥ 55 dB

If the test plug complies with these requirements, the 100 Ω or 120 Ω resistors shall be removed from the baluns before any mated plug/socket measurements are made.

For product qualification testing, a minimum of five (5) test plugs shall be used. TOC NEXT results may be rounded to the nearest 0,1 dB. Of the minimum five test plugs used, three are subject to the following additional TOC requirements for pin combinations 4 and 5 as well as 3 and 6.

a) At least one of the five test plugs used shall exhibit TOC NEXT loss in the range from ≥40,0 dB to <40,5 dB at 100 MHz.

b) At least one of the five test plugs used shall exhibit TOC NEXT loss in the range from ≥40,5 dB to <41,5 dB at 100 MHz.

c) At least one of the five test plugs used shall exhibit TOC NEXT loss of ≥41,5 dB at 100 MHz.

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

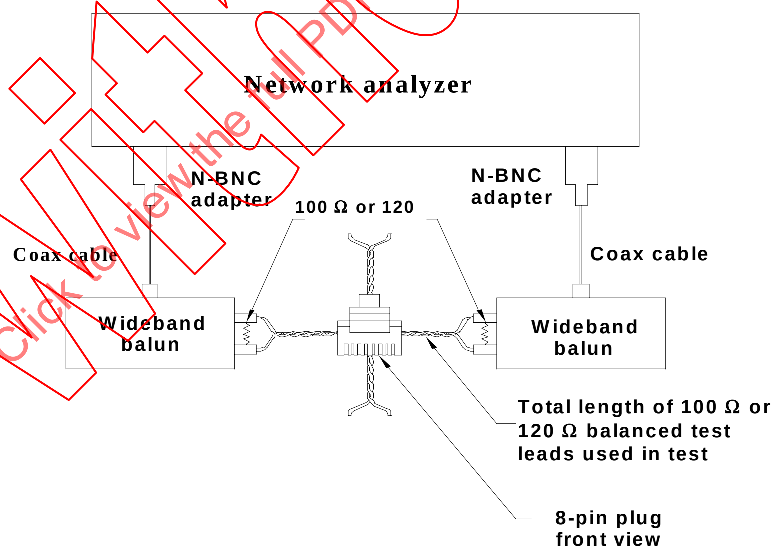


Figure A.10 – Test plug qualification measurement

A.3.3 Typical TO measurement procedure

An example of a measurement procedure that may be used to categorise near-end crosstalk for various types of TOs is shown in figure A.11. Although it may not be directly applicable to other types of connecting hardware, it is shown to illustrate a setup that is accurate, simple to implement, and that will allow a large number of connectors to be characterised in a short period of time. Set-up variations that yield equivalent results are also acceptable.

Advantages of this procedure are lack of any soldered connections, the re-use of one 8-pin modular plug that is terminated with balanced test leads, and that all test leads can be as short as 50 mm. The test setup is shown in figure A.11. Test baluns may also be connected directly to the network analyser. The separation between baluns is minimised. To make solderless connections to balun ports, the test leads are fitted with pins from an integrated circuit (IC) socket. These pins may be easily removed from a socket and attached to the terminals of the balun. Connections to the baluns are then made by inserting conductors from the test leads into the hollow portion of the pin receptacles (figure A.11, detail B). This connection is comparable to inserting an IC into a socket. A pressure fit is provided, and no soldering is required, nor are any special tools required.

The 8-pin plug used in this setup is terminated per A.3.1 with a short piece of category 5 cable, which has the outer jacket removed approximately 6 mm beyond the plug (see A.3.1). Beyond the jacket, the cable elements are oriented 90° with respect to one another as shown in figure A.11, detail C. The tips of these conductors are connected to measurement baluns by insertion into the balun mounted IC sockets (figure A.11, detail B). The lengths of the balanced test leads are adjusted to just reach the baluns, with the two pairs being measured in exactly opposite directions coming out of the test plug (180° apart). In this way, various pair combinations may be measured without soldering.

To factor out attenuation of the set up, a series of normalising jacks are constructed from PC mountable jacks. There is one normalising jack for each of six possible pair combinations (based on four test pairs). Each normalising jack connects a specific transmit pair to a specific receive pair. For example, when measuring pins 4 and 5 and 3 and 6, the normalising jack for this combination allows a signal entering pins 4 and 5 to exit on pins 3 and 6. Care should be taken to assure that the loop-back connections on the normalising jack are configured to preserve balun polarity. Once the jack is mated to the measurement plug, the analyser is calibrated. Since the connector under test is considered to consist of a mated plug and socket, it is important that the normalising and calibration procedures do not factor out crosstalk noise that may be attributed to the modular plug and jack combination. To measure a TO, the plug is then mated with the test jack, and NEXT loss measurements are performed. When terminating the test jack with 100 Ω or 120 Ω resistors, they should be connected directly to the cable termination.

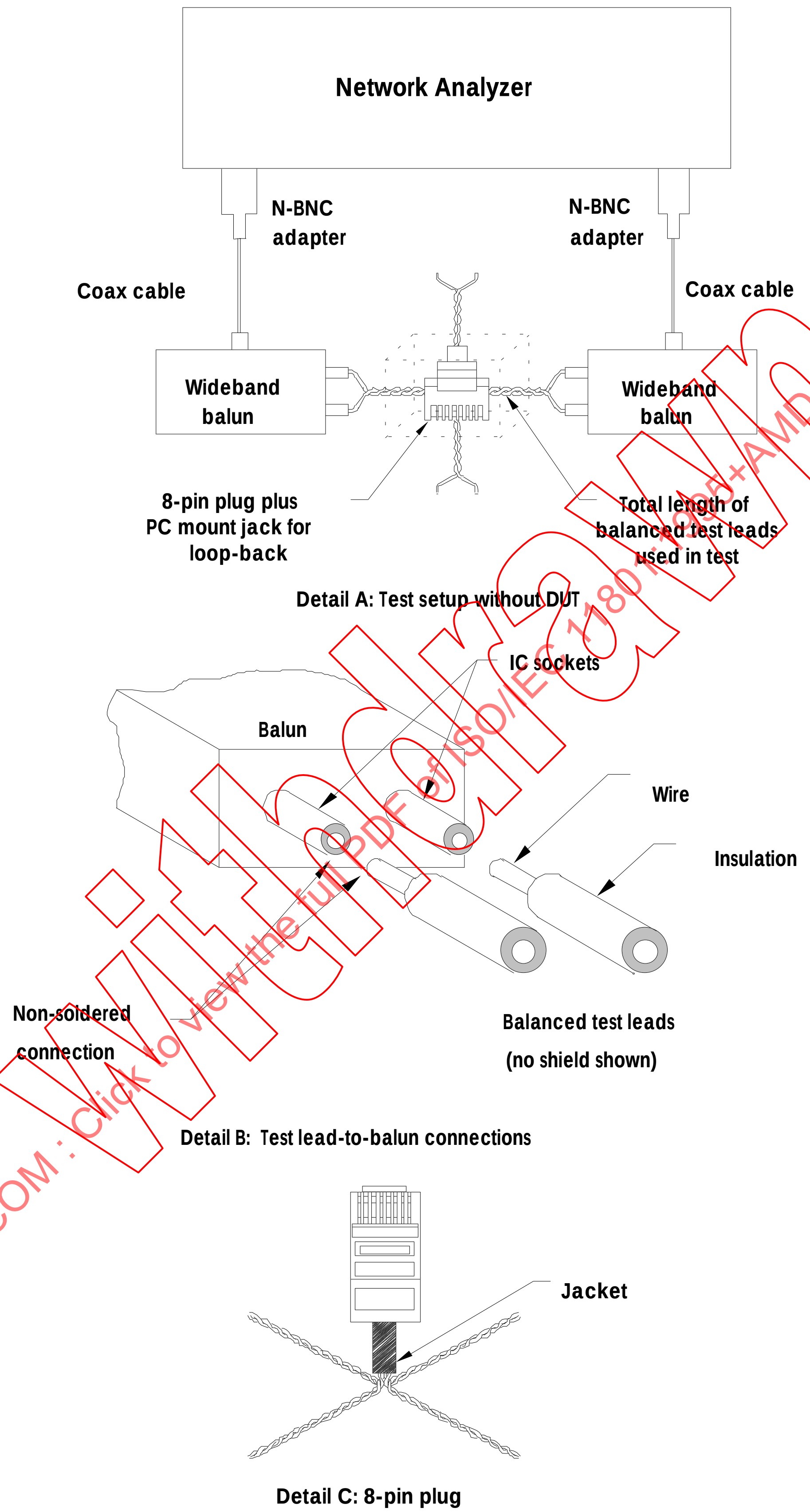


Figure A.11 – Typical TO NEXT measurement set-up

Annex B
(normative)

Reliability testing of connecting hardware for balanced cabling

B.1 Introduction

The reliability 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 building cabling system. Product life 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 the test cycle. In addition, the product shall not show evidence of degradation with respect to ease of mechanical termination, safety or other functional attributes at any time during or after testing.

To ensure that all connecting hardware for the 100 Ω, 120 Ω and 150 Ω cabling systems will perform reliably under field installation conditions, it shall be capable of passing the test sequence illustrated in figure B.1, when mounted and connected in accordance with manufacturer's guidelines. Unless otherwise specified, tests should be carried out under standard atmospheric conditions in accordance with 5.3.1 of IEC 60068-1.

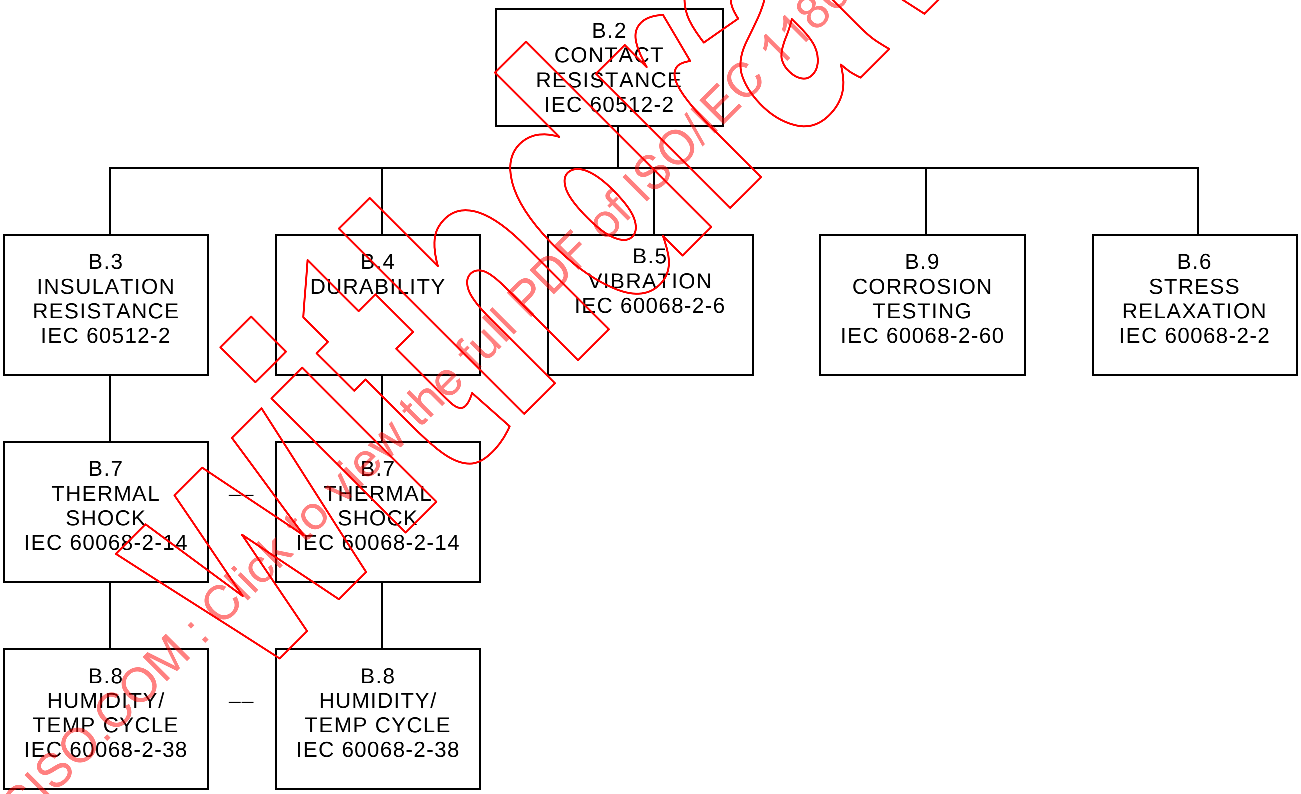


Figure B.1 – Reliability test programme

For each test sequence, a minimum of 10 product samples, consisting of at least eight test circuits (conductors) each, or a minimum of 20 product samples, consisting of at least four test circuits (conductors) each, shall be used to compile data for supporting a conclusion that pass criteria are satisfied. Unless otherwise specified, two-piece connectors shall be in a mated state during environmental conditioning.

NOTE 1 It is intended to replace the specifications in this annex by reference to international specifications as they become available.

NOTE 2 For connecting hardware with 8-position modular connectors, the modular connection shall comply with the level A reliability requirements of IEC 60603-7. For connecting hardware with 4-position hermaphroditic connectors, the hermaphroditic connection shall comply with IEC 60807-8 reliability requirements.

B.2 Contact resistance measurement

Contact resistance shall be measured in accordance with IEC 60512-2, Test Method 2A (Millivolt Level Method) and shall conform with the following requirements.

a) If voltage probes cannot be placed within 1,3 mm from the connection point, bulk resistance should be measured and subtracted out to determine contact resistance.

b) Initial interface resistance between mated elements of connecting hardware as well as between connecting hardware and cabling shall not exceed 2,5 mΩ. Also, elements of a connecting system that are subject to more than a single connecting operation throughout normal use shall not exhibit an initial interface resistance in excess of 2,5 mΩ, when newly terminated, at prescribed measurement intervals during or after environmental conditioning.

c) Whenever contact resistance measurements are required on the following tests, interface resistance shall not change by more than 5 mΩ from the initial value.

For 2-piece connectors and shield terminations, the interface resistance of the mated contacts or shield connection shall not exceed 20 mΩ initially, or at the prescribed measurement intervals during or after environmental conditioning.

B.3 Insulation resistance

Insulation resistance shall be measured in accordance with IEC 60512-2, Test 3a, Method C, Test Voltage 500 V d.c. Insulation resistance between any two conductors shall be at least 100 MΩ.

These specimens shall be used as sample group A.

B.4 Durability

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

Evaluation
Inspect and measure contact resistance after 100 cycles. These specimens shall be used as sample group B.

NOTE According to IEC specifications, the TO interface is subject to a minimum durability requirement of 750 cycles. For other connections that are subject to frequent access, the same durability rating (≥750 cycles) is recommended.

B.5 Vibration

Vibration tests shall be performed in accordance with IEC 60068-2-6, Test Method Fc and Guidance.

a) Test conditions

1) Frequency range:	10 Hz – 55 Hz
2) Displacement amplitude:	0,75 mm
3) Sweep cycles:	20 (each of three linear axes)
4) Endurance time:	1 h 45 min (each axis)

b) Evaluation

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

B.6 Stress relaxation

Stress relaxation tests shall be performed in accordance with IEC 60068-2-2, Test Method Ba.

a) Test conditions

1) Test temperature: (70 ± 2) °C

2) Duration: 500 h

b) Evaluation

Inspect and measure contact resistance at (168 ± 10) h intervals.

B.7 Thermal shock

Thermal shock tests shall be performed in accordance with IEC 60068-2-14, Test Method Nb. One-half of sample group A terminals shall be tested in mated (terminated) state. The remaining sample group A terminals shall be tested in an unmated (unterminated) state. Sample group B terminals shall be tested in mated (terminated) state only.

a) Test conditions

1) Low temperature (T_A): (–40 ± 2) °C

2) High temperature (T_B): (70 ± 2) °C

3) Minimum average rate of temperature change: 3 °C/min

4) Exposure time (t_1): 30 min (each temperature)

5) Number of cycles: 100

6) Sample group B shall be subjected to 33 insertion and withdrawal cycles after 50 temperature cycles.

b) Evaluation

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

B.8 Humidity/temperature cycle

Humidity/temperature cycle testing shall be performed in accordance with IEC 60068-2-38, Test Method Z/AD with cold subcycle. One-half of sample group A terminals shall be tested in mated (terminated) state. The remaining sample group A terminals shall be tested in an unmated (unterminated) state. Sample group B terminals shall be tested in mated (terminated) state only.

a) Test conditions

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

1) Low temperature: (25 ± 2) °C

2) High temperature: (65 ± 2) °C

3) Cold subcycle: (–10 ± 2) °C

4) Relative humidity at high and low temperature): (93 ± 3)%

5) Cycle time: 24 h

6) Number of cycles: 21

7) Sample group B shall be subjected to 33 insertion and withdrawal cycles after 7 days and an additional 34 cycles after 21 days.

b) Evaluation

Inspect and measure contact resistance (for groups A and B) and insulation resistance (for group A only) immediately upon removal from the test chamber at 7 day intervals, and after final drying. Recovery of insulation resistance from a humid state to at least 100 MΩ shall occur within 1 h.

B.9 Corrosion testing

Corrosion testing shall be performed in accordance with IEC 60068-2-60 TTD, Method C.

a) Test conditions:

1)	Mixture of polluting gases:	SO_2 (0,5 ± 0,1) × 10^{-6} (vol./vol.)
		H_2S (0,1 ± 0,02) × 10^{-6} (vol./vol.)
2)	Temperature:	(25 ± 2) °C
3)	Relative humidity:	(75 ± 3) %
4)	Duration:	10 days

b) Evaluation

Inspect and measure contact resistance upon removal from the test chamber.

The corrosion test requirements of this annex are for further study.

Annex C
(normative)

Requirements for flexible 100 Ω, 120 Ω and 150 Ω balanced cables

C.1 General requirements

This annex covers additional requirements for flexible patch cords for use with 100 Ω, 120 Ω and 150 Ω balanced cables and connecting hardware. It is strongly recommended that other flexible cables, such as work area and equipment cables, conform to these requirements. The electrical performance of stranded work area cabling, patch cords and equipment cables should fulfil the electrical requirements of the installed horizontal cable given in 8.1 for 100 Ω and 120 Ω balanced cables of the same category, and in 8.2 for 150 Ω balanced cables. In some cases, stranded cables used for patch cords may deviate from the colour scheme specified in IEC 60708-1. For example, it may be desired to provide visual differentiation between solid or stranded conductor cables.

The attenuation in dB/100 m and the d.c. loop resistance in Ω/100 m should not be more than 50 % higher than required in clause 8. It should be noted that these values lead to a maximum equivalent electrical length of 15 m based on 10 m of mechanical length. If these values of the flexible cable exceed the value prescribed above, the mechanical length shall be reduced accordingly.

NOTE 1 Equivalent NEXT loss requirements and attenuation requirements for short lengths of flexible cables with and without connectors are for further study.

NOTE 2 It is intended to supplement the requirements in this annex by reference to International Standards as these become available.

C.2 Additional requirements for 150 Ω flexible cables

In addition to the higher attenuation and d.c. loop resistance for 150 Ω flexible cables the mechanical and electrical requirements of tables C.1 and C.2 shall supersede the corresponding requirements of 8.2 for solid 150 Ω cables.

Table C.1 – Different mechanical characteristics for 150 Ω flexible cables

Cable characteristics		Units	Requirements	Test method
1	Mechanical characteristics			
1.1	Diameter of conductor	mm	0,46 to 0,52	3.4.1 of IEC 61156-1
1.2	Diameter over insulated conductor	mm	≤1,9	3.4.1 of IEC 61156-1
1.7	Number of cable units in a cable		1	
1.9	Outer diameter of cable	mm	≤9,5	3.4.1 of IEC 61156-1