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REDLINE VERSION

INTERNATIONAL STANDARD

Multicore and symmetrical pair/quad cables for digital communications –
Part 1: Generic specification

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colour inside

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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MULTICORE AND SYMMETRICAL PAIR/QUAD CABLES FOR DIGITAL COMMUNICATIONS –

Part 1: Generic specification

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 61156-1:2007+AMD1:2009 CSV. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 61156-1 has been prepared by subcommittee 46C: Wires and symmetric cables, of IEC technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2007 and Amendment 1 published in 2009. This edition constitutes a technical revision.

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

a) modification of the scope in Clause 1 and updating of normative references documents in Clause 2;
b) addition of PoE-related definitions in Clause 3;
c) clarification of differential-mode and common-mode resistors, correction of formulae and addition of IEC 62153-4-9 test method for coupling attenuation in Clause 6;
d) introduction of balunless measurement method in 6.3.1, modification of equipment requirements of unbalance attenuation in 6.3.5 and updating of balun's performance in Table 1;
e) deletion of 'three layers of cables on a drum' method in alien (exogenous) near-end crosstalk measurement in 6.3.8 and addition of terminated input impedance in 6.3.11.4.

The text of this International Standard is based on the following documents:

Draft	Report on voting
46C/1242/FDIS	46C/1249/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English and French.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 61156 series, published under the general title *Multicore and symmetrical pair/quad cables for digital communications*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

MULTICORE AND SYMMETRICAL PAIR/QUAD CABLES FOR DIGITAL COMMUNICATIONS –

Part 1: Generic specification

1 Scope

This part of IEC 61156 is applicable to communication systems such as ISDN, local area networks and data communication systems and specifies the definitions, requirements and test methods of multicore, symmetrical pair and quad cables.

This document is applicable to communication systems such as local area networks (LANs) and data communication cables. It is also applicable to cables used for industrial applications, customer premises wiring and generic cabling comprising installation cables and cables for work area wiring which are defined in ISO/IEC 11801 (all parts).

The cables covered by this document are intended to operate with voltages and currents normally encountered in communication systems. While these cables are not intended to be used in conjunction with low impedance sources, for example the electric power supplies of public utility mains, they are intended to be used to support the delivery of low voltage remote powering applications including but not restricted to Power over Ethernet as specified in ISO/IEC/IEEE 8802-3. More information on the capacity to support these applications according to the installation practices are given in IEC 61156-1-4, IEC TR 61156-1-6 and ISO/IEC TS 29125.

2 Normative references

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

IEC 60028, *International standard of resistance for copper*

IEC 60050-726, *International Electrotechnical Vocabulary (IEV) – Part 726: Transmission lines and wave guides*

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Tests A: Cold*

IEC 60169-22, *Radio-frequency connectors – Part 22: RF two-pole bayonet coupled connectors for use with shielded balanced cables having twin inner conductors (Type BNO)*

IEC 60189-1:19862018, *Low-frequency cables and wires with PVC insulation and PVC sheath – Part 1: General test and measuring methods*[1)]

IEC 60304, *Standard colours for insulation for low-frequency cables and wires*

IEC 60332-1-1, *Tests on electric and optical fibre cables under fire conditions – Part 1-1: Test for vertical flame propagation for a single insulated wire or cable – Apparatus*

[1)] There exists a 2007 edition of 60189-1.

IEC 60332-2-1, *Tests on electric and optical fibre cables under fire conditions – Part 2-1: Test for vertical flame propagation for a single small insulated wire or cable – Apparatus*

IEC 60332-1-2, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*

IEC 60332-2-2, *Tests on electric and optical fibre cables under fire conditions – Part 2-2: Test for vertical flame propagation for a single small insulated wire or cable – Procedure for diffusion flame*

IEC 60332-3-10, *Tests on electric cables under fire conditions – Part 3-10: Test for vertical flame spread of vertically-mounted bunched wires or cables – Apparatus*

IEC 60332-3-24, *Tests on electric and optical fibre cables under fire conditions – Part 3-24: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category C*

IEC 60332-3-25, *Tests on electric and optical fibre cables under fire conditions – Part 3-25: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category D*

IEC 60708, *Low-frequency cables with polyolefin insulation and moisture barrier polyolefin sheath*

IEC 60754-2, *Test on gases evolved during combustion of electric materials from cables – Part 2: Determination of the degree of acidity of gases evolved during the combustion of materials taken from electric cables by measuring pH and conductivity Determination of acidity (by pH measurement) and conductivity*

IEC 60794-1-2:2003, *Optical fibre cables – Part 1-2: Generic specification – Basic optical cable test procedures*

IEC 60794-1-21:2015, *Optical fibre cables – Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical test methods*

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

IEC 60811-1-2:1985, *Common test methods for insulating and sheathing materials of electric and optical cables – Part 1: Methods for general application – Section Two: Thermal ageing methods*

IEC 60811-1-3:1993, *Common test methods for insulating and sheathing materials of electric and optical cables – Part 1: Methods for general application – Section Three: Methods for determining the density – Water absorption tests – Shrinkage test*

IEC 60811-1-4:1985, *Common test methods for insulating and sheathing materials of electric and optical cables – Part 1: Methods for general application – Section Four: Test at low temperature*

IEC 60811-3-1:1985, *Common test methods for insulating and sheathing materials of electric and optical cables – Part 3: Methods specific to PVC compounds – Section One: Pressure test at high temperature – Tests for resistance to cracking*

IEC 60811-4-2:2004, *Insulating and sheathing materials of electric cables – Common test methods – Part 4-2: Methods specific to polyethylene and polypropylene compounds –Tensile strength and elongation at break after conditioning at elevated temperature – Wrapping test*

~~*after conditioning at elevated temperature – Wrapping test after thermal ageing in air – Measurement of mass increase – Long-term stability test – Test method for copper-catalyzed oxidative degradation*~~

IEC 60811-201, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 201: General tests – Measurement of insulation thickness*

IEC 60811-202, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 202: General tests – Measurement of thickness of non-metallic sheath*

IEC 60811-203, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 203: General tests – Measurement of overall dimensions*

IEC 60811-401, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 401: Miscellaneous tests – Thermal ageing methods – Ageing in an air oven*

IEC 60811-501, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulating and sheathing compounds*

IEC 60811-502, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 502: Mechanical tests – Shrinkage test for insulations*

IEC 60811-504, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 504: Mechanical tests – Bending tests at low temperature for insulation and sheaths*

IEC 60811-506, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 506: Mechanical tests – Impact test at low temperature for insulations and sheaths*

IEC 60811-508, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 508: Mechanical tests – Pressure test at high temperature for insulation and sheaths*

IEC 60811-509, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 509: Mechanical tests – Test for resistance of insulations and sheaths to cracking (heat shock test)*

IEC 60811-510, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 510: Mechanical tests – Methods specific to polyethylene and polypropylene compounds – Wrapping test after thermal ageing in air*

IEC 61034 (all parts), *Measurement of smoke density of cables burning under defined conditions*

IEC TR 61156-1-2[2], *Multicore and symmetrical pair/quad cables for digital communications – Part 1-2: Electrical transmission characteristics and test methods of symmetrical pair/quad cables*

IEC TR 61156-1-5, *Multicore and symmetrical pair/quad cables for digital communications – Part 1-5: Correction procedures for the measurement results of return loss and input impedance*

IEC 61196-1-105, *Coaxial communication cables – Part 1-105: Electrical test methods – Test for withstand voltage of cable dielectric*

2 IEC TR 61156-1-2 is due to become a TS in 2023.

IEC 62012-1:~~2004~~2002, *Multicore and symmetrical pair/quad cables for digital communications to be used in harsh environments – Part 1: Generic specification*

IEC 62153-4-3:2013, *Metallic communication cables test methods – Part 4-3: Electromagnetic compatibility (EMC) – Surface transfer impedance – Triaxial method*

~~IEC 62153-4-4, *Metallic communication cables test methods – Part 4-4: Electromagnetic compatibility (EMC) – Shielded screening attenuation, test method for measuring of the screening attenuation a_s up to and above 3 GHz*~~

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

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

IEC 62255 (all parts), *Multicore and symmetrical pair/quad cables for broadband digital communications (high bit rate digital access telecommunication networks) – Outside plant cables*

ISO/IEC TS 29125:2017, *Information technology – Telecommunications cabling requirements for remote powering of terminal equipment*

~~ITU-T Recommendation G.117:1996, *Transmission aspects of unbalance about earth* –~~

~~ITU-T Recommendation O.9:1999, *Measuring arrangements to assess the degree of unbalance about earth*~~

3 Terms and definitions

For the purposes of this document, the following terms and definitions~~, as well as those given in IEC 60050-726,~~ apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
resistance unbalance
difference in resistance of the conductors within a pair or one side of a quad or between pairs or quads

Note 1 to entry: Resistance unbalance is expressed as a percentage (%).

3.2
mutual capacitance
electrical charge storage parameter of a pair of conductors (or with respect to the side of a quad)

Note 1 to entry: Mutual capacitance is one of the four primary transmission line parameters: mutual capacitance, mutual inductance, resistance and conductance.

Note 2 to entry: Mutual capacitance is expressed in pF/m..

3.3
capacitance unbalance to earth
arithmetic difference of the capacitance to earth of the conductors of a pair or one side of a quad

Note 1 to entry: Capacitance unbalance is expressed in pF/m.

3.4
screen
continuous conducting layer or assembly of conducting layers having the function of reducing the penetration of an electric, magnetic or electromagnetic field into a given region

[SOURCE: IEC 60050-195:2021,195-02-37, modified – "continuous conducting layer or assembly of conducting layers having the function of reducing " has replaced "device intended to reduce "]

3.5
balun
~~balanced to unbalanced impedance matching transformer~~

device to provide impedance transformation between balanced and unbalanced components

[SOURCE:ISO/IEC 11801-4:2017, 3.1.2]

3.6
balunless
virtual balun used instead of the physical transformers, achieved by mathematical algorithm, and calculated from lumped parameters or distributed parameter network

3.7
transfer impedance
Z_T
quotient of the longitudinal voltage of an electrically short uniform cable, induced in the outer circuit – formed by the screen under test and the measuring jig – and the current fed into the inner circuit – the cable under test itself or vice versa, related to unit length

Note 1 to entry: Transfer impedance is expressed in mΩ/m.

[SOURCE: IEC 62153-4-3:2013, 3.3, modified – "of an electrically short uniform cable" has been added, "outer circuit" has replaced "matched outer circuit", "the cable under test itself" has been added, "related to unit length" has replaced "(see Figure 1)".]

3.8
coupling attenuation
a_C
~~ratio between the transmitted power through the conductors and the maximum radiated peak power, conducted and generated by the exited common-mode currents~~

for a screened balanced cable, the sum of the effects of the unbalance attenuation a_U of the symmetric pair and the screening attenuation α_s of the screen of the cable under test

Note 1 to entry: For electrically long devices, i.e. above the cut-off frequency, the coupling attenuation α_C is defined as the logarithmic ratio of the feeding power P_1 and the periodic maximum values of the coupled power $P_{r,\,max}$ in the outer circuit.

Note 2 to entry: Coupling attenuation is expressed in dB.

[SOURCE: IEC 62153-4-7:2021, 3.4, modified –"cable" has replaced "device", "sum of the effects'" has replaced "sum", Note 2 has been added.]

3.9
current carrying capacity
maximum current a cable circuit (one or several conductors) can support resulting in a specified increase of the surface temperature of the conductor beyond the ambient temperature, not exceeding the maximum allowed operating temperature of the cable

3.10
velocity of propagation
~~(~~phase velocity~~)~~
speed at which a sinusoidal signal propagates on a pair in the cable

Note 1 to entry: Velocity of propagation is expressed in m/s.

3.11
~~(~~phase delay~~)~~
delay
time duration between the instants that the wave front of a sinusoidal travelling wave, defined by a specified phase, passes two given points in a cable

Note 1 to entry: Phase delay is expressed in s/m.

3.12
differential phase delay
~~(~~delay skew~~)~~
difference in phase delay between any two pairs in the cable

Note 1 to entry: Differential phase delay (skew) is expressed in s.

3.13
attenuation
decrease in magnitude of power of a signal that propagates along a pair of a cable

Note 1 to entry: Attenuation is expressed in dB/m.

3.14
ambient temperature
temperature of the room or space surrounding the cable

Note 1 to entry: Ambient temperature is expressed in degree Celsius (°C).

3.15
operating temperature
surface temperature of the conductors of a cable

Note 1 to entry: The operating temperature is the sum of the ambient temperature and of the temperature increase due to the carried power.

Note 2 to entry: Operating temperature is expressed in degree Celsius (°C).

3.16
unbalance attenuation
UA
~~magnitude of power of a signal that propagates between the common-mode circuit and the differential-mode circuit of a cable~~

logarithmic ratio of the differential mode power to the common mode power in a balanced line, or vice versa

Note 1 to entry: Unbalance attenuation is expressed in dB.

Note 2 to entry: Unbalance attenuation is also often referred to as conversion loss: TCL (transverse conversion loss), TCTL (transverse conversion transfer loss), LCL (longitudinal conversion loss), LCTL (longitudinal conversion transfer loss), EL TCTL (equal level transverse conversion transfer loss) and EL LCTL (equal level longitudinal conversion loss transfer loss).

3.17
transverse conversion loss
TCL
logarithmic ratio of the differential-mode circuit power at the near end and the common-mode coupling power measured at the near end

3.18
equal level transverse conversion transfer loss
EL TCTL
output-to-output measurement of the logarithmic ratio of the differential-mode circuit power at the near end and the common-mode coupling power measured at the far end

Note 1 to entry: EL TCTL is calculated by the difference between the measured TCTL and the differential-mode insertion loss of the disturbed pair.

3.19
near-end crosstalk
NEXT
magnitude of the signal power coupling from a disturbing pair at the near end to a disturbed pair measured at the near end

Note 1 to entry: Near-end crosstalk is expressed in dB.

3.20
far-end crosstalk
FEXT
magnitude of the signal power coupling from a disturbing pair at the near end to a disturbed pair measured at the far end

Note 1 to entry: Far-end crosstalk is expressed in dB.

3.21
power sum of crosstalk
PS
summation of the crosstalk power from all disturbing pairs into a disturbed pair

Note 1 to entry: The summation is applicable to near-end and far-end crosstalk.

Note 2 to entry: The power sum of crosstalk is expressed in dB.

~~**3.12**~~
~~**attenuation to crosstalk ratio, near-end**~~
~~*ACR-N*~~
~~arithmetic difference between the near-end crosstalk and the attenuation of the disturbed pair~~

~~NOTE Attenuation to crosstalk ratio, near-end, is expressed in dB.~~

3.22
attenuation to crosstalk ratio, far-end
ACR-F
arithmetic difference between the far-end crosstalk and the attenuation of the disturbed pair

Note 1 to entry: Attenuation to crosstalk ratio, far-end, is expressed in dB.

3.23
alien (exogenous) near-end crosstalk
ANEXT
near-end crosstalk where the disturbing and disturbed pairs are contained in different cables

Note 1 to entry: Alien (exogenous) near-end crosstalk is expressed in dB.

3.24
alien (exogenous) far-end crosstalk
AFEXT
far-end crosstalk where the disturbing and disturbed pairs are contained in different cables

Note 1 to entry: Alien (exogenous) far-end crosstalk is expressed in dB.

3.25
alien (exogenous) far-end crosstalk
AACR-F
far-end crosstalk where the disturbing and disturbed pairs are contained in different cables

Note 1 to entry: Alien (exogenous) far-end crosstalk is expressed in dB.

3.26
power sum of alien (exogenous) near-end crosstalk
~~***PSA***~~
PS ANEXT
summation of the near-end alien (exogenous) crosstalk power from all disturbing pairs into a disturbed pair in different cables

~~Note 1 The summation is applicable to near-end and far-end alien (exogenous) crosstalk.~~

Note 1 to entry: The power sum of alien (exogenous) near-end crosstalk is expressed in dB.

3.27
power sum of alien (exogenous) far-end crosstalk
PS AACR-F
summation of the alien (exogenous) far-end crosstalk power from all disturbing pairs into a disturbed pair in different cables

Note 1 to entry: The power sum of far-end alien (exogenous) crosstalk is expressed in dB.

3.28
characteristic impedance
Z_C
impedance at the input of a homogeneous line of infinite length

Note 1 to entry: The impedance value is expressed in Ω, ~~calculated~~ at relevant frequencies, as the square root of the product of the impedance measured at the near end (input) of a cable pair when the far end is terminated by ~~a short~~ an open circuit load and then an ~~open~~ short circuit load.

Note 2 to entry: The asymptotic value at high frequencies is denoted as Z_∞.

Note 3 to entry: The characteristic impedance of a homogeneous cable pair is given by the quotient of a voltage wave and current wave which are propagating in the same direction, either forwards or backwards.

Note 4 to entry: For homogeneous ideal cables, this test method yields a flat smooth curve over the whole frequency range. Real cables with distortions give curves with some roughness.

3.29
terminated input impedance
Z_{in}
impedance value, expressed in Ω, at relevant frequencies, measured at the near end (input) when the far end is terminated with the system nominal impedance, Z_R

~~(See IEC/TR 62152.)~~

3.30
fitted characteristic impedance
Z_m
impedance value, expressed in Ω, calculated by applying a least squares function fitting algorithm to the measured characteristic impedance values

3.31
mean characteristic impedance
Z_∞
asymptotic value at which the characteristic impedance approaches at sufficiently high frequencies (≈100 MHz) such that the imaginary part (phase angle) is insignificant

Note 1 to entry: Normally measured from the capacitance and time delay.

Note 2 to entry: Applicable for cables with frequency independence of mutual capacitance.

3.32
return loss
RL
ratio of reflected power to input power at the input terminals of a cable pair

Note 1 to entry: Return loss is expressed in dB.

3.33
bundled cable
grouping or assembly of several individual cables that are systematically laid up

Note 1 to entry: Bundled cables are also referred to as speed-wrap, whip, or loomed cables.

3.34
remote powering
supply of power to application specific equipment via balanced cabling

[SOURCE: ISO/IEC TS 29125:2017, 3.1.5]

3.35
safety extra-low voltage
SELV
AC voltage the RMS value of which does not exceed 50 V or ripple-free DC voltage the value of which does not exceed 120 V, between conductors, or between any conductor and reference earth, in an electric circuit which has galvanic separation from the supplying electric power system by such means as a separate-winding transformer

Note 1 to entry: Maximum voltage lower than 50 V AC or 120 V ripple-free DC may be specified in particular requirements, especially when direct contact with live parts is allowed.

Note 2 to entry: The voltage limit should not be exceeded at any load between full load and no-load when the source is a safety isolating transformer.

Note 3 to entry: Ripple-free qualifies conventionally an RMS ripple voltage of not more than 10 % of the DC component; the maximum peak value does not exceed 140 V for a nominal 120 V ripple-free DC system and 70 V for a nominal 60 V ripple-free DC system.

3.36
continuous operating temperature
COT
maximum temperature which ensures the stability and integrity of the material for the expected life of the equipment, or part, in its intended application

3.37
hygroscopic
characteristic of a material to absorb moisture from the atmosphere

3.38
wicking
longitudinal flow of a liquid in a material due to capillary action

4 Installation considerations

The cables shall be designed to meet the installation conditions encountered for each area as follows.

a) Equipment cables

The cables are used between work stations and peripheral equipment (for example, printer).

b) Work area cables

The cables are used between the work station and the communication outlets.

c) Horizontal floor wiring cables

The cables are used between the work area communication outlet and the communication closet.

d) Riser cables and building back-bone cables

The cables are used for horizontal installation or vertically between floors.

e) Campus cables

These cables are used to interconnect buildings and shall be suitable for outdoor installation. The cables ~~should~~ shall be sheathed and protected in accordance with IEC 62255 (all parts).

f) Delivery of power

For cables delivering power using only SELV systems for remote powering, the COT shall be considered.

NOTE The related document is IEC 60364-7-716.

5 Materials and cable construction

5.1 General remarks

The choice of materials and cable construction shall be suitable for the intended application and installation of the cable. ~~Particular care shall be taken to meet~~ Any special requirements for EMC (electromagnetic compatibility), fire performance, or SELV should be considered.

5.2 Cable constructions

5.2.1 General

The cable construction shall be in accordance with the details and dimensions given in the relevant detail specification.

5.2.2 Conductor

The conductor shall consist of annealed copper, uniform in quality and free from defects. The properties of the copper shall be in accordance with IEC 60028.

The conductor may be either solid or stranded. The solid conductor shall be circular in section and may be plain or metal-coated. The solid conductor shall be drawn in one piece. Joints in the solid conductor are permitted, provided that the breaking strength of a joint is not less than 85 % of the breaking strength of the unjointed solid conductor.

The stranded conductor shall consist of strands circular in section and assembled without insulation between them by concentric stranding or bunched.

NOTE A bunched strand is not recommended for insulation displacement connection (IDC) application.

The individual strands of the conductor may be plain or metal-coated.

Joints in individual strands are permitted provided that the tensile strength of a joint is not less than 85 % of the breaking strength of the unjointed individual strand. Joints in the complete stranded conductor are not permitted unless allowed and specified in the relevant detail specification.

The conductor of the work area and equipment cables may consist of one or more elements of thin copper or copper alloy tape which shall be applied spirally over a fibrous thread. Joints in the complete element are not permitted.

5.2.3 Insulation

5.2.3.1 General requirements

The conductor insulation is composed of one or more suitable dielectric materials. The insulation may be solid, cellular or composite (for example, foam skin).

The insulation shall be continuous, having a uniform thickness.

The insulation shall be applied to fit closely to the conductor.

The insulated conductors may be identified by colours ~~and/or~~, additional ring markings ~~and/~~or symbols achieved by the use of coloured insulation or by a coloured surface using extrusion, printing or painting. Colours shall be clearly identifiable and shall correspond reasonably with the standard colours shown in IEC 60304.

5.2.3.2 Colour code

The colour code for insulation is given in the relevant detail specification.

5.2.4 Cable element

5.2.4.1 General

The cable element is

– a pair consisting of two insulated conductors twisted together and designated wire "a" and wire "b", or

– a quad consisting of four insulated conductors twisted together and designated wire "a", wire "c", wire "b" and wire "d" in order of rotation.

The choice of the maximum average length of lay in the finished cable shall be made with respect to the specified crosstalk requirements, handling performance and the pair or quad integrity.

NOTE Forming the element with a variable lay can lead to the infrequent but acceptable occurrence of the maximum lay being longer than the specified length of lay.

5.2.4.2 Screening of the cable element

When a screen is required over the pair or quad, it may consist of the following:

a) ~~an aluminium~~ a metallic tape laminated to a plastic tape;

b) ~~an aluminium~~ a metallic tape laminated to a plastic tape and a metal-coated or plain copper drain wire whereby the metal tape is in contact with the drain wire;

c) a metallic braid;

d) ~~an aluminium~~ a metallic tape laminated to a plastic tape and a metallic braid.

~~Care should be taken when putting dissimilar metals in contact with each other.~~ Coatings or other methods of protection ~~may~~ should be ~~necessary~~ considered in order to prevent galvanic interaction when putting dissimilar metals in contact with each other.

A protective wrapping may be applied either under ~~and/~~or over the screen or both.

5.2.5 Cable make-up

The cable elements may be laid up in concentric layers or in unit construction. The cable core may be protected by wrappings of a non-hygroscopic, non-wicking tape.

NOTE 1 Fillers ~~may~~ can be used to maintain a circular formation.

NOTE 2 Forming the element with a variable lay can lead to the infrequent but acceptable occurrence of the maximum lay being longer than the specified length of lay.

5.2.6 Screening of the cable core

The cable core may be ~~screened~~ covered by a screen being part of the shielding and grounding system of the cabling. The possible design can be

a) ~~an aluminium~~ a metallic tape laminated to a plastic tape which may be bonded to the sheath, for example F/UTP structure;
b) ~~an aluminium~~ a metallic tape laminated to a plastic tape and a metal-coated or plain copper drain wire whereby the metal tape is in contact with the drain wire, for example F/UTP structure;
c) a metallic braid, for example S/UTP structure;
d) ~~an aluminium~~ a metallic tape laminated to a plastic tape and a metallic braid, for example SF/UTP structure;
e) plain copper or aluminium tape, for example F/UTP structure.

~~Care should be taken when putting dissimilar metals in contact with each other.~~ An unlaminated metallic tape is also permitted if it can meet the requirements of performance, for example, strength.

Coatings or other methods of protection ~~may~~ should be ~~necessary~~ considered in order to prevent galvanic interaction when putting dissimilar metals in contact with each other.

A protective wrapping may be applied either under ~~and/~~or over the screen, or both. Typical designs and their denominations are listed in Annex A.

5.2.7 Sheath

The sheath shall be a polymeric material.

The sheath shall be continuous, having a uniform thickness.

The sheath shall be applied to fit closely to the core of the cable. In the case of screened cables, the sheath shall not adhere to the screen except when it is intentionally bonded to it.

The colour of the sheath may be specified in the relevant detail specification.

5.2.8 Identification

5.2.8.1 Cable marking

Each length of cable shall bear the name of the supplier and the cable type and, when provided, the year of manufacture, using one of the following methods:

a) coloured threads or tapes;

b) printed tape;

c) printing on the core wrappings;

d) marking on the sheath.

Additional markings, for example maximum voltage, temperature rating, etc., may be provided on the sheath as indicated in the relevant detail specification.

5.2.8.2 Labelling

The following information shall be provided either on a label attached to each length of the finished cable or on the outside of the product package:

a) type of cable;

b) supplier's name or logo;

c) year of manufacture;

d) length of cable in metres.

5.2.9 Finished cable

The finished cable shall have adequate protection for storage and shipment.

6 Characteristics and requirements

6.1 General remarks – Test configurations

Unless otherwise specified, all the tests shall be performed assuming that the operating temperature is 20 °C. The temperature of the cable shall be stabilized at 20 °C and the test signal shall be low enough to avoid any temperature increase.

NOTE Temperature rise is expected when testing for the cable's application in remote powering installations.

The computed requirements, rounded to one decimal place, shall be used to determine compliance.

Typical test configurations for the test specimen are

a) laid out on a non-metallic surface at least 25 mm from a conductive surface;

b) supported in aerial spans in such a way that there is a minimum separation of 25 mm between convolutions;

c) wound as a single open helix on a drum with at least 25 mm between turns.

The configurations a), b) and c) are not necessary for screened cables.

The parameters of mutual capacitance, crosstalk, characteristic impedance and attenuation sometimes show measured values up to 10 % higher when the cable is measured in its packaging. This difference arises due to the tight packaging density and interwinding effects. Also, box packaging ~~may~~ can negatively affect the cable return loss, crosstalk and characteristic impedance with full or partial recovery of cable performance after installation.

In case of doubt, the measurements of mutual capacitance, impedance, attenuation and crosstalk shall be performed on a cable sample removed from its packaging.

Measurement procedures for alien (exogenous) crosstalk specify ~~options~~ the special test configurations for the mounting of the cables ~~into special test configurations~~.

~~The common-mode termination resistors shall be~~

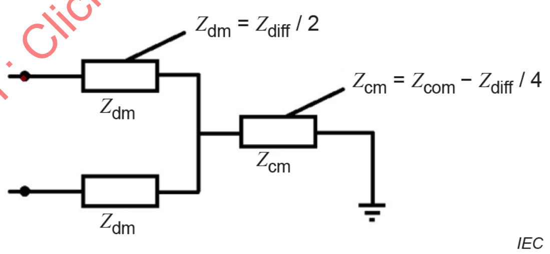
- ~~0 Ω for individually screened pair cables;~~
- ~~25 Ω for overall screened cables;~~
- ~~45 Ω to 50 Ω for unscreened cables.~~

The differential-mode and common-mode termination resistors should be used to terminate inactive pairs and opposite ends of active pairs for near-end crosstalk and far-end crosstalk testing (see Figure 1). For cables having a nominal impedance (Z_{diff}) of 100 Ω, the common-mode impedance (Z_{com}) is:

- about 75 Ω for up to 25 pair-count unscreened pair cables,
- about 50 Ω for common screened pair cables and more than 25 pair-count unscreened pair cables,
- about 25 Ω for individually screened pair cables.

In principle in balun measurements, the test shall be carried out with the condition that differential-mode impedance (Z_{diff}) and common mode impedance (Z_{com}) of the test specimen are matched by the balun and the vector network analyzer (or equivalent instruments), respectively.

But in practice, as the vector network analyzer (or equivalent instrument) used in the measurement has 50 Ω ports in general and the common mode impedance of the balun is also 50 Ω, the common mode impedance of the termination shall be 50 Ω unless otherwise specified. This is to simplify measurements when the common mode impedance of the test specimen varies from 25 Ω to 75 Ω.



Key

Z_{dm} is the differential-mode termination resistor (Ω);

Z_{cm} is the common-mode termination resistor (Ω).

Z_{diff} is the differential-mode impedance of cable (Ω);

Z_{com} is the common-mode impedance of cable (Ω).

Figure 1 – Resistor terminations in balun measurements

Resistor terminations in balunless measurements can be found in IEC TR 61156-1-2.

6.2 Electrical characteristics and tests

6.2.1 Conductor resistance

The measurement of the conductor resistance shall be in accordance with ~~6.1 of IEC 60189-1~~ IEC 60189-1:2018, 8.1.

NOTE For resistance, general information can be found in IEC TR 61156-1-6.

6.2.2 Resistance unbalance

6.2.2.1 General requirement

The measurement of the resistance unbalance and the accuracy of the measurement equipment shall be in accordance with IEC 60708.

NOTE For resistance unbalance, general information can be found in IEC TR 61156-1-6.

6.2.2.2 Resistance unbalance within a pair

The resistance unbalance between conductors of a pair or on the same side of a quad is given by

$$\Delta R = \frac{(R_{max} - R_{min})}{(R_{max} + R_{min})} \times 100\% \qquad (1)$$

where

ΔR is the conductor resistance unbalance (%);

R_{max} is the resistance for the conductor with the highest resistance value (Ω);

R_{min} is the resistance for the conductor with the lowest resistance value (Ω).

6.2.2.3 Resistance unbalance between pairs

The resistance unbalance between pairs or sides of quads is given by

~~$$\Delta RP_{i,k} = 100 \frac{\left| R_{max\ i} \cdot R_{min\ i} \left(R_{max\ k} + R_{min\ k}\right) - R_{max\ k} \cdot R_{min\ k} \left(R_{max\ i} + R_{min\ i}\right)\right|}{R_{max\ i} \cdot R_{min\ i} \left(R_{max\ k} + R_{min\ k}\right) + R_{max\ k} \cdot R_{min\ k} \left(R_{max\ i} + R_{min\ i}\right)} \qquad (2)$$~~

$$\Delta RP_{i,k} = \frac{\left| R_{max\ i} \times R_{min\ i} \left(R_{max\ k} + R_{min\ k}\right) - R_{max\ k} \times R_{min\ k} \left(R_{max\ i} + R_{min\ i}\right)\right|}{R_{max\ i} \times R_{min\ i} \left(R_{max\ k} + R_{min\ k}\right) + R_{max\ k} \times R_{min\ k} \left(R_{max\ i} + R_{min\ i}\right)} \times 100\% \qquad (2)$$

where

$\Delta RP_{i,k}$ is the resistance unbalance between pair i and pair k (%);

R_{max} is the resistance of the wire with the highest resistance of a pair (Ω);

R_{min} is the resistance of the wire with the lowest resistance of a pair (Ω);

i,k $i \neq k$ where i = 1 to n and k = 1 to n for n = number of pairs.

6.2.3 Dielectric strength

This measurement shall be carried out before the measurement of insulation resistance described in 6.2.4.

The measurement of dielectric strength shall be in accordance with IEC 61196-1-105 for conductor/conductor, conductor/screen (if present) and screen/screen (if present).

NOTE This test is important to ensure safety is not contravened in remote powering installations.

6.2.4 Insulation resistance

This measurement shall be carried out after the dielectric strength test described in 6.2.3.

The measurement of insulation resistance between conductor/conductor, conductor/ screen and screen/screen shall be in accordance with IEC 60189-1:2018, 8.3. The test voltage shall be between 100 V and 500 V DC unless otherwise specified in the detail specification.

6.2.5 Mutual capacitance

The measurement of the mutual capacitance of pairs in a multipair or quad cable shall be in accordance with IEC 60189-1:2018, 8.4.

6.2.6 Capacitance unbalance to earth

The measurement of the capacitance unbalance in a multipair or quad cable shall be in accordance with IEC 60189-1:2018, 8.5.

The capacitance unbalance to earth of a pair or one side of a quad is given by

$$\Delta C_e = C_1 - C_2 \tag{3}$$

where

ΔC_e is the pair-to-earth capacitance unbalance (pF/km);

C_1 is the capacitance between conductor "a" and conductor "b", with conductor "b" connected to all other conductors, to the screen (if present) and to earth (pF/km);

C_2 is the capacitance between conductor "b" and conductor "a", with conductor "a" connected to all other conductors, to the screen (if present) and to earth (pF/km).

~~If the cable under test has a length, L, other than 500 m, the measured value shall be corrected:~~

~~– for pair-to-pair and side-to-side by~~

$$C_{corr} = \frac{C_{meas}}{0{,}5 \times \left(L/500 + \sqrt{L/500}\right)} \tag{4}$$

~~– for pair-to-earth and side-to-earth by~~

$$C_{corr} = \frac{C_{meas}}{L/500} \tag{5}$$

~~where~~

~~C_{corr} is the corrected capacitance (pF/m);~~

~~C_{meas} is the measured capacitance (pF/m);~~

~~L is the length of cable under test (m).~~

The test result of the capacitance unbalance to earth shall be corrected:

– for pair-to-earth and side-to-earth by

$$\Delta C_e = C_{meas} \times \frac{1000}{L} \quad (4)$$

where

ΔC_e is the capacitance unbalance to earth (pF/km);

C_{meas} is the measured capacitance (pF/km);

L is the length of cable under test (m).

If required, the test result of capacitance unbalance for pair-to-pair and side-to-side shall be specified in the detailed specification.

6.2.7 Transfer impedance

The measurement of the transfer impedance shall be in accordance with IEC 62153-4-3. All of the screens shall be connected together at the ends of the test specimen. The transfer impedance shall be measured over the frequency range indicated in the relevant sectional specification.

6.2.8 Coupling attenuation

The ~~measurement~~ test method of the coupling attenuation shall be in accordance with IEC 62153-4-5 or IEC 62153-4-9. All of the screens shall be connected together at the ends of the test specimen. The coupling attenuation of all pairs within the specimen shall be measured over the frequency range indicated in the relevant sectional specification.

IEC 62153-4-9 shall be the referee test method to resolve doubts or dispute.

6.2.9 Current-carrying capacity

~~Under consideration.~~

If required, the test method for current carrying capacity is described in IEC 61156-1-4. As the current carrying capacity is significantly determined by the installation conditions, general guidance of ISO/IEC TS 29125 should be considered.

NOTE The minimum conductor size (maximum resistance) will be used in the calculation of each cable being considered for its maximum current carrying capacity as batch deliveries can vary.

6.3 Transmission characteristics

6.3.1 General requirements

Transmission measurements are in the balanced mode with measuring equipment (network analyzer or signal generator~~/~~ and receiver) and baluns to connect the cable to the equipment. The baluns shall be selected to match the test equipment to the cable nominal impedance and shall have the relevant performance characteristics given in Table 1. ~~The residual mismatch of the baluns is compensated by calibrating the system with the baluns connected to a short length (≤1 m) of the cable to be tested.~~

All the tests shall be carried out over the whole specified frequency range and at the same frequency points of the calibration procedure. A full two-port calibration shall be done to get the best accuracy, and the length of the cable for a through calibration should be as short as possible.

All the tests shall be carried out in both directions or at both ends.

An alternative to balun measurement method is the balunless measurement method which is specified in IEC TR 61156-1-2. For frequencies higher than 1 GHz, the balunless measurement method is recommended.

The length of cable under test shall be 100 m, unless otherwise specified.

6.3.2 Velocity of propagation (phase velocity)

The velocity of propagation shall be determined over the frequency range indicated in the relevant sectional specification by radian frequency and phase constant.

The test equipment schematic is given in Figure 2. For this measurement, the common-mode balun ports are optional.

The measurement determines the frequency interval, Δf for which the phase of the output signal makes a 2π radians rotation in comparison with the input signal.

The velocity of propagation is determined from

$$v_p = L \cdot \Delta f \qquad (6)$$

where

v_p is the phase velocity (m/s);

L is the length of the cable under test (m);

Δf is the frequency interval (Hz).

The velocity of propagation is given by

$$v_{(f)} = \frac{\omega_{(f)}}{\beta_{(f)}} = \frac{2\pi f}{\beta_{(f)}} \qquad (5)$$

where

f is the frequency (Hz);

$v_{(f)}$ is the phase velocity at frequency f (m/s);

$\beta_{(f)}$ is the phase constant (rad/m);

$\omega_{(f)}$ is the radian frequency.

In the high frequency, the cable's propagation velocity is approximately constant, so the phase velocity may be assessed by the group velocity for an easier measurement. When signals with multiple frequency components propagate along a cable, if these frequencies are very close and their differences are much smaller than the central frequency, the group velocity is determined from Formula (6). Δf is the frequency interval, for which the phase of the output signal makes a 2π radians rotation in comparison with the input signal.

$$v_{(G)} = L \times \Delta f \qquad (6)$$

where

$v_{(G)}$ is the group velocity (m/s);

L is the length of the cable under test (m);

Δf is the frequency interval (Hz).

In order to evaluate Δf with sufficient accuracy, the frequency difference $\Delta f'$ for n rotations of 2π radians ~~may~~ can be measured as

$$\Delta f = \Delta f'/n \tag{7}$$

where

Δf is the frequency interval (Hz);

$\Delta f'$ is the frequency difference for n rotations (Hz);

n is the number of rotations ≤ 10.

Detailed information of phase velocity and group velocity can be found in IEC TR 61156-1-2.

6.3.3 Phase delay and differential delay (delay skew)

The phase delay is determined from the phase velocity:

$$\tau_p = \frac{L}{v_p} \tag{8}$$

where

τ_p is the phase delay (s);

v_p is the phase velocity (m/s);

L is the cable length under test (m).

The differential phase delay (delay skew) is determined from

$$\Delta\tau_p = L \times \left| \frac{1}{v_{p,1}} - \frac{1}{v_{p,2}} \right| \tag{9}$$

where

$\Delta\tau_p$ is the differential phase delay (delay skew) (s);

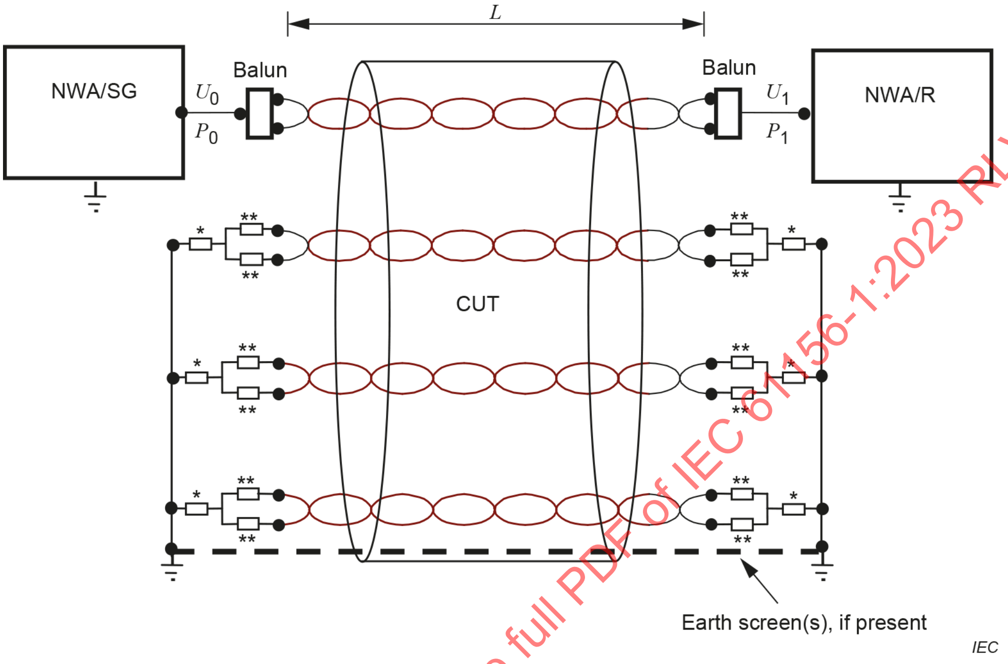
$v_{p,1}$ is the phase velocity of one pair (m/s);

$v_{p,2}$ is the phase velocity of another pair (m/s).

6.3.4 Attenuation

6.3.4.1 Attenuation at 20 °C operating temperature

The measurement shall be over the frequency range indicated in the relevant sectional specification. The test schematic is given in Figure 2. For this measurement, the common- mode balun ports are optional.



Key

CUT cable under test

NWA/SG network analyzer port or signal generator

NWA/R network analyzer port or receiver

* common-mode termination resistor

** differential-mode termination resistor (matched in pairs)

L length of cable under test (m)

U_0 voltage at network analyzer port or signal generator (V)

U_1 voltage at network analyzer port or receiver (V)

P_0 power at network analyzer port or signal generator (W)

P_1 power at network analyzer port or receiver (W)

Figure 2 – Test set-up for the measurement of attenuation, velocity of propagation and phase delay

The measurements are made at ambient temperature, and attenuation on a for 100 m length of cable is given by Formula (10).

$$\alpha = 10 \times \log_{10}\left(\frac{P_0}{P_1}\right) \quad (10)$$

$$= 20 \times \log_{10}\left(\frac{U_0}{U_1}\right)$$

where

~~α is the measured attenuation (dB/100 m) and is corrected to 20 °C as follows.~~

$$\alpha = \left|\frac{100}{L}\right| \times 10\lg\left|\frac{P_0}{P_1}\right| \tag{10}$$

where

α is the attenuation in 100 m (dB/100 m) and is corrected to 20 °C as follows.

$$\alpha_{20} = \frac{\alpha}{1 + \delta_{\text{cable}} \times (T - 20)} \tag{11}$$

where

α_{20} is the attenuation corrected to 20 °C (dB/100 m);

δ_{cable} is the attenuation temperature coefficient (%/°C);

T is the ambient temperature (°C).

Attenuation temperature coefficient values are given in the relevant sectional specification.

6.3.4.2 Attenuation at elevated ambient temperatures

6.3.4.2.1 Test chamber

The test chamber shall be either an air-circulating oven or an environmental chamber. The test chamber shall be capable of maintaining the required test temperature, ±2 °C, for the duration of the test. The chamber dimensions shall be adequate to contain the sample and fixtures as required to support the sample. The chamber shall be provided with access ports for connecting the sample to the test equipment. The maximum length of the cable ends extending out of the test chamber shall be 1 m.

6.3.4.2.2 Sample preparation and test configuration

The sample may be loosely coiled with a minimum diameter of 18 cm and placed in the chamber. In this configuration the wraps of the coil may be in close proximity and inter-winding coupling may appear in the test results for unscreened cable.

Alternatively, the sample may be wound on a non-metallic drum with adjacent wraps separated by a minimum of 2,5 cm which will eliminate inter-winding coupling for unscreened cable.

6.3.4.2.3 Test procedure

The attenuation of the sample shall be measured at ambient temperature in accordance with 6.3.4.1 after conditioning in the chamber for at least 4 h.

The temperature in the chamber shall be maintained at the required temperature, and the attenuation of the sample shall be measured again after a time duration of between 4 h and 24 h. The test signal shall be low enough to avoid any temperature increase.

A mathematical smoothing algorithm that ~~may~~ can be applied to the measured attenuation data to correct for inter-winding coupling is given by the following:

~~$$\alpha_{\text{sm}} = a + b \times \sqrt{f} + c \times f + d / \sqrt{f} \tag{12}$$~~

$$\alpha_{sm} = a \times \sqrt{f} + b \times f + c / \sqrt{f} + d \qquad (12)$$

where

α_{sm} is the smoothed attenuation data (dB/100 m);

a, b, c, d are the regression coefficients;

f is the frequency (Hz).

6.3.4.3 Attenuation temperature coefficient

The attenuation temperature coefficient is given by Formula (13).

$$\delta_{cable} = \frac{\alpha_{T2} - \alpha_{T1}}{\alpha_{T1} \times (T_2 - T_1)} \times 100\% \qquad (13)$$

where

δ_{cable} is the attenuation temperature coefficient (%/°C);

α_{T1} is the attenuation at temperature T_1 (dB/100 m);

α_{T2} is the attenuation at temperature T_2 (dB/100 m);

T_1 is the reference or ambient temperature (°C);

T_2 is the elevated temperature (°C).

NOTE The calculation according to Formula (13) is applicable to both the measured and the smoothed attenuation data.

6.3.5 Unbalance attenuation

6.3.5.1 Equipment

a) ~~It is mandatory to create~~ A defined return (common-mode) path shall be created for unbalanced attenuation measurement. This is normally achieved by earthing all other pairs and screen(s) if present in common to the balun earth. The pairs shall be terminated with differential-mode and common-mode terminations and earthed at near and far ends. However, the cable under test may be wound onto an earthed metal drum. The drum surface may have a suitable groove, wide enough to contain the cable and shall be adequate to hold 100 m of cable in one layer.

b) Both the balun method and the balunless method are permitted, in order to do a measure for unbalance attenuation. For the balun measurement method, the baluns shall have a common-mode port and the characteristics given in Table 1. For the balunless measurement method, the equipment shall comply with IEC TR 61156-1-2.

c) A vector network analyzer or generator~~/~~ and receiver combination suitable for the required frequency and dynamic range can be used.

~~c) The baluns shall have a common-mode port and the characteristics given in Table 1.~~

d) A time domain reflectometer or a VNA having a time domain analysis function by using inverse discrete Fourier transformation can be used as ~~(~~optional~~)~~ equipment.

Table 1 – Test balun performance characteristics

Parameter	Class A-250 value	Class A-600 value	Class B value
~~Impedance, primary[a]~~	~~50 Ω unbalanced~~	~~50 Ω unbalanced~~	~~50 Ω unbalanced~~
~~Impedance, secondary~~	~~Matched balanced~~	~~Matched balanced~~	~~Matched balanced~~
~~Insertion loss~~	~~3 dB max.~~	~~3 dB max.~~	~~10 dB max.~~
~~Return loss, secondary~~	~~20 dB min.~~	~~12 dB min., 5-15 MHz~~ ~~20 dB min., 15-550 MHz~~ ~~17,5 dB min., 550-600 MHz~~	~~6 dB min.~~
~~Return loss, common mode[b]~~	~~10 dB min.~~	~~15 dB min., 5-15 MHz~~ ~~20 dB min., 15-400 MHz~~ ~~15 dB min., 400-600 MHz~~	~~10 dB min.~~
~~Power rating~~	~~0,1 W min.~~	~~0,1 W min.~~	~~0,1 W min.~~
~~Longitudinal balance[c]~~	~~60 dB min.~~	~~60 dB min., 15-350 MHz~~ ~~50 dB min., 350-600 MHz~~	~~35 dB min.~~
~~Output signal balance[c]~~	~~50 dB min.~~	~~60 dB min., 15-350 MHz~~ ~~50 dB min., 350-600 MHz~~	~~35 dB min.~~
~~Common-mode rejection[c]~~	~~50 dB min.~~	~~60 dB min., 15-350 MHz~~ ~~50 dB min., 350-600 MHz~~	~~35 dB min.~~

Parameter	Class A-500 1 MHz to 500 MHz	Class A-1 000 1 MHz to 1 000 MHz	Class A-2 000 1 MHz to 2 000 MHz
Impedance, primary [a]	50 Ω unbalanced	50 Ω unbalanced	50 Ω unbalanced
Impedance, secondary	Matched balanced [d]	Matched balanced [d]	Matched balanced [d]
Insertion loss, maximum	2,0 dB	3,0 dB	4,5 dB
Return loss, secondary, minimum	12 dB min., 1 MHz to 15 MHz 20 dB min., 15 MHz to 500 MHz	12 dB, 4 MHz to 15 MHz 20 dB, 15 MHz to 550 MHz 17,5 dB, 550 MHz to 600 MHz 10 dB, 600 MHz to 1 000 MHz	8 dB, 1 MHz to 3 MHz 12 dB, 3 MHz to 15 MHz 20 dB, 15 MHz to 1 000 MHz 18 dB, 1 000 MHz to 2 000 MHz
Return loss, common mode [b], minimum	15 dB min., 1 MHz to 15 MHz 20 dB min., 15 MHz to 400 MHz 15 dB min., 400 MHz to 500 MHz	15 dB, 4 MHz to 15 MHz 20 dB, 15 MHz to 400 MHz 15 dB, 400 MHz to 600 MHz 10 dB, 600 MHz to 1 000 MHz	6 dB, 1 MHz to 3 MHz 10 dB, 3 MHz to 500 MHz ffs., 500 MHz to 2 000 MHz
Power rating	0,1 W min.	0,1 W	0,1 W min.
Longitudinal balance [c], minimum	60 dB min., 1 MHz to 100 MHz 50 dB min., 100 MHz to 500 MHz	60 dB, 4 MHz to 350 MHz 50 dB, 350 MHz to 600 MHz 40 dB, 600 MHz to 1 000 MHz	60 dB, 1 MHz to 100 MHz 50 dB, 100 MHz to 500 MHz 42 dB, 500 MHz to 1 000 MHz 34 dB, 1 000 MHz to 2 000 MHz
Output signal balance[c], minimum	50 dB,minumum	60 dB, 4 MHz to 350 MHz 50 dB, 350 MHz to 600 MHz 40 dB, 600 MHz to 1 000 MHz	Under considerartion

Parameter	Class A-500 1 MHz to 500 MHz	Class A-1 000 1 MHz to 1 000 MHz	Class A-2 000 1 MHz to 2 000 MHz
Common-mode rejection[c], minimum	50 dB	50 dB, 4 MHz to 600 MHz 40 dB, 600 MHz to 1 000 MHz	50 dB, 1 MHz to 500 MHz 42 dB, 500 MHz to 1 000 MHz 34 dB, 1 000 MHz to 2 000 MHz

Special guidelines for the use of baluns

~~1) For best accuracy, the baluns should be supplied with connectors (for example, with IEC 60169-22 connectors).~~

~~2) For tests up to 250 MHz, class A-250 baluns should be used.~~

~~3) For tests up to 600 MHz, class A-600 baluns should be used.~~

~~4) For class B baluns, there is a trade-off between insertion loss and return loss. Return loss can be improved by using an attenuator, which then increases insertion loss. If return loss is less than 10 dB, insertion loss shall be less than 5 dB. If Insertion loss is higher than 5 dB, return loss shall be higher than 10 dB.~~

1) For tests up to 500 MHz, class A-500 baluns should be used.

2) For tests up to 1 000 MHz, class A-1000 baluns should be used.

3) For tests up to 2 000 MHz, the balunless test method is preferred. See IEC TR 61156-1-2 for detailed information on the balunless test method.

4) Common mode port of baluns are optional in 6.3 except for unbalance attenuation measurement.

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

[b] Measured by connecting the balanced output terminals together and measuring the return loss. The unbalanced balun input terminal shall be terminated by a 50 Ω load.

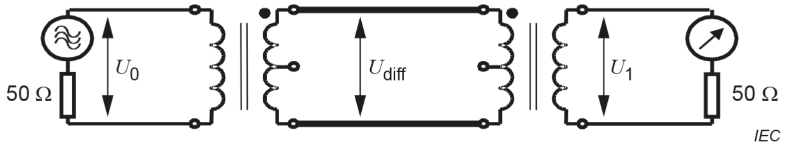
[c] Measured according to ITU T Recommendation G.117 and ITU-T Recommendation O.9.

[d] For 120 Ω cables, 120 Ω baluns will be used only in cases where it is requested by the user. Usually 100 Ω baluns will be used.

6.3.5.2 Balun calibration

a) The reference line calibration (0 dB line) shall be determined by connecting coaxial cables between the analyzer input and output. The same coaxial cables shall also be used for the balun loss measurements. The calibration shall be established over the whole frequency range specified in the relevant cable specification. This calibration method is valid for closely matched baluns that satisfy the characteristics of Table 1.

b) Figure 3 gives the schematic for the measurement of the differential-mode loss of the baluns. Two baluns are connected back to back on the symmetrical output side and their attenuation measured over the specified frequency range. The connection between the two baluns shall be made with negligible loss.



Key

U_0 voltage at network analyzer port or signal generator (V);

U_1 voltage at network analyzer port or receiver (V);

U_{diff} voltage at symmetrical port of baluns (V).

Figure 3 – Test set-up for the measurement of the differential-mode loss of the baluns

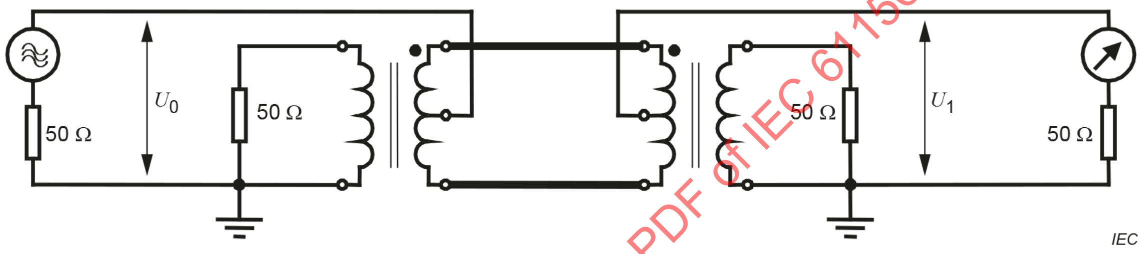
The differential-mode loss of the single balun~~s~~ is given by

~~$$\alpha_{diff} = 0{,}5 \times \left(20 \times \log_{10}\left|\frac{U_1}{U_0}\right|\right)$$ (14)~~

$$\alpha_{diff} = 0{,}5 \times \left(20 \lg\left|\frac{U_0}{U_1}\right|\right) = -\,0{,}5 \times \left(20 \lg |S_{21}|\right) \quad (14)$$

where α_{diff} is the differential-mode loss of the single balun~~s~~ (dB).

c) Figure 4 gives the schematic for the measurement of the common-mode loss of the baluns. The baluns used in b) are connected together; the unbalanced balun ports are terminated with the nominal test equipment impedance, and the test equipment is connected to the common-mode port (centre tap) of the baluns.



Key

U_0 voltage at network analyzer port or signal generator (V);

U_1 voltage at network analyzer port or receiver (V).

Figure 4 – Test set-up for the measurement of the common-mode loss of the baluns

The common-mode loss of the single balun~~s~~ is given by

~~$$\alpha_{com} = 0{,}5 \times \left(20 \times \log_{10}\left|\frac{U_1}{U_0}\right|\right)$$ (15)~~

$$\alpha_{com} = 0{,}5 \times \left(20 \lg\left|\frac{U_0}{U_1}\right|\right) = -\,0{,}5 \times \left(20 \lg |S_{21}|\right) \quad (15)$$

where α_{com} is the common-mode loss of the single balun (dB).

d) The operational attenuation of the balun α_{balun} takes into account the common-mode and differential-mode losses of the balun:

$$\alpha_{balun} = \alpha_{diff} + \alpha_{com} \quad (16)$$

where α_{balun} is the operational attenuation or intrinsic loss of the balun (dB).

NOTE More precise results can be obtained using either poling of the baluns for α_{diff} and α_{com} and averaging the results or using three baluns. In the latter case, the assumption of identical baluns is not required.

e) The voltage ratio of the balun can be expressed by the turns ratio of the balun and the operational attenuation of the balun:

$$20\times\log_{10}\left|\frac{U_{\text{diff}}}{U_0}\right| = 10\times\log_{10}\left|\frac{Z_{\text{diff}}}{Z_0}\right| - \alpha_{\text{balun}}$$

$$20\times\log_{10}\left|\frac{U_{\text{diff}}}{U_1}\right| = 10\times\log_{10}\left|\frac{Z_{\text{diff}}}{Z_1}\right| - \alpha_{\text{balun}} \quad (17)$$

$$20\lg\left|\frac{U_{\text{diff}}}{U_0}\right| = 10\lg\left|\frac{Z_{\text{diff}}}{Z_0}\right| - \alpha_{\text{balun}}$$

$$20\lg\left|\frac{U_{\text{diff}}}{U_1}\right| = 10\lg\left|\frac{Z_{\text{diff}}}{Z_1}\right| - \alpha_{\text{balun}} \quad (17)$$

where

U_{diff} is the differential-mode voltage at the input of the cable under test (V);

U_0 is the voltage at the network analyzer port or signal generator (V);

U_1 is the voltage at the input of the load (V);

Z_{diff} is the characteristic impedance of the differential-mode circuit (Ω);

Z_0 is the output impedance of the network analyzer or signal generator (Ω);

Z_1 is the input impedance of the load (Ω).

6.3.5.3 Measurements

~~All pairs/quads of the cable shall be measured at both ends of the cable under test (CUT). The attenuation unbalance shall be measured over the specified frequency range and at the same frequency points as for the calibration procedure.~~

~~For cables having a nominal impedance of 100 Ω, the value of Z_{com} is 75 Ω for up to 25 pair-count unscreened pair cables, 50 Ω for common screened pair cables and more than 25 pair-count unscreened pair cables, and 25 Ω for individually screened pair cables. The impedance of the common-mode circuit Z_{com} can be measured more precisely either with a time domain reflectometer (TDR) or a network analyser. The two conductors of the pair are connected together at both ends and the impedance is measured between these conductors and the return path.~~

6.3.5.3.1 ~~Cable under test (CUT)~~ Sample preparation

The ends of the CUT shall be prepared so that the twisting of the pairs/quads is maintained up to the terminals of the test equipment. If not otherwise specified, the CUT shall have a length of 100 m ± 1 m. All pairs not under test shall be connected to earth through ~~appropriate common-mode (see 6.1) and~~ differential-mode and common-mode terminations at the near and far end. ~~The screens, if any, shall be connected to earth at both ends of the cable.~~

The impedance of the common-mode circuit Z_{com} can be measured more precisely either with a time domain reflectometer (TDR) or a network analyzer. The two conductors of the pair are connected together at both ends and the impedance is measured between these conductors and the return path.

If not otherwise specified, the common-mode terminations should be 50 Ω. The screens, if any, shall be connected to earth at both ends of the cable.

6.3.5.3.2 Test set-up for unbalance measurements

Figure 5 gives a schematic of the measurement for unbalance attenuation at the near end.

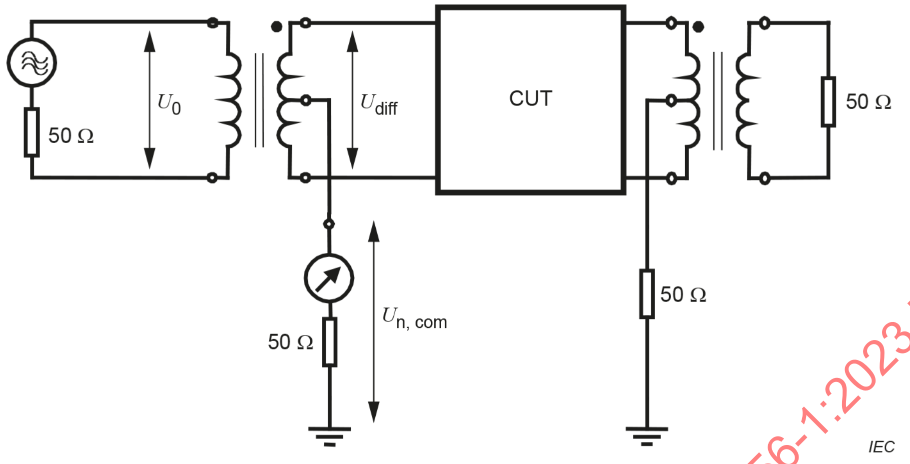


Figure 5 – Test set-up for unbalance attenuation at near end (TCL)

$$\alpha_{meas} = 20 \times \log_{10} \left| \frac{U_{n,\ com}}{U_0} \right| \qquad (18)$$

$$\alpha_{meas} = 20 \lg \left| \frac{U_0}{U_{n,com}} \right| = -20 \lg \left| S_{21} \right| \qquad (18)$$

where

α_{meas} is the measured attenuation (dB);

$U_{n,com}$ is the voltage in the common-mode circuit at the near end balun (V);

n, f are the indices to designate the near end and far end, respectively.

U_0 is the voltage in the primary (unbalanced) circuit at the near end balun (V).

Figure 6 gives a schematic of the measurement for unbalance attenuation at the far end.

NOTE In theory, the 50 Ω common mode termination in Figures 4 and 5 should be Z_{com}, but the error in using 50 Ω is small.

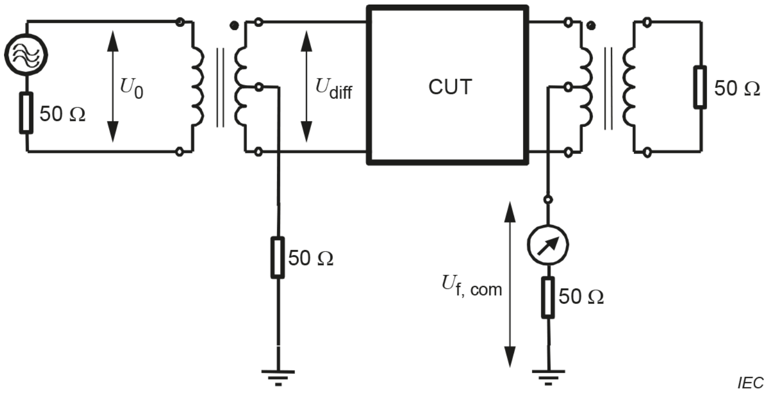


Figure 6 – Test set-up for unbalance attenuation at far end (TCTL)

$$\alpha_{meas} = 20 \times \log_{10} \left| \frac{U_{f,\,com}}{U_0} \right| \quad (19)$$

$$\alpha_{meas} = 20 \lg \left| \frac{U_0}{U_{f,\,com}} \right| \quad (19)$$

where

α_{meas} is the measured attenuation (dB);

$U_{f,com}$ is the voltage in the common-mode circuit at the far end balun (V);

U_0 is the voltage in the primary (unbalanced) circuit at the near end balun (V).

6.3.5.3.3 Expression of test result

The unbalance attenuation is defined as the logarithmic ratio of the common-mode power to the differential-mode power.

$$\alpha_{u,n \atop u,f} = 20 \times \log_{10} \left| \frac{\sqrt{P_{n,com \atop f,com}}}{\sqrt{P_{diff}}} \right| = 20 \times \log_{10} \left| \frac{U_{n,com \atop f,com}}{U_{diff}} \right| + 10 \times \log_{10} \left| \frac{Z_{diff}}{Z_{com}} \right| \quad (20)$$

$$\alpha_{u,n \atop u,f} = 10 \lg \left| \frac{P_{diff}}{P_{n,com \atop f,com}} \right| = 20 \lg \left| \frac{U_{diff}}{U_{n,com \atop f,com}} \right| + 10 \lg \left| \frac{Z_{com}}{Z_{diff}} \right| \quad (20)$$

where

α_u is the unbalance attenuation (dB);

P_{com} is the matched common-mode power (W);

P_{diff} is the matched differential-mode power (W);

n, f are the near end and far end, respectively;

Z_{diff} is the characteristic impedance of the differential-mode circuit (Ω);

Z_{com} is the characteristic impedance of the common-mode circuit (Ω).

When measuring with S-parameter test-sets, the output voltage of the generator is measured instead of the differential-mode voltage in the cable under test. Taking the operational attenuation of the balun into account, the formula for the unbalance attenuation near or far end is:

$$\alpha_{\substack{u,n\\u,f}} = 10\times\log_{10}\left|\frac{P_{\substack{n,com\\f,com}}}{P_{diff}}\right| = 10\times\log_{10}\left|\frac{P_{\substack{n,com\\f,com}}}{P_0}\right| - \alpha_{balun} \tag{21}$$

~~(21)~~

$$= 20\times\log_{10}\left|\frac{U_{\substack{n,com\\f,com}}}{U_0}\right| + 10\times\log_{10}\left|\frac{Z_0}{Z_{com}}\right| - \alpha_{balun}$$

$$\alpha_{\substack{u,n\\f,n}} = \alpha_{meas} + 10\times\log_{10}\left|\frac{Z_0}{Z_{com}}\right| - \alpha_{balun}$$

~~(22)~~

$$\alpha_{\substack{u,n\\u,f}} = 10\lg\left|\frac{P_{diff}}{P_{\substack{n,com\\f,com}}}\right| = 10\lg\left|\frac{P_0}{P_{\substack{n,com\\f,com}}}\right| - \alpha_{balun} = \alpha_{meas} + 10\lg\left|\frac{Z_0}{Z_{com}}\right| - \alpha_{balun} = -20\lg|S_{21}| + 10\lg\left|\frac{Z_0}{Z_{com}}\right| - \alpha_{balun} \quad (21)$$

The equal level unbalance attenuation at the far end is then

$$EL\ \alpha_{u,f} = \alpha_{meas} + 10\times\log_{10}\left|\frac{Z_0}{Z_{com}}\right| - \alpha_{balun} - \alpha_{cable}$$

~~(23)~~

$$EL\ \alpha_{u,f} = \alpha_{meas} + 10\lg\left|\frac{Z_0}{Z_{com}}\right| - \alpha_{balun} - \alpha_{cable} = -20\lg|S_{21}| + 10\lg\left|\frac{Z_0}{Z_{com}}\right| - \alpha_{balun} - \alpha_{cable} \quad (22)$$

where

$EL\ \alpha_{u,f}$ is the equal level unbalance attenuation at the far end (EL TCTL) (dB);

α_{cable} is the attenuation of the ~~cable~~ pair under test (dB);

Z_0 is the output impedance of the network analyzer or signal generator (Ω);

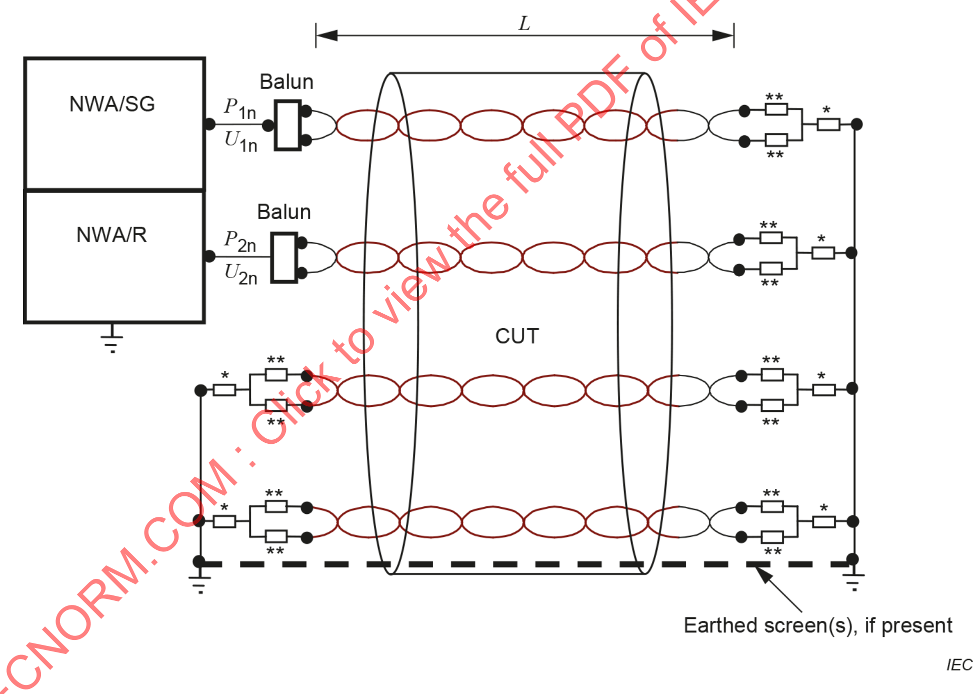
Z_{com} is the operational impedance of the common-mode circuit, 50 Ω.

6.3.6 Near-end crosstalk

Figure 7 gives the schematic for the measurement of near-end crosstalk. The near-end crosstalk loss shall be measured using a network analyzer or equivalent measuring equipment over the frequency range indicated in the relevant sectional specification. One end of the pairs under test shall be connected to baluns, the other end shall be connected to earth through appropriate common-mode (see 6.1) and differential-mode terminations.

The test schematic is given in Figure 6. The pairs under test shall be connected to earth at the far end through appropriate common-mode (see 6.1) and differential-mode terminations. The baluns shall comply with the relevant requirements of Table 1 and shall be selected to match the test equipment to the cable nominal impedance.

All pairs not under test shall be connected to earth through appropriate common-mode (see 6.1) and differential-mode terminations at the near and far end. The screens, if any, shall be connected to earth at both ends of the cable. Precautions shall be taken to minimize End effect couplings shall be minimized. When the cable sheath is removed, the pairs shall maintain their twist and shall be well separated.



Key

CUT cable under test

NWA/SG network analyzer port or signal generator

NWA/R network analyzer port or receiver

* common-mode termination resistor (see 6.1)

** differential-mode termination resistor (matched in pairs)

L length of cable under test (m)

Figure 7 – Test set-up for near-end crosstalk

Near-end crosstalk loss NEXT is given by

$$NEXT = 10 \times \log_{10}\left|\frac{P_{1n}}{P_{2n}}\right| = 20 \times \log_{10}\left|\frac{U_{1n}}{U_{2n}}\right| + 10 \times \log_{10}\left|\frac{Z_1}{Z_2}\right| \qquad \text{(24)}$$

$$NEXT = 10\lg\left|\frac{P_{1n}}{P_{2n}}\right| = 20\lg\left|\frac{U_{1n}}{U_{2n}}\right| + 10\lg\left|\frac{Z_2}{Z_1}\right| = -20\lg\left|S_{21}\right| + 10\lg\left|\frac{Z_2}{Z_1}\right| \qquad (23)$$

where

$NEXT$	is the near-end crosstalk (dB);
P_{1n}	is the input power of the disturbing pair at the near end (W);
P_{2n}	is the output power of the disturbed pair at the near end (W);
U_{1n}	is the input voltage of the disturbing pair at the near end (V);
U_{2n}	is the output voltage of the disturbed pair at the near end (V);
Z_1	is the characteristic impedance of the disturbing pair (Ω);
Z_2	is the characteristic impedance of the disturbed pair (Ω).

Measurements shall be on a length of at least 100 m. For a length greater than 100 m, the measured value may be corrected to 100 m using the following correction formula:

$$NEXT_{100} = NEXT + 10 \times \log_{10}\left[\left(1 - 10^{-\frac{\alpha \cdot L}{5}}\right) \Big/ \left(1 - 10^{-\frac{\alpha}{5}}\right)\right] \qquad \text{(25)}$$

$$NEXT_{100} = NEXT - 10\lg\left[\left(1 - 10^{-\left(\frac{\alpha}{5}\right) \times \left(\frac{100}{L}\right)}\right) \Big/ \left(1 - 10^{-\left(\frac{\alpha}{5}\right)}\right)\right] \qquad (24)$$

where

$NEXT_{100}$	is the near-end crosstalk corrected to a length of 100 m (dB);
$NEXT$	is the near-end crosstalk on the measured cable length (dB);
α	is the attenuation of the measured cable length (dB).

The power sum near-end crosstalk PS NEXT is calculated from

$$PS\_NEXT_j = -10 \times \log_{10} \sum_{\substack{i=1 \\ i \neq j}}^{m} \left(10^{\frac{NEXT_{i,j}}{10}} \right) \quad (26)$$

$$PS\ NEXT_j = -10 \lg \sum_{\substack{i=1 \\ i \neq j}}^{m} \left(10^{\frac{-NEXT_{i,j}}{10}} \right) \quad (25)$$

where

$PS\ NEXT_j$ is the power sum of the pair j (dB);

$NEXT_{i,j}$ is the crosstalk coupled from the pairs i into the pair j (dB);

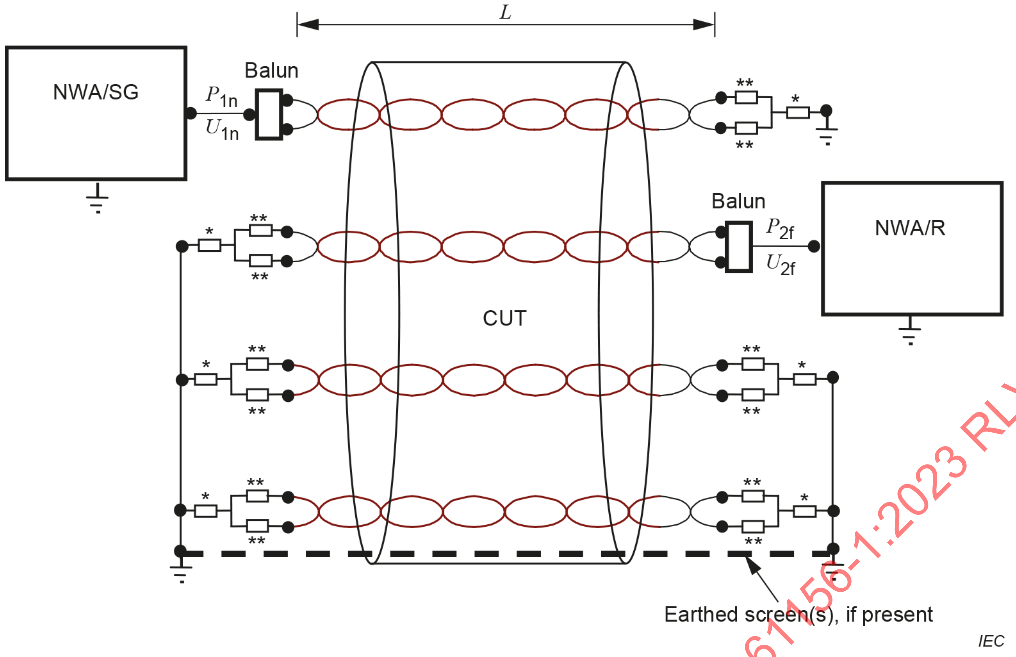
m is the number of pairs contained within the cable.

6.3.7 Far-end crosstalk

Figure 8 gives the schematic for the measurement of far-end crosstalk. The far-end crosstalk loss shall be measured using a network analyzer or equivalent measuring equipment over the frequency range indicated in the relevant sectional specification. One end of the pairs under test shall be connected to baluns, the other end shall be connected to earth through appropriate common-mode (see 6.1) and differential-mode terminations.

The pairs under test shall be connected to baluns which comply with the relevant requirements of Table 1. The baluns shall be selected to match the test equipment to the cable nominal impedance.

All pairs not under test shall be connected to earth through appropriate common-mode (see 6.1) and differential-mode terminations at the near and far end. The screens, if any, shall be connected to earth at both ends of the cable. Precautions shall be taken to minimize End effect couplings shall be minimized. When the cable sheath is removed, the pairs shall maintain their twist and shall be well separated.



Key

CUT	cable under test
NWA/SG	network analyzer port or signal generator
NWA/R	network analyzer port or receiver
*	common-mode termination resistor (see 6.1)
**	differential-mode termination resistor (matched in pairs)
L	length of cable under test (in m)

Figure 8 – Test set-up for far-end crosstalk

The measurement shall be carried on a length of at least 100 m.

Far-end crosstalk is given by

$$FEXT = 10 \times \log_{10} \left| \frac{P_{1n}}{P_{2f}} \right| = 20 \times \log_{10} \left| \frac{U_{1n}}{U_{2f}} \right| + 10 \times \log_{10} \left| \frac{Z_1}{Z_2} \right| \quad (27)$$

$$FEXT = 10 \lg \left| \frac{P_{1n}}{P_{2f}} \right| = 20 \lg \left| \frac{U_{1n}}{U_{2f}} \right| + 10 \lg \left| \frac{Z_2}{Z_1} \right| = -20 \lg |S_{21}| + 10 \lg \left| \frac{Z_2}{Z_1} \right| \quad (26)$$

where

$FEXT$ is the far-end crosstalk (dB);

P_{1n} is the input power of the disturbing pair at the near end (W);

P_{2f} is the output power of the disturbed pair under test at the far end (W);

U_{1n} is the input voltage of the disturbing pair at the near end (V);

U_{2f} is the output voltage of the disturbed pair at the far end (V);

Z_1 is the characteristic impedance of the disturbing pair (Ω);

Z_2 is the characteristic impedance of the disturbed pair (Ω).

Equal level far-end crosstalk loss is given by Formula (28) and related to FEXT by the attenuation of the disturbing pair in the measured cable length:

$$EL\ FEXT = 10 \times \log_{10}\left|\frac{P_{1f}}{P_{2f}}\right| = 20 \times \log_{10}\left|\frac{U_{1f}}{U_{2f}}\right| + 10 \times \log_{10}\left|\frac{Z_1}{Z_2}\right| \quad (28)$$

where

EL FEXT is the equal level far-end crosstalk (dB);

P_{1f} is the output power of the disturbing pair at the far end (W);

U_{1f} is the output voltage of the disturbing pair at the far end (V).

EL FEXT is related to *FEXT* by the attenuation of the disturbing pair in the measured cable length:

$$EL\ FEXT = FEXT - \alpha_1 \quad (29)$$

where

α_1 is the attenuation of the disturbing pair (dB).

$$EL\ FEXT = 10\lg\left|\frac{P_{1f}}{P_{2f}}\right| = 10\lg\left|\frac{P_{1n}}{P_{2f}}\right| - 10\lg\left|\frac{P_{1n}}{P_{1f}}\right| = FEXT - \alpha_1 \quad (27)$$

where

EL FEXT is the equal level far-end crosstalk (dB);

FEXT is the far-end crosstalk (dB);

P_{1f} is the output power of the disturbing pair at the far end (W);

P_{2f} is the output power of the disturbed pair under test at the far end (W);

P_{1n} is the input power of the disturbing pair at the near end (W);

α_1 is the attenuation of the disturbing pair (dB).

It is recommended that the maximum cable length to be measured be limited to 300 305 m in order to minimize errors resulting from the noise floor of the testing equipment. For lengths greater than 100 m, the measured values of FEXT and the calculated values of the EL FEXT shall be corrected to a length of 100 m as follows:

~~$FEXT_{100} = FEXT + 10 \times \log_{10} (L/100) + \alpha_1 (1 - L/100)$ (30)~~

~~$EL\ FEXT_{100} = EL\ FEXT + 10 \times \log_{10} (L/100)$ (31)~~

$$FEXT_{100} = FEXT + 10\lg\left(\frac{L}{100}\right) + \alpha_1 \times \left(\frac{100}{L} - 1\right) \quad (28)$$

$$EL\ FEXT_{100} = EL\ FEXT + 10\lg\left(\frac{L}{100}\right) \quad (29)$$

where

$FEXT_{100}$	is the far-end crosstalk corrected to a length of 100 m (dB);
$FEXT$	is the measured far-end crosstalk (dB);
$EL\ FEXT_{100}$	is the equal level far-end crosstalk corrected to a length of 100 m (dB);
$EL\ FEXT$	is the equal level far-end crosstalk (dB);
L	is the measured cable length (m);
α_1	is the measured attenuation of disturbing pair ~~attenuation~~ (dB).

The power sum far-end crosstalk PS EL FEXT is calculated from

~~$PS\ EL\ FEXT_j = -10 \times \log_{10} \sum_{i=1, i \neq j}^{m} 10^{\frac{-EL\ FEXT_{i,j}}{10}}$ (32)~~

$$PS\ EL\ FEXT_j = -10\lg \sum_{\substack{i=1 \\ i \neq j}}^{m} 10^{\frac{-EL\ FEXT_{i,j}}{10}} \quad (30)$$

where

$PS\ EL\ FEXT_j$	is the power sum of the pair j (dB);
$EL\ FEXT_{i,j}$	is the crosstalk coupled from the pairs i into the pair j (dB);
m	is the number of pairs contained within the cable.

The attenuation-to-crosstalk ratio far end is defined as the ratio of the attenuation of the disturbed pair to the far-end crosstalk, both in nepers, or the difference of the far-end crosstalk and the attenuation of the disturbed pair if both are expressed in dB. Hence:

$$ACR - F_j = FEXT_{i,j} - \alpha_j \quad (31)$$

where

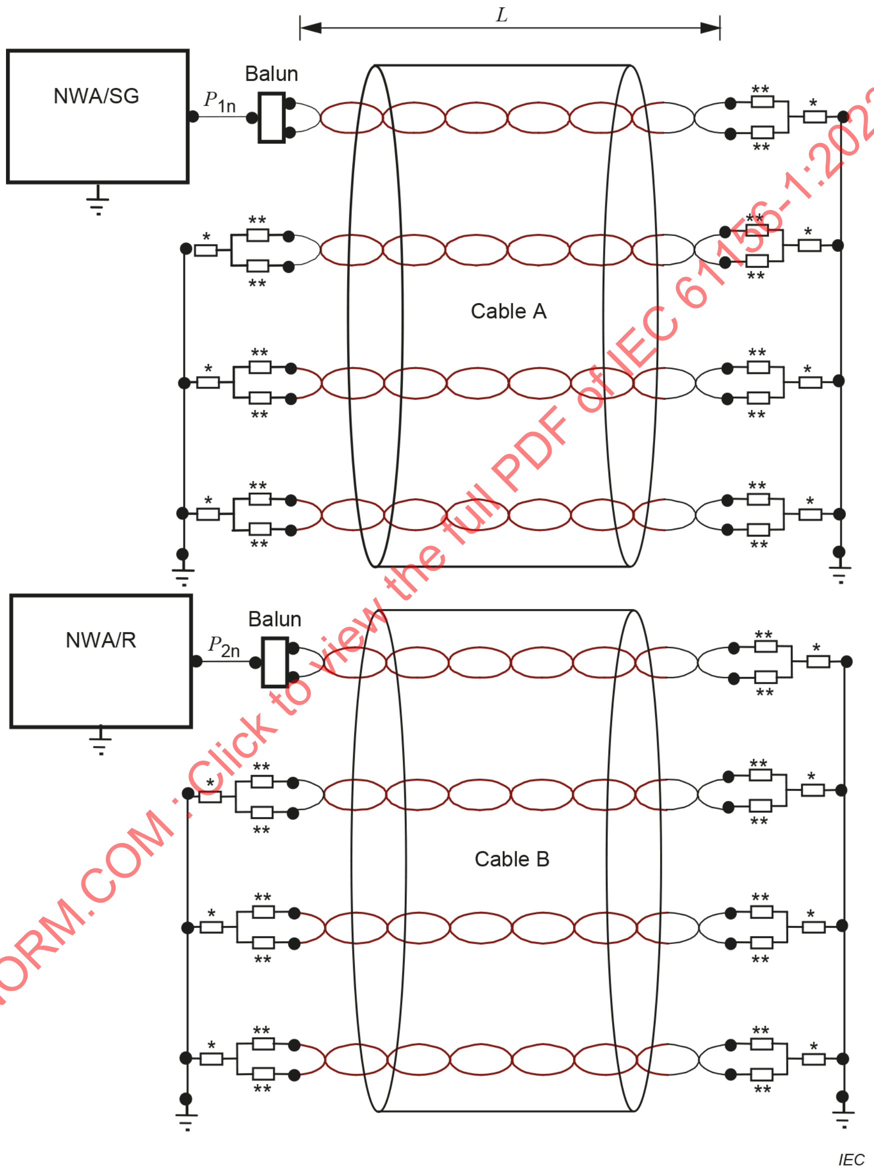
$ACR - F_j$	is the attenuation to crosstalk ratio far-end in (dB);
α_j	is the attenuation of the disturbed pair $_j$ in (dB);

$FEXT_{i,j}$ is the far-end crosstalk coupled from the pair i into the disturbed pair j.

6.3.8 Alien (exogenous) near-end crosstalk

6.3.8.1 General

Figure 9 gives the schematic for the measurement of alien (exogenous) near-end crosstalk, ANEXT. The same test equipment and sample-end preparation considerations relevant to the measurement of NEXT are relevant to the measurement of ANEXT. The cable fan-out shall not be greater than 1 m. The measurement shall be over the frequency range indicated in the relevant sectional specification.



Key

Cable A, B	two cables in the test assembly configuration (other cables in the assembly are not shown)
NWA/SG	network analyzer port or signal generator
NWA/R	network analyzer port or receiver
*	common mode termination resistor (see 6.1)
**	differential mode termination resistor (matched in pairs)
L	length of test assembly under test (in m)

Figure 9 – Test set-up for alien (exogenous) near-end crosstalk

Alien near-end crosstalk (ANEXT) given by

$$ANEXT = 10 \times \log_{10} |P_{1n}/P_{2n}| \qquad (34)$$

$$ANEXT = 10\lg\left|\frac{P_{1n}}{P_{2n}}\right| \qquad (32)$$

where

$ANEXT$ is the alien (exogenous) near-end crosstalk (dB);

P_{1n} is the input power of the disturbing pair at the near end (W);

P_{2n} is the output power of the disturbed pair at the near end (W).

The disturbing and disturbed pairs are contained within different cables.

For near-end and far-end alien (exogenous) crosstalk the power sum is defined as:

$$PS\ AX-talk_j = -10 \times \log_{10}\left(\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{-\frac{AX-talk_{i,j,l}}{10}}\right) \qquad (35)$$

$$PS\ AX-talk_j = -10\lg\left(\sum_{l=1}^{N}\sum_{i=1}^{n} 10^{-\frac{AX-talk_{i,j,l}}{10}}\right) \qquad (33)$$

where

$PS\ AX-talk_j$ is the power sum of pair j (dB);

$AX\text{-}talk_{i,j,l}$ is the crosstalk between pair j of a given cable and pair i of a neighbouring cable (dB);

j is the number of the disturbed pair;

i is the current number of a disturbing pair in a disturbing cable;

l is the number of the disturbing cable;

N is the total number of disturbing cables;

n is the total number of disturbing pairs.

The cables to be tested are mounted into a configuration as specified in the relevant sectional specification.

The test method configuration involves six cables around one cable.

The cable arrangement shall be either a bundle.

a) a bundle

or

b) three layers of cables on a drum.

6.3.8.2 Six cables around one cable

The seven cables to be tested are mounted into the test assembly configuration shown in the cross-section in Figure 10. The test assembly length shall be specified in the relevant sectional specification. The assembly cross-section shall be maintained, without longitudinal twist, throughout the assembly length by means of suitable non-metallic binder material. The binder material may be applied as discrete straps such as tie wraps and self-clinging or adhesive straps. The binder material may be applied helically about the cables in the form of a continuous thread or tape. The binder material shall not visibly compress or deform the cross-section. The spacing of the discrete binder and the pitch of the continuous binder shall be adequate to maintain the cable components in close proximity, without visible spacing, as depicted in Figure 10. The test assembly shall be laid out as depicted in Figure 11 (with serpentine looping as necessary) in a loop in such a way that a minimum separation of 10 cm is maintained between sections of the loop. A non-metallic floor is suitable for laying out the test assembly.

The crosstalk from each pair of cables 1 through 6 to each of the pairs of cable 7 shall be measured across the frequency range specified in the relevant sectional specification.

The power sum alien (exogenous) near-end crosstalk, PS ANEXT, shall be calculated from the measured values according to Formula (33).

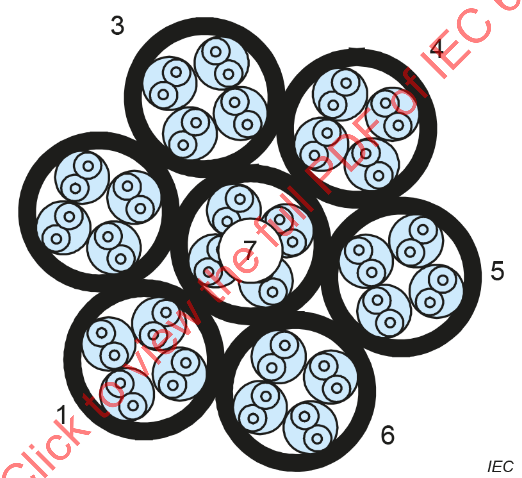


Figure 10 – Test assembly cross-section: six cables around one cable

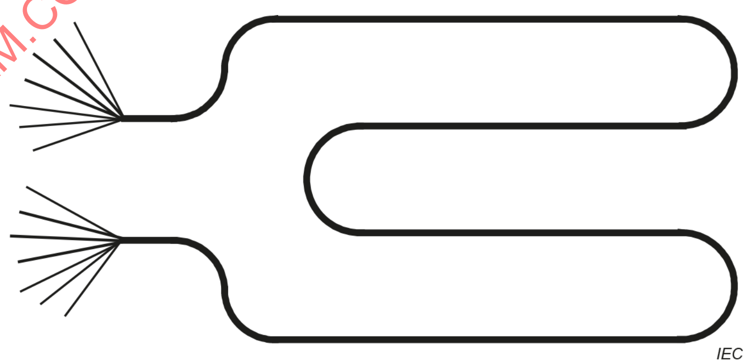


Figure 11 – Test assembly layout: six cables around one cable

~~**6.3.7.2 Six cables around one cable on a drum (three layers on a drum)**~~

~~The principle is to reproduce a "6 around 1" on the drum. The sample is a set of 3 specimens of cable of 100 m length. They are wound all together and side by side on a wooden drum in order to form a first layer (cables 8, 5 and 4 in Figure 18). The wooden drum shall have a minimum diameter of 1,20 m. Next, a new set of 3 cables of 100 m is wound above the first~~

layer in order to build a second layer; the cables are put as shown in Figure 18 and described as cables 6, V and 3. Finally, a third set of 3 cables is wound to obtain a third layer described as cables 1, 2 and 7. All of the (9×100) m cables shall come from the same production batch.

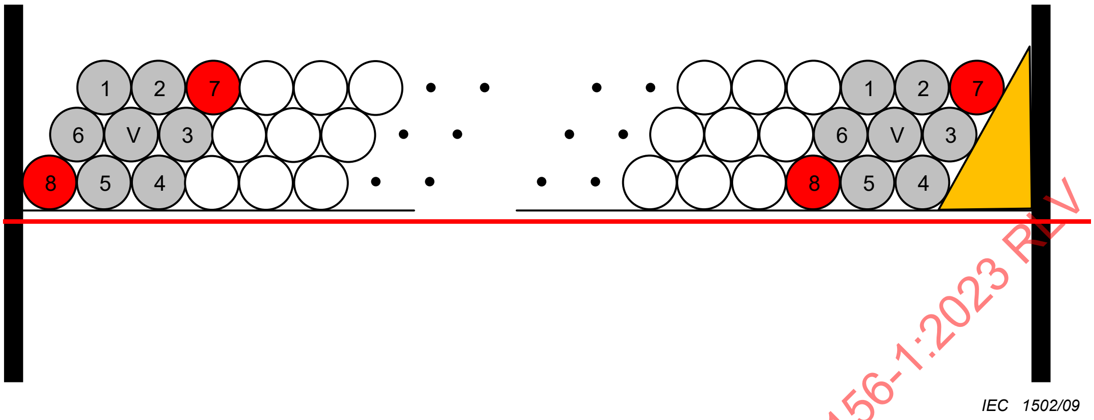


Figure 18 – Schematic diagram representing the position of the 9 cables on a wooden drum

According to the "6 around 1" principle, the disturbed cable V is surrounded by 6 cables called cable 1 to cable 6 (see Figure 18).

The regularity of this construction is maintained for example by a wrapping tape around the assembly as shown in the Figure 19. At both ends, a bundle is set-up by using adhesive tapes spaced on the assembly every 10 cm.

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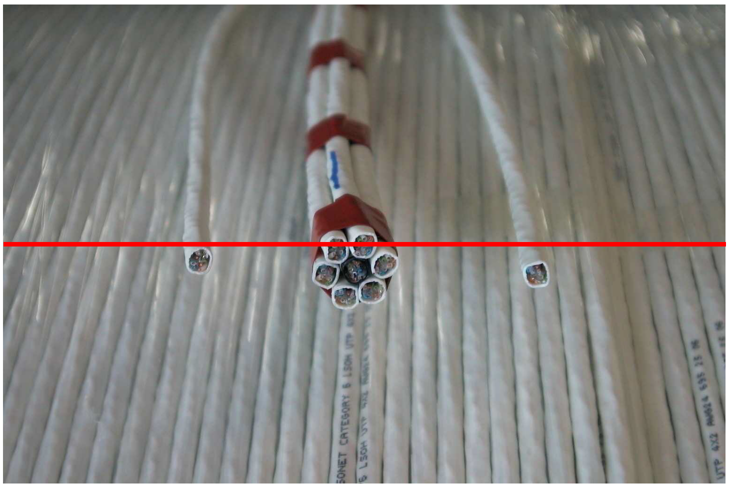
Figure 19 – Arrangement of the cables on the drum

Figure 20 shows the "6 around 1" construction at both ends and 2 extra cables (cable 7 and cable 8) which are here only for insuring a perfect assembly, but also for further investigation, if needed.



~~Figure 20 – Preparation of one end~~

6.3.9 Alien (exogenous) far-end crosstalk

Measurement of alien (exogenous) far-end crosstalk, AFEXT, involves the same test equipment and sample-end preparation considerations relevant to the measurement of FEXT. The cables to be tested are mounted into a configuration, as specified in the relevant sectional specification and as described in 6.3.8.2~~, for the six-around-one configuration and 6.3.7.2 for the four-parallel-cable configuration~~ for six cables around one.

The PS AFEXT shall be calculated from the measured values according to Formula (33).

PS AFEXT requirements may be given in terms of PS AACR-F where AACR-F shall be calculated from the measured values according to Formula (34).

$$AACR\text{-}F = AFEXT - \alpha \tag{34}$$

where

$AACR\text{-}F$ is the attenuation alien (exogenous) crosstalk ratio at the far end (dB);

$AFEXT$ is the alien (exogenous) far-end crosstalk (dB);

α is the attenuation of the disturbed pair (dB).

~~*PS AACRF* is calculated according to equation (35).~~

6.3.10 Alien (exogenous) crosstalk of bundled cables

Alien (exogenous) crosstalk, (ANEXT and AFEXT), is measured directly on the bundled cable and does not require the preparation of a specific test assembly configuration.

The bundled cable shall be laid out as depicted in Figure 11 (with serpentine looping as necessary) in a loop in such a way that a minimum separation of 10 cm is maintained between sections of the loop. A non-metallic floor is suitable for laying out the test assembly.

The near-end (NEXT) and far-end (~~*IO*~~ FEXT) crosstalk of each pair of one disturbed cable due to all pairs in the surrounding disturbing cables shall be measured across the frequency range specified in the relevant sectional specification.

Each cable of the bundle shall in turn be treated as the disturbed cable and the near-end (NEXT) and far-end (~~*IO*~~ FEXT) crosstalk due to all pairs in the surrounding disturbing cables shall be measured across the frequency range specified in the relevant sectional specification.

The power sum alien (exogenous) crosstalk, PS ANEXT and PS AFEXT, shall be calculated from the measured values according to Formula (33).

6.3.11 Impedance

6.3.11.1 Preparation of cable under test

The cable under test (CUT) shall be prepared so that end effects are minimized. Both ends of the cable under test shall be prepared to minimize end effects. For frequencies of measurements greater than or equal to 1 000 MHz, it is recommended that no more than 20 mm of jacket should be removed from pairs; for frequencies of measurements lower than 1 000 MHz, it is recommended that no more than 40 mm jacket should be removed from the pairs. When the cable sheath is removed, the pairs shall maintain their twist and shall be well separated.

Unscreened cables shall be suspended or laid on a non-conducting surface so that multiple traversals are separated by a minimum of 25 mm.

6.3.11.2 Test equipment for characteristic impedance, terminated input impedance and fitted impedance Measurement

The measurement is in a balanced configuration with a network analyzer (together with an S-parameter unit) or an impedance meter. The balun shall have the relevant characteristics given in Table 1 corresponding to the measurement frequency range; for this measurement, the common-mode balun ports in Table 1 are optional. The measurement schematic is given in Figure 12.

The measurement shall be done at the frequency, or in the whole frequency range, indicated in the relevant sectional specification.

A three-step calibration procedure (using open-, short- and load-circuit terminations) is performed at the secondary side of the balun before the measurement.

For improvement of impedance measurement uncertainty, IEC TR 61156-1-5 should be considered.

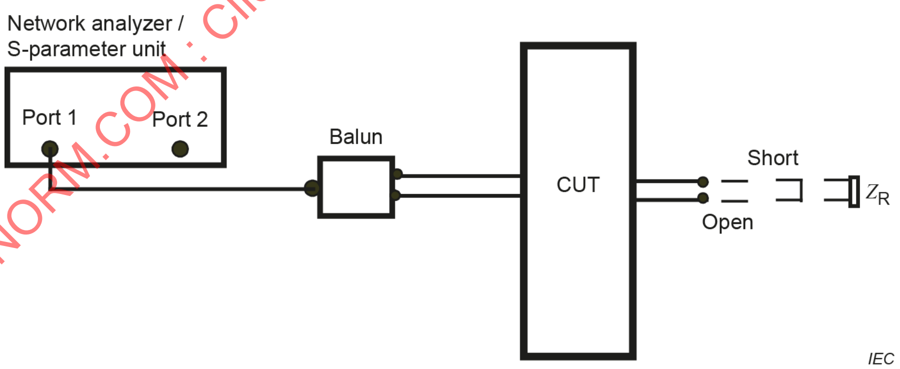


Figure 12 – Test set-up for characteristic impedance, terminated input impedance, and return loss

6.3.10.1.2 Procedure

A three-step calibration procedure (using open, short and reference-load terminations) is performed at the secondary of the balun with the cable pair disconnected.

The S_{11} parameter is measured with the cable pair connected to the balun and terminated with open circuit, short circuit and reference load, Z_R. The impedance is calculated from the measured S_{11} parameters.

$$Z_{meas} = Z_R \left| \frac{1+S_{11}}{1-S_{11}} \right| \quad (37)$$

where

Z_{meas} is the impedance for open circuit, short circuit terminations (Ω);

Z_R is the reference load (Ω);

S_{11} is the measured wave scattering parameter for open- and short-circuit terminations.

6.3.11.3 Characteristic impedance

A three-step calibration procedure (using open, short and load circuit terminations) is performed at the secondary side of the balun before the measurement.

The near end of the cable under test shall be connected to the test equipment via balun, the far end shall be terminated by the open circuit termination and short circuit termination. The scattering parameter S_{xx} shall be measured to obtain characteristic impedance values. The impedance is calculated from the measured S_{xx} parameters.

$$Z_{meas} = Z_R \times \left| \frac{1+S_{xx}}{1-S_{xx}} \right| \quad (35)$$

where

Z_{meas} is the impedance for open-circuit termination or short-circuit termination (Ω);

Z_R is the system nominal impedance (Ω);

S_{xx} is the measured wave scattering parameter for open circuit termination and short circuit termination, x is the vector network analyzer port number.

The characteristic impedance is calculated as the square root of the product of the open circuit and short circuit measured values and is given by

$$Z_C = \sqrt{\left| Z_{OC} \cdot Z_{SC} \right|} \quad (36)$$

where

Z_C is the characteristic impedance (Ω);

Z_{OC} is the measured open circuit impedance (Ω);

Z_{SC} is the measured short circuit impedance (Ω).

6.3.11.4 Terminated input impedance

A single terminated impedance measurement at the near end can be made to get the terminated input impedance. In this condition, the far end of the cable under test is terminated by a load impedance in place of the open circuit termination and short circuit termination; the load impedance value should be equal to the nominal impedance Z_R. Z_{in} is calculated from the measured S_{xx} parameter.

$$Z_{in} = Z_R \times \left| \frac{1+S_{xx}}{1-S_{xx}} \right| \quad (37)$$

where

Z_{in} is the terminated input impedance (Ω);

Z_R is the system nominal impedance (Ω);

S_{xx} is the measured wave scattering parameter for load circuit termination, and x is the vector network analyzer port number.

6.3.11.5 Fitted characteristic impedance

Function fitting is used for computing a smoothed characteristic impedance when the cable exhibits significant structural effects.

The fitting function is given by

$$|Z_m| = k_0 + \frac{k_1}{f^{1/2}} + \frac{k_2}{f} + \frac{k_3}{f^{3/2}} \quad (38)$$

where

$|Z_m|$ is the magnitude of the fitted characteristic impedance (Ω);

k_0, k_1, k_2, k_3 are the least squares coefficients;

f is the frequency (Hz).

NOTE More details of how to calculate the least squares coefficients can be found in IEC TR 61156-1-2.

6.3.11.6 Mean characteristic impedance

Mean characteristic impedance is calculated using the formula

$$Z_\infty = \tau / C \quad (39)$$

where

Z_∞ is the mean characteristic impedance (Ω);

τ is the time delay (s);

C is the mutual capacitance (F).

This method shall only be applied to cables having a mutual capacitance which does not change over frequency. The measurement shall be done at frequencies over 100 MHz where the phase delay approaches an asymptotic value.

6.3.12 Return loss

6.3.12.1 Preparation of cable under test

The cable under test shall be prepared ~~so that end effects are minimized~~ in accordance with 6.3.11.1. ~~Unscreened cables shall be suspended or laid on a non-conducting surface so that multiple traversals are separated by a minimum of 25 mm.~~

6.3.12.2 ~~Equipment~~ Measurement

The measurement is in a balanced configuration with a network analyzer (together with a wave scattering parameter unit). The balun shall have the relevant characteristics given in Table 1 corresponding to the measurement frequency range. For return loss measurement, the common-mode port of the balun in Table 1 is optional. The measurement schematic is given in Figure 12. The load ~~resistor~~ termination value shall be equal to the nominal ~~cable~~ impedance (Z_R).

The measurement shall be done at the frequency, or in the whole frequency range, indicated in the relevant sectional specification.

6.3.12.3 Procedure

A three-step calibration procedure (using open, short and load circuit terminations) is performed at the secondary side of the balun ~~with the cable pair disconnected~~ before the measurement.

The near end of the cable under test shall be connected to the test equipment via balun, and the far end shall be terminated by the load circuit termination. Return loss is given by the wave scattering parameter directly from the network analyzer as follows.

~~$$RL = -20 \times \log_{10} |S_{11}| \quad (40)$$~~

$$RL = -20 \lg |S_{xx}| \quad (40)$$

where

RL is the return loss (dB);

~~S_{11}~~ S_{xx} is the measured wave scattering parameter for load circuit termination, and x is the vector network analyzer port number.

6.4 Mechanical and dimensional characteristics and requirements

6.4.1 Measurement of dimensions

~~The measurement of thickness and diameter of the insulation and sheath shall be in accordance with Clause 8 of IEC 60811-1-1.~~

Determination of insulation thickness and sheath thickness shall be in accordance with IEC 60811-201 and IEC 60811-202, respectively, and the measurement of overall dimensions shall be in accordance with IEC 60811-203.

6.4.2 Elongation at break of the conductor

~~The method of measuring is described in 4.3 of IEC 60189-1.~~

Determination of the elongation at the break of the conductor is described in IEC 60189-1:2018, 6.3.

6.4.3 Tensile strength of the insulation

~~The method of measuring is described in 9.1.7 of IEC 60811-1-1.~~

Determination of the tensile strength of the insulation is described in IEC 60811-501.

6.4.4 Elongation at break of the insulation

~~The method of measuring is described in 9.1.7 of IEC 60811-1-1.~~

Determination of the elongation at the break of the insulation is described in IEC 60811-501.

6.4.5 Adhesion of the insulation to the conductor

~~The method of measuring is described in 4.4 of IEC 60189-1.~~

Determination of the adhesion of the insulation to the conductor is described in IEC 60189-1:2018, 6.4.

6.4.6 Elongation at break of the sheath

~~The method of measuring is described in 9.2.7 of IEC 60811-1-1.~~

Determination of the elongation at the break of the sheath is described in IEC 60811-501.

6.4.7 Tensile strength of the sheath

~~The method of measuring is described in 9.2.7 of IEC 60811-1-1.~~

Determination of the tensile strength of the sheath is described in IEC 60811-501.

6.4.8 Crush test of the cable

~~The method of measuring is described in 3.3.6 of IEC 62012-1.~~

Determination of the crush of the cable is described in IEC 62012-1:2002, 3.3.6.

6.4.9 Cold Impact test of the cable

~~The method of measuring is described in 8.5 of IEC 60811-1-4.~~

Determination of the impact test of the cable is described in IEC 60811-506.

6.4.10 Bending under tension

6.4.10.1 Equipment

The apparatus consists of

a) a tensile power device with a maximum error of ±3 %;

b) if required for a particular user application, a measuring apparatus for the determination of change in the transmission performance;

c) for the U-bend test: one roller with radius, r, as given in the relevant sectional specification and as shown in Figure 13;

d) for the S-bend test: two rollers each with a radius, R, and separated by distance~~,~~ Y~~, apart~~, as given in the relevant sectional specification and as shown in Figure 14;

e) a reference frame that shall be provided for locating the test sample sheath marks that are applied at points A and B as shown in Figure 13 and Figure 14.

6.4.10.2 Test sample

The test sample shall be taken from one end of a finished cable. Both ends of the specimen shall be terminated in such a way that the specified load can be applied and any specified transmission tests can be carried out.

The sample shall be marked at points A and B as shown in Figure 13 and Figure 14. The total length of the test sample and the length between points A and B shall be as given in the relevant sectional specification, taking into account the length needed to carry out the specified transmission tests.

6.4.10.3 Procedure

6.4.10.3.1 General

The test shall be carried out at ambient temperature. If specified in the relevant sectional specification, the transmission performance shall be recorded before the load is applied, and after the test when the load is zero. One of the two following tests shall be used, as indicated in the relevant sectional specification.

6.4.10.3.2 U-bend test

The cable shall be moved around the roller through a minimum of 180° (U-bend) as shown in Figure 13.

The tension shall be continuously increased to the value given in the relevant sectional specification.

Moving the sample from point A to point B (see Figure 13) and then returning to point A is considered to be one cycle. The sample shall be subjected to bending under tension with the speed of movement and number of cycles given in the relevant sectional specification.

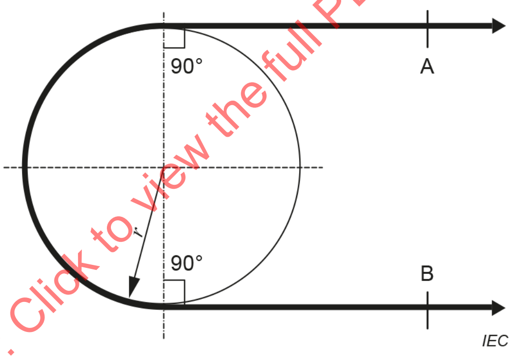


Figure 13 – U-bend test configuration

6.4.10.3.3 S-bend test

The cable shall be moved around two rollers in an S form manner (S-bend), as shown in Figure 14.

The tension shall be continuously increased to the value given in the relevant sectional specification.

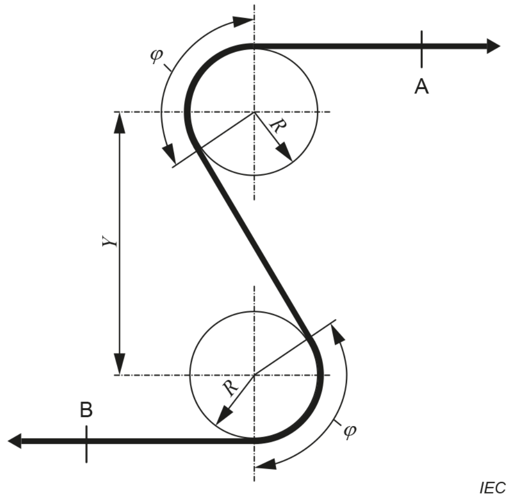


Figure 14 – S-bend test configuration

Moving the sample from point A to point B (see Figure 14) and then returning to point A is considered to be one cycle. The sample shall be subjected to bending under tension with the speed of movement and number of cycles given in the relevant sectional specification.

6.4.10.3.4 Dielectric strength and insulation resistance

After completing the bending test, the sample shall be tested for conductor/conductor and conductor/screen dielectric strength and insulation resistance. The magnitude of the voltage and the test duration shall be as given in the relevant sectional specification.

6.4.10.4 Test report

The test report shall give the following test conditions:

- bending test used (U-bend or S-bend);
- length of the test sample and the length between the sheath marks at points A and B;
- end preparation;
- tension device;
- radius, r, of rollers in the U-bend test;
- radius, R, of rollers in the S-bend test;
- roller separation, Y, in the S-bend test;
- bending angle, φ, in the S-bend test;
- speed of movement;
- number of moving cycles;
- applied voltage and duration ~~in~~ of the dielectric strength and insulation resistance test;
- maximum tension applied during test;
- test temperature~~,~~.

~~and record the pass/fail conditions as required by the relevant sectional specification.~~

The pass or fail conditions shall be recorded as required by the relevant sectional specification.

6.4.11 Repeated bending of the cable

6.4.11.1 Equipment

The apparatus shall permit a sample to be bent backwards and forwards through angles up to 180°, the two extreme positions making an angle of 90° on both sides of the vertical, whilst being subjected to a tensile load. A suitable apparatus is shown in Figure 15. Other equivalent apparatus may be used.

The bending arm shall have an adjustable clamp or fixture to hold the test sample securely during the entire test.

The apparatus shall be capable of cycling. Displacing the sample from the vertical position to the extreme right position, then oscillating to the extreme left position and returning to the original vertical position is considered to be one cycle. Unless otherwise specified in the relevant sectional specification, the bending rate shall be approximately one cycle in 2 s.

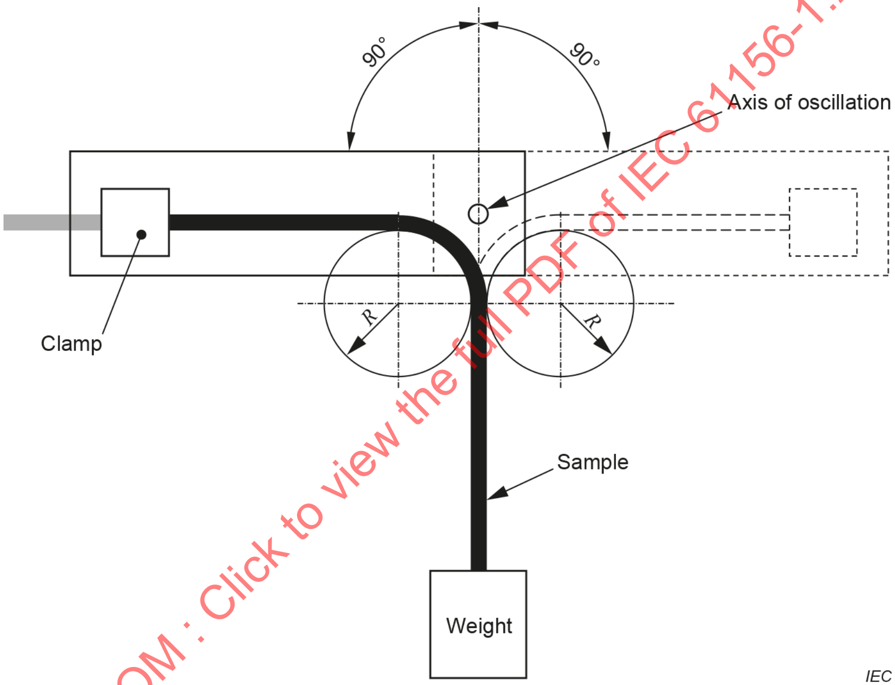


Figure 15 – Repeated bending test configuration

The apparatus shall include any test equipment needed to measure the changes in transmission performance requested in the relevant sectional specification.

6.4.11.2 Test sample length

The sample length shall be sufficient to carry out the testing specified. When only physical damage is to be evaluated, the length may range from 1 m (for example, for small diameter patch cords) to 5 m (for larger diameter cables). Longer lengths ~~may~~ can be necessary to permit transmission measurements.

The length of the test sample shall be indicated in the relevant sectional specification.

6.4.11.3 Procedure

The following procedure shall be followed.

a) Precondition the sample at ambient temperature for 24 h.

b) Fix the sample to the apparatus as shown in Figure 15.

c) Apply the weight of mass as shown in the relevant sectional specification.

d) Measure the acceptance criteria parameters to establish baseline values.

e) Carry out repeated bending for the number of cycles specified in the relevant sectional specification.

f) Carry out acceptance criteria parameter measurements. If necessary, the sample may be removed from the apparatus for visual examination.

6.4.11.4 Requirements

The acceptance criteria for the test shall be stated in the relevant sectional specification. Typical failure modes include loss of transmission performance, loss of continuity or physical damage to the cable.

6.4.11.5 Test report

The test report shall give the following test conditions:

- angle of displacement;
- number of cycles;
- mass of the weight;
- bending radius, R;
- test temperature.

The pass/fail conditions shall be recorded as required in the relevant sectional specification.

6.4.12 Tensile performance of the cable

The method of measuring the tensile performance of the cable is described in ~~Clause 5 of IEC 60794-1-2~~ IEC 60794-1-21:2015, method E1.

6.4.13 Shock test of the cable

The method of measuring the shock performance of the cable is described in IEC 62012-1:2002, 3.4.4.

6.4.14 Bump test of the cable

The method of measuring the bump performance of the cable is described in IEC 62012-1:2002, 3.4.3.

6.4.15 Vibration test of the cable

The method of measuring the vibration performance of the cable is described in IEC 62012-1:2002, 3.4.2.

6.5 Environmental characteristics

6.5.1 Shrinkage of the insulation

The method of measuring the shrinkage of the insulation is described in ~~Clause 10 of IEC 60811-1-3~~ IEC 60811-502.

6.5.2 Wrapping test of the insulation after thermal ageing

The method of measuring the ageing performance of the insulation is described in ~~Clause 10 of IEC 60811-4-2~~ IEC 60811-510.

6.5.3 Bending test of the insulation at low temperature

The method of measuring the cold bend test performance is described in ~~8.1 of IEC 60811-1-4~~ IEC 60811-504.

6.5.4 Elongation at break of the sheath after ageing

Samples of sheath are prepared and tested in accordance with ~~9.2 of IEC 60811-1-1~~ IEC 60811-501 after ageing, in accordance with ~~8.1 of IEC 60811-1-2~~ IEC 60811-401, for a time and temperature described in the relevant sectional specification.

6.5.5 Tensile strength of the sheath after ageing

Samples of sheath are prepared and tested in accordance with ~~9.2 of IEC 60811-1-1~~ IEC 60811-501after ageing, in accordance with ~~8.1 of IEC 60811-1-2~~ IEC 60811-401, for a time and temperature described in the relevant sectional specification.

6.5.6 Sheath pressure test at high temperature

The method of measuring the sheath pressure test is described in ~~8.2 of IEC 60811-3-1~~ IEC 60811-508.

6.5.7 Cold bend test of the cable

6.5.7.1 Equipment

The cold bend test apparatus shall be in accordance with ~~IEC 60811-1-4~~ IEC 60811-504 with a mandrel diameter as specified in the relevant sectional specification.

6.5.7.2 Test sample

The sample shall be taken from one end of the finished cable. The length shall be approximately 120 × cable diameter and it shall be coiled to a diameter not less than 30 × cable diameter.

6.5.7.3 Procedure

The sample and test apparatus shall be cooled in a cold chamber in accordance with test ~~Aa~~Ab of IEC 60068-2-1:2007 for a period of not less than 4 h at the temperature specified in the relevant sectional specification.

If the mandrel is metal, it shall be conditioned at the same time as the sample.

After the cooling period and while still in the cold chamber, the sample shall be wrapped three times around the mandrel at a wrapping velocity of approximately 1 turn per 4 s. Alternatively, the sample may be removed from the chamber after conditioning and wound around the mandrel provided the test is completed within 30 s after removal from the chamber.

After completing the cold bend test, the sample shall be tested for conductor/conductor and conductor/screen dielectric strength and insulation resistance. The magnitude of the voltage and the test duration shall be as given in the relevant sectional specification.

After the dielectric strength test, the sample shall be stripped into its component elements.

6.5.7.4 Test report

The test report shall give the following test conditions:

- cable diameter;
- coiling diameter;

- mandrel diameter;
- applied voltage and duration ~~in~~ of the dielectric strength test and insulation resistance;
- test temperature;

and record the pass/fail conditions as required in the relevant sectional specification.

6.5.8 Heat shock test

The method of measuring the heat shock is described in ~~9.2 of IEC 60811-3-1~~ IEC 60811-509.

6.5.9 Damp heat, steady state

The method of measuring the damp-heat steady-state performance of the cable is described in IEC 62012-1:2002, 3.5.2.

6.5.10 Solar radiation

Samples of the cable sheath shall be conditioned in a carbon-arc or xenon-arc weatherometer for a specified period of time. At the end of the conditioning period, the elongation and tensile strength of the specimens shall be measured, respectively, in accordance with 6.4.6 and 6.4.7. The results shall be compared to those obtained on unconditioned specimens.

6.5.11 Solvents and contaminating fluids

The method of measuring the solvents and contaminating fluids performance of the cable is described in IEC 62012-1:2002, 3.6.1.

6.5.12 Salt mist and sulphur dioxide

The method of measuring the salt mist and sulphur dioxide performance of the cable is described in IEC 62012-1:2002, 3.6.2.

6.5.13 Water immersion

A 100 m sample of the completed cable shall be immersed in water for a specified period of time at a temperature of 20 °C ± 3 °C. At the end of the immersion period and while still immersed in the water, the insulation resistance of the conductors shall be measured in accordance with 6.2.4.

6.5.14 Hygroscopicity

The material is considered to be non-hygroscopic when a dry sample of the material is placed in an environment of 65 % ± 5 % relative humidity and 20 °C ± 1 °C for 3 h and the amount of moisture gained does not exceed 1 % by weight.

6.5.15 Wicking

6.5.15.1 Equipment

The following equipment shall be used in 6.5.15.2.

a) Beaker: 500 ml to 1 000 ml.

b) Laboratory stand: with movable crossbar.

c) Weight: 25 g, lead sinker type (3).

d) Fluorescein dye solution: 0,1 g/l of water.

e) Filter paper 25 mm × 25 mm (3 pieces).

6.5.15.2 Procedure

The following procedure shall be used.

a) Cut three (3) lengths of material, approximately 450 mm long, to be tested and attach lead sinker type weights to one end of each sample.

b) Attach the opposite end of each sample length to the crossbar with a minimum space of 25 mm between samples. See Figure 16.

c) Attach one section of filter paper to each sample with a paper clip, approximately 75 mm above the weight.

d) Fill the beaker with the fluorescein solution to a depth of about 75 mm.

e) Position the crossbar with attached, hanging samples in place directly over the filled beaker. Lower the crossbar so that the weighted sample end enters the solution positioning the bottom of the filter paper 25 mm above the surface. Record time of entry.

~~f)~~ The sample shall be considered "non-wicking" if the solution does not wick and wet the lower edge of the filter paper within 6 h.

Dimensions in millimetres

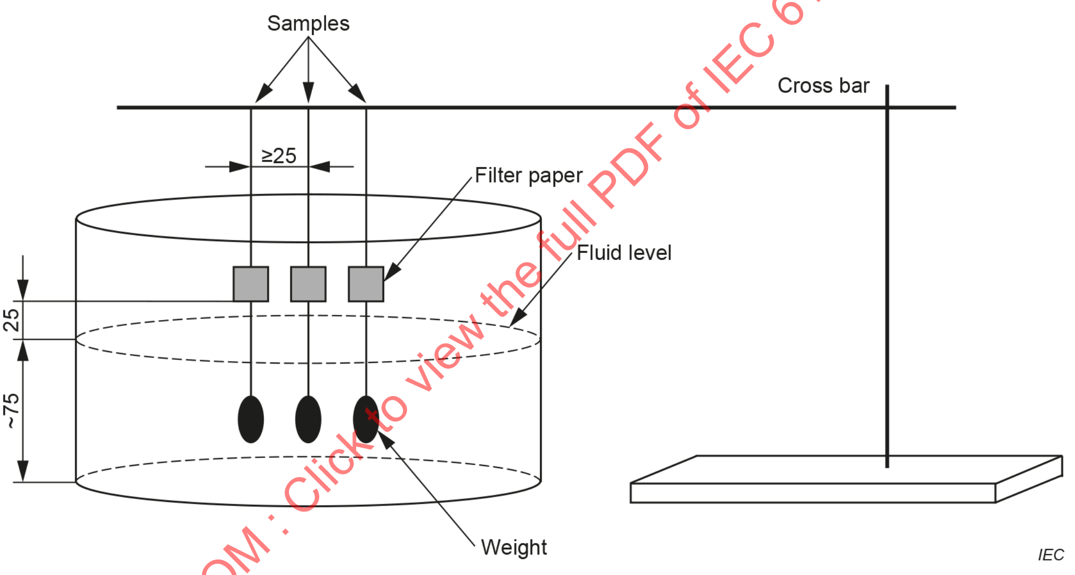


Figure 16 – Wicking test configuration

6.5.16 Flame propagation characteristics of a single cable

The method of measuring the burning performance of a single cable is specified in ~~IEC 60332-1-1~~ IEC 60332-1-2. When this method is not suitable because a small conductor ~~may~~ can melt under the application of the flame, the cable shall be tested in accordance with ~~IEC 60332-2-1~~ IEC 60332-2-2.

6.5.17 Flame propagation characteristics of bunched cables

~~The method of measuring the burning performance of bunched cables is specified in IEC 60332-3-10 and in IEC 60332-3-24.~~

If not specified differently in the relevant detail specification or by local regulations (e.g. European Construction Products Regulation), the method of measuring the burning performance of bunched cables is specified either in IEC 60332-3-24 or IEC 60332-3-25, or both, depending on the overall dimensions of the cable.

6.5.18 Resistance to fire test method

Under consideration.

6.5.19 Halogen gas evolution

The method of measuring the evolution of halogen gas is specified in IEC 60754-2.

6.5.20 Smoke generation

The method of measuring the amount of smoke generated is specified in IEC 61034 (all parts).

6.5.21 Toxic gas emission

Under consideration.

6.5.22 Integrated fire test method for cables in environmental air handling spaces

The method of testing the combined flame and smoke for cables in environmental air handling spaces is described in IEC 62012-1:2002, Annex A.

Annex A
(informative)

Acronyms for common cable constructions

The acronym structure for the cable name is defined in Table A.1. Some common cable construction examples are given in Figure A.1.

Table A.1 – Cable construction acronyms

Acronym		
XX / ABB		
XX – Overall screen	**A – Cable element screen**	**BB – Cable element type**
U – Unscreened F – Foil screened S – Braid screened SF – Braid and foil screened	U – Unscreened F – Foil screened	TP – Twisted pair TQ – Twisted quad

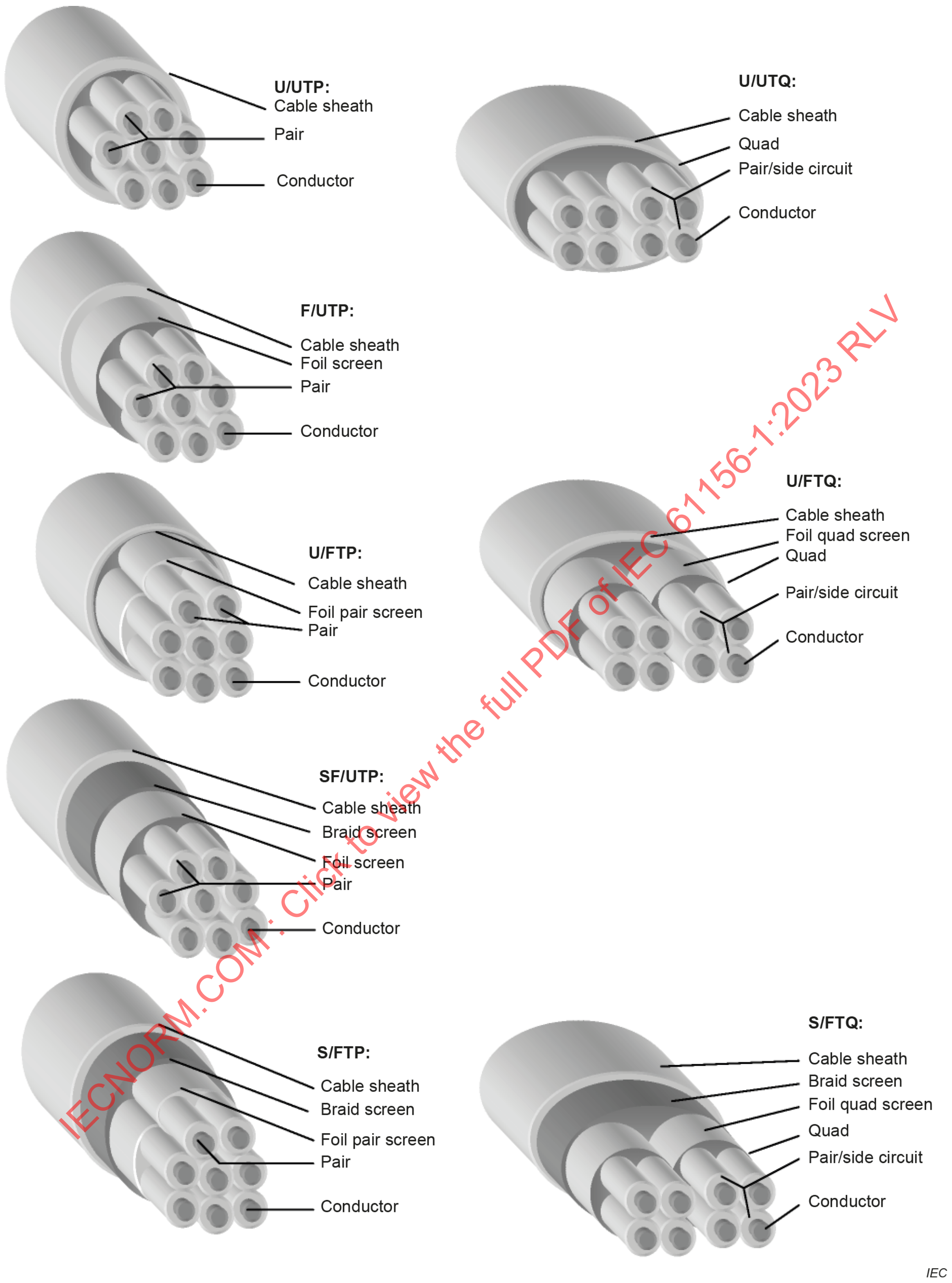


Figure A.1 – Common cable construction examples

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[3] Under preparation. Stage at the time of publication: IEC CDV 60364-7-716:2022.

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Multicore and symmetrical pair/quad cables for digital communications – Part 1: Generic specification

Câbles multiconducteurs à paires symétriques et quartes pour transmissions numériques – Partie 1: Spécification générique

IEC 61156-1:2023-03(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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MULTICORE AND SYMMETRICAL PAIR/QUAD CABLES FOR DIGITAL COMMUNICATIONS –

Part 1: Generic specification

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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IEC 61156-1 has been prepared by subcommittee 46C: Wires and symmetric cables, of IEC technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2007 and Amendment 1 published in 2009. This edition constitutes a technical revision.

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

a) modification of the scope in Clause 1 and updating of normative references documents in Clause 2;

b) addition of PoE-related definitions in Clause 3;

c) clarification of differential-mode and common-mode resistors, correction of formulae and addition of IEC 62153-4-9 test method for coupling attenuation in Clause 6;

d) introduction of balunless measurement method in 6.3.1, modification of equipment requirements of unbalance attenuation in 6.3.5 and updating of balun's performance in Table 1;

e) deletion of 'three layers of cables on a drum' method in alien (exogenous) near-end crosstalk measurement in 6.3.8 and addition of terminated input impedance in 6.3.11.4.

The text of this International Standard is based on the following documents:

Draft	Report on voting
46C/1242/FDIS	46C/1249/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English and French.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 61156 series, published under the general title *Multicore and symmetrical pair/quad cables for digital communications*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

MULTICORE AND SYMMETRICAL PAIR/QUAD CABLES FOR DIGITAL COMMUNICATIONS –

Part 1: Generic specification

1 Scope

This part of IEC 61156 specifies the definitions, requirements and test methods of multicore, symmetrical pair and quad cables.

This document is applicable to communication systems such as local area networks (LANs) and data communication cables. It is also applicable to cables used for industrial applications, customer premises wiring and generic cabling comprising installation cables and cables for work area wiring which are defined in ISO/IEC 11801 (all parts).

The cables covered by this document are intended to operate with voltages and currents normally encountered in communication systems. While these cables are not intended to be used in conjunction with low impedance sources, for example the electric power supplies of public utility mains, they are intended to be used to support the delivery of low voltage remote powering applications including but not restricted to Power over Ethernet as specified in ISO/IEC/IEEE 8802-3. More information on the capacity to support these applications according to the installation practices are given in IEC 61156-1-4, IEC TR 61156-1-6 and ISO/IEC TS 29125.

2 Normative references

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

IEC 60028, *International standard of resistance for copper*

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Tests A: Cold*

IEC 60189-1:2018, *Low-frequency cables and wires with PVC insulation and PVC sheath – Part 1: General test and measuring methods*

IEC 60304, *Standard colours for insulation for low-frequency cables and wires*

IEC 60332-1-2, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*

IEC 60332-2-2, *Tests on electric and optical fibre cables under fire conditions – Part 2-2: Test for vertical flame propagation for a single small insulated wire or cable – Procedure for diffusion flame*

IEC 60332-3-24, *Tests on electric and optical fibre cables under fire conditions – Part 3-24: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category C*

IEC 60332-3-25, *Tests on electric and optical fibre cables under fire conditions – Part 3-25: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category D*

IEC 60708, *Low-frequency cables with polyolefin insulation and moisture barrier polyolefin sheath*

IEC 60754-2, *Test on gases evolved during combustion of materials from cables – Part 2: Determination of acidity (by pH measurement) and conductivity*

IEC 60794-1-21:2015, *Optical fibre cables – Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical test methods*

IEC 60811-201, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 201: General tests – Measurement of insulation thickness*

IEC 60811-202, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 202: General tests – Measurement of thickness of non-metallic sheath*

IEC 60811-203, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 203: General tests – Measurement of overall dimensions*

IEC 60811-401, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 401: Miscellaneous tests – Thermal ageing methods – Ageing in an air oven*

IEC 60811-501, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulating and sheathing compounds*

IEC 60811-502, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 502: Mechanical tests – Shrinkage test for insulations*

IEC 60811-504, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 504: Mechanical tests – Bending tests at low temperature for insulation and sheaths*

IEC 60811-506, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 506: Mechanical tests – Impact test at low temperature for insulations and sheaths*

IEC 60811-508, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 508: Mechanical tests – Pressure test at high temperature for insulation and sheaths*

IEC 60811-509, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 509: Mechanical tests – Test for resistance of insulations and sheaths to cracking (heat shock test)*

IEC 60811-510, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 510: Mechanical tests – Methods specific to polyethylene and polypropylene compounds – Wrapping test after thermal ageing in air*

IEC 61034 (all parts), *Measurement of smoke density of cables burning under defined conditions*

IEC TR 61156-1-2[1], *Multicore and symmetrical pair/quad cables for digital communications – Part 1-2: Electrical transmission characteristics and test methods of symmetrical pair/quad cables*

[1] IEC TR 61156-1-2 is due to become a TS in 2023.

IEC TR 61156-1-5, *Multicore and symmetrical pair/quad cables for digital communications – Part 1-5: Correction procedures for the measurement results of return loss and input impedance*

IEC 61196-1-105, *Coaxial communication cables – Part 1-105: Electrical test methods – Test for withstand voltage of cable dielectric*

IEC 62012-1:2002, *Multicore and symmetrical pair/quad cables for digital communications to be used in harsh environments – Part 1: Generic specification*

IEC 62153-4-3:2013, *Metallic communication cables test methods – Part 4-3: Electromagnetic compatibility (EMC) – Surface transfer impedance – Triaxial method*

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

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

IEC 62255 (all parts), *Multicore and symmetrical pair/quad cables for broadband digital communications (high bit rate digital access telecommunication networks) – Outside plant cables*

ISO/IEC TS 29125:2017, *Information technology – Telecommunications cabling requirements for remote powering of terminal equipment*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
resistance unbalance
difference in resistance of the conductors within a pair or one side of a quad or between pairs or quads

Note 1 to entry: Resistance unbalance is expressed as a percentage (%).

3.2
mutual capacitance
electrical charge storage parameter of a pair of conductors (or with respect to the side of a quad)

Note 1 to entry: Mutual capacitance is one of the four primary transmission line parameters: mutual capacitance, mutual inductance, resistance and conductance.

Note 2 to entry: Mutual capacitance is expressed in pF/m..

3.3
capacitance unbalance to earth
arithmetic difference of the capacitance to earth of the conductors of a pair or one side of a quad

Note 1 to entry: Capacitance unbalance is expressed in pF/m.

3.4
screen
continuous conducting layer or assembly of conducting layers having the function of reducing the penetration of an electric, magnetic or electromagnetic field into a given region

[SOURCE: IEC 60050-195:2021,195-02-37, modified – "continuous conducting layer or assembly of conducting layers having the function of reducing " has replaced "device intended to reduce "]

3.5
balun
device to provide impedance transformation between balanced and unbalanced components

[SOURCE:ISO/IEC 11801-4:2017, 3.1.2]

3.6
balunless
virtual balun used instead of the physical transformers, achieved by mathematical algorithm, and calculated from lumped parameters or distributed parameter network

3.7
transfer impedance
Z_T
quotient of the longitudinal voltage of an electrically short uniform cable, induced in the outer circuit – formed by the screen under test and the measuring jig – and the current fed into the inner circuit – the cable under test itself or vice versa, related to unit length

Note 1 to entry: Transfer impedance is expressed in mΩ/m.

[SOURCE: IEC 62153-4-3:2013, 3.3, modified – "of an electrically short uniform cable" has been added, "outer circuit" has replaced "matched outer circuit", "the cable under test itself" has been added, "related to unit length" has replaced "(see Figure 1)".]

3.8
coupling attenuation
a_c
for a screened balanced cable, the sum of the effects of the unbalance attenuation a_U of the symmetric pair and the screening attenuation α_s of the screen of the cable under test

Note 1 to entry: For electrically long devices, i.e. above the cut-off frequency, the coupling attenuation α_C is defined as the logarithmic ratio of the feeding power P_1 and the periodic maximum values of the coupled power $P_{r,\ max}$ in the outer circuit.

Note 2 to entry: Coupling attenuation is expressed in dB.

[SOURCE: IEC 62153-4-7:2021, 3.4, modified –"cable" has replaced "device", "sum of the effects'" has replaced "sum", Note 2 has been added.]

3.9
current carrying capacity
maximum current a cable circuit (one or several conductors) can support resulting in a specified increase of the surface temperature of the conductor beyond the ambient temperature, not exceeding the maximum allowed operating temperature of the cable

3.10
velocity of propagation
phase velocity
speed at which a sinusoidal signal propagates on a pair in the cable

Note 1 to entry: Velocity of propagation is expressed in m/s.

3.11
phase delay
delay
time duration between the instants that the wave front of a sinusoidal travelling wave, defined by a specified phase, passes two given points in a cable

Note 1 to entry: Phase delay is expressed in s/m.

3.12
differential phase delay
delay skew
difference in phase delay between any two pairs in the cable

Note 1 to entry: Differential phase delay (skew) is expressed in s.

3.13
attenuation
decrease in magnitude of power of a signal that propagates along a pair of a cable

Note 1 to entry: Attenuation is expressed in dB/m.

3.14
ambient temperature
temperature of the room or space surrounding the cable

Note 1 to entry: Ambient temperature is expressed in degree Celsius (°C).

3.15
operating temperature
surface temperature of the conductors of a cable

Note 1 to entry: The operating temperature is the sum of the ambient temperature and of the temperature increase due to the carried power.

Note 2 to entry: Operating temperature is expressed in degree Celsius (°C).

3.16
unbalance attenuation
UA
logarithmic ratio of the differential mode power to the common mode power in a balanced line, or vice versa

Note 1 to entry: Unbalance attenuation is expressed in dB.

Note 2 to entry: Unbalance attenuation is also often referred to as conversion loss: TCL (transverse conversion loss), TCTL (transverse conversion transfer loss), LCL (longitudinal conversion loss), LCTL (longitudinal conversion transfer loss), EL TCTL (equal level transverse conversion transfer loss) and EL LCTL (equal level longitudinal conversion loss transfer loss).

3.17
transverse conversion loss
TCL
logarithmic ratio of the differential-mode circuit power at the near end and the common-mode coupling power measured at the near end

3.18
equal level transverse conversion transfer loss
EL TCTL
output-to-output measurement of the logarithmic ratio of the differential-mode circuit power at the near end and the common-mode coupling power measured at the far end

Note 1 to entry: EL TCTL is calculated by the difference between the measured TCTL and the differential-mode insertion loss of the disturbed pair.

3.19
near-end crosstalk
NEXT
magnitude of the signal power coupling from a disturbing pair at the near end to a disturbed pair measured at the near end

Note 1 to entry: Near-end crosstalk is expressed in dB.

3.20
far-end crosstalk
FEXT
magnitude of the signal power coupling from a disturbing pair at the near end to a disturbed pair measured at the far end

Note 1 to entry: Far-end crosstalk is expressed in dB.

3.21
power sum of crosstalk
PS
summation of the crosstalk power from all disturbing pairs into a disturbed pair

Note 1 to entry: The summation is applicable to near-end and far-end crosstalk.

Note 2 to entry: The power sum of crosstalk is expressed in dB.

3.22
attenuation to crosstalk ratio, far-end
ACR-F
arithmetic difference between the far-end crosstalk and the attenuation of the disturbed pair

Note 1 to entry: Attenuation to crosstalk ratio, far-end, is expressed in dB.

3.23
alien (exogenous) near-end crosstalk
ANEXT
near-end crosstalk where the disturbing and disturbed pairs are contained in different cables

Note 1 to entry: Alien (exogenous) near-end crosstalk is expressed in dB.

3.24
alien (exogenous) far-end crosstalk
AFEXT
far-end crosstalk where the disturbing and disturbed pairs are contained in different cables

Note 1 to entry: Alien (exogenous) far-end crosstalk is expressed in dB.

3.25
alien (exogenous) far-end crosstalk
AACR-F
far-end crosstalk where the disturbing and disturbed pairs are contained in different cables

Note 1 to entry: Alien (exogenous) far-end crosstalk is expressed in dB.

3.26
power sum of alien (exogenous) near-end crosstalk
PS ANEXT
summation of the near-end alien (exogenous) crosstalk power from all disturbing pairs into a disturbed pair in different cables

Note 1 to entry: The power sum of alien (exogenous) near-end crosstalk is expressed in dB.

3.27
power sum of alien (exogenous) far-end crosstalk
PS AACR-F
summation of the alien (exogenous) far-end crosstalk power from all disturbing pairs into a disturbed pair in different cables

Note 1 to entry: The power sum of far-end alien (exogenous) crosstalk is expressed in dB.

3.28
characteristic impedance
Z_C
impedance at the input of a homogeneous line of infinite length

Note 1 to entry: The impedance value is expressed in Ω, at relevant frequencies, as the square root of the product of the impedance measured at the near end (input) of a cable pair when the far end is terminated by an open circuit load and then an short circuit load.

Note 2 to entry: The asymptotic value at high frequencies is denoted as Z_∞.

Note 3 to entry: The characteristic impedance of a homogeneous cable pair is given by the quotient of a voltage wave and current wave which are propagating in the same direction, either forwards or backwards.

Note 4 to entry: For homogeneous ideal cables, this test method yields a flat smooth curve over the whole frequency range. Real cables with distortions give curves with some roughness.

3.29
terminated input impedance
Z_{in}
impedance value, expressed in Ω, at relevant frequencies, measured at the near end (input) when the far end is terminated with the system nominal impedance, Z_R

3.30
fitted characteristic impedance
Z_m
impedance value, expressed in Ω, calculated by applying a least squares function fitting algorithm to the measured characteristic impedance values

3.31
mean characteristic impedance
Z_∞
asymptotic value at which the characteristic impedance approaches at sufficiently high frequencies (≈100 MHz) such that the imaginary part (phase angle) is insignificant

Note 1 to entry: Normally measured from the capacitance and time delay.

Note 2 to entry: Applicable for cables with frequency independence of mutual capacitance.

3.32
return loss
RL
ratio of reflected power to input power at the input terminals of a cable pair

Note 1 to entry: Return loss is expressed in dB.

3.33
bundled cable
grouping or assembly of several individual cables that are systematically laid up

Note 1 to entry: Bundled cables are also referred to as speed-wrap, whip, or loomed cables.

3.34
remote powering
supply of power to application specific equipment via balanced cabling

[SOURCE: ISO/IEC TS 29125:2017, 3.1.5]

3.35
safety extra-low voltage
SELV
AC voltage the RMS value of which does not exceed 50 V or ripple-free DC voltage the value of which does not exceed 120 V, between conductors, or between any conductor and reference earth, in an electric circuit which has galvanic separation from the supplying electric power system by such means as a separate-winding transformer

Note 1 to entry: Maximum voltage lower than 50 V AC or 120 V ripple-free DC may be specified in particular requirements, especially when direct contact with live parts is allowed.

Note 2 to entry: The voltage limit should not be exceeded at any load between full load and no-load when the source is a safety isolating transformer.

Note 3 to entry: Ripple-free qualifies conventionally an RMS ripple voltage of not more than 10 % of the DC component; the maximum peak value does not exceed 140 V for a nominal 120 V ripple-free DC system and 70 V for a nominal 60 V ripple-free DC system.

3.36
continuous operating temperature
COT
maximum temperature which ensures the stability and integrity of the material for the expected life of the equipment, or part, in its intended application

3.37
hygroscopic
characteristic of a material to absorb moisture from the atmosphere

3.38
wicking
longitudinal flow of a liquid in a material due to capillary action

4 Installation considerations

The cables shall be designed to meet the installation conditions encountered for each area as follows.

a) Equipment cables

   The cables are used between work stations and peripheral equipment (for example, printer).

b) Work area cables

   The cables are used between the work station and the communication outlets.

c) Horizontal floor wiring cables

   The cables are used between the work area communication outlet and the communication closet.

d) Riser cables and building back-bone cables

   The cables are used for horizontal installation or vertically between floors.

e) Campus cables

These cables are used to interconnect buildings and shall be suitable for outdoor installation. The cables shall be sheathed and protected in accordance with IEC 62255 (all parts).

f) Delivery of power

For cables delivering power using only SELV systems for remote powering, the COT shall be considered.

NOTE The related document is IEC 60364-7-716.

5 Materials and cable construction

5.1 General remarks

The choice of materials and cable construction shall be suitable for the intended application and installation of the cable. Any special requirements for EMC (electromagnetic compatibility), fire performance, or SELV should be considered.

5.2 Cable constructions

5.2.1 General

The cable construction shall be in accordance with the details and dimensions given in the relevant detail specification.

5.2.2 Conductor

The conductor shall consist of annealed copper, uniform in quality and free from defects. The properties of the copper shall be in accordance with IEC 60028.

The conductor may be either solid or stranded. The solid conductor shall be circular in section and may be plain or metal-coated. The solid conductor shall be drawn in one piece. Joints in the solid conductor are permitted, provided that the breaking strength of a joint is not less than 85 % of the breaking strength of the unjointed solid conductor.

The stranded conductor shall consist of strands circular in section and assembled without insulation between them by concentric stranding or bunched.

NOTE A bunched strand is not recommended for insulation displacement connection (IDC) application.

The individual strands of the conductor may be plain or metal-coated.

Joints in individual strands are permitted provided that the tensile strength of a joint is not less than 85 % of the breaking strength of the unjointed individual strand. Joints in the complete stranded conductor are not permitted unless allowed and specified in the relevant detail specification.

The conductor of the work area and equipment cables may consist of one or more elements of thin copper or copper alloy tape which shall be applied spirally over a fibrous thread. Joints in the complete element are not permitted.

5.2.3 Insulation

5.2.3.1 General requirements

The conductor insulation is composed of one or more suitable dielectric materials. The insulation may be solid, cellular or composite (for example, foam skin).

The insulation shall be continuous, having a uniform thickness.

The insulation shall be applied to fit closely to the conductor.

The insulated conductors may be identified by colours, additional ring markings or symbols achieved by the use of coloured insulation or by a coloured surface using extrusion, printing or painting. Colours shall be clearly identifiable and shall correspond reasonably with the standard colours shown in IEC 60304.

5.2.3.2 Colour code

The colour code for insulation is given in the relevant detail specification.

5.2.4 Cable element

5.2.4.1 General

The cable element is

– a pair consisting of two insulated conductors twisted together and designated wire "a" and wire "b", or
– a quad consisting of four insulated conductors twisted together and designated wire "a", wire "c", wire "b" and wire "d" in order of rotation.

The choice of the maximum average length of lay in the finished cable shall be made with respect to the specified crosstalk requirements, handling performance and the pair or quad integrity.

NOTE Forming the element with a variable lay can lead to the infrequent but acceptable occurrence of the maximum lay being longer than the specified length of lay.

5.2.4.2 Screening of the cable element

When a screen is required over the pair or quad, it may consist of the following:

a) a metallic tape laminated to a plastic tape;
b) a metallic tape laminated to a plastic tape and a metal-coated or plain copper drain wire whereby the metal tape is in contact with the drain wire;
c) a metallic braid;
d) a metallic tape laminated to a plastic tape and a metallic braid.

Coatings or other methods of protection should be considered in order to prevent galvanic interaction when putting dissimilar metals in contact with each other.

A protective wrapping may be applied either under or over the screen or both.

5.2.5 Cable make-up

The cable elements may be laid up in concentric layers or in unit construction. The cable core may be protected by wrappings of a non-hygroscopic, non-wicking tape.

NOTE 1 Fillers can be used to maintain a circular formation.

NOTE 2 Forming the element with a variable lay can lead to the infrequent but acceptable occurrence of the maximum lay being longer than the specified length of lay.

5.2.6 Screening of the cable core

The cable core may be covered by a screen being part of the shielding and grounding system of the cabling. The possible design can be

a) a metallic tape laminated to a plastic tape which may be bonded to the sheath, for example F/UTP structure;
b) a metallic tape laminated to a plastic tape and a metal-coated or plain copper drain wire whereby the metal tape is in contact with the drain wire, for example F/UTP structure;
c) a metallic braid, for example S/UTP structure;
d) a metallic tape laminated to a plastic tape and a metallic braid, for example SF/UTP structure;
e) plain copper or aluminium tape, for example F/UTP structure.

An unlaminated metallic tape is also permitted if it can meet the requirements of performance, for example, strength.

Coatings or other methods of protection should be considered in order to prevent galvanic interaction when putting dissimilar metals in contact with each other.

A protective wrapping may be applied either under or over the screen, or both. Typical designs and their denominations are listed in Annex A.

5.2.7 Sheath

The sheath shall be a polymeric material.

The sheath shall be continuous, having a uniform thickness.

The sheath shall be applied to fit closely to the core of the cable. In the case of screened cables, the sheath shall not adhere to the screen except when it is intentionally bonded to it.

The colour of the sheath may be specified in the relevant detail specification.

5.2.8 Identification

5.2.8.1 Cable marking

Each length of cable shall bear the name of the supplier and the cable type and, when provided, the year of manufacture, using one of the following methods:

a) coloured threads or tapes;
b) printed tape;
c) printing on the core wrappings;
d) marking on the sheath.

Additional markings, for example maximum voltage, temperature rating, etc., may be provided on the sheath as indicated in the relevant detail specification.

5.2.8.2 Labelling

The following information shall be provided either on a label attached to each length of the finished cable or on the outside of the product package:

a) type of cable;
b) supplier's name or logo;
c) year of manufacture;

d) length of cable in metres.

5.2.9 Finished cable

The finished cable shall have adequate protection for storage and shipment.

6 Characteristics and requirements

6.1 General remarks – Test configurations

Unless otherwise specified, all the tests shall be performed assuming that the operating temperature is 20 °C. The temperature of the cable shall be stabilized at 20 °C and the test signal shall be low enough to avoid any temperature increase.

NOTE Temperature rise is expected when testing for the cable's application in remote powering installations.

The computed requirements, rounded to one decimal place, shall be used to determine compliance.

Typical test configurations for the test specimen are

a) laid out on a non-metallic surface at least 25 mm from a conductive surface;

b) supported in aerial spans in such a way that there is a minimum separation of 25 mm between convolutions;

c) wound as a single open helix on a drum with at least 25 mm between turns.

The configurations a), b) and c) are not necessary for screened cables.

The parameters of mutual capacitance, crosstalk, characteristic impedance and attenuation sometimes show measured values up to 10 % higher when the cable is measured in its packaging. This difference arises due to the tight packaging density and interwinding effects. Also, box packaging can negatively affect the cable return loss, crosstalk and characteristic impedance with full or partial recovery of cable performance after installation.

In case of doubt, the measurements of mutual capacitance, impedance, attenuation and crosstalk shall be performed on a cable sample removed from its packaging.

Measurement procedures for alien (exogenous) crosstalk specify the special test configurations for the mounting of the cables.

The differential-mode and common-mode termination resistors should be used to terminate inactive pairs and opposite ends of active pairs for near-end crosstalk and far-end crosstalk testing (see Figure 1). For cables having a nominal impedance (Z_{diff}) of 100 Ω, the common-mode impedance (Z_{com}) is:

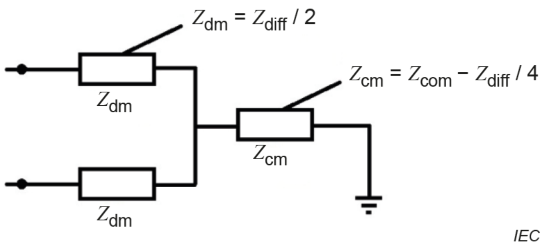
– about 75 Ω for up to 25 pair-count unscreened pair cables,

– about 50 Ω for common screened pair cables and more than 25 pair-count unscreened pair cables,

– about 25 Ω for individually screened pair cables.

In principle in balun measurements, the test shall be carried out with the condition that differential-mode impedance (Z_{diff}) and common mode impedance (Z_{com}) of the test specimen are matched by the balun and the vector network analyzer (or equivalent instruments), respectively.

But in practice, as the vector network analyzer (or equivalent instrument) used in the measurement has 50 Ω ports in general and the common mode impedance of the balun is also 50 Ω, the common mode impedance of the termination shall be 50 Ω unless otherwise specified. This is to simplify measurements when the common mode impedance of the test specimen varies from 25 Ω to 75 Ω.



Key

Z_{dm} is the differential-mode termination resistor (Ω);

Z_{cm} is the common-mode termination resistor (Ω).

Z_{diff} is the differential-mode impedance of cable (Ω);

Z_{com} is the common-mode impedance of cable (Ω).

Figure 1 – Resistor terminations in balun measurements

Resistor terminations in balunless measurements can be found in IEC TR 61156-1-2.

6.2 Electrical characteristics and tests

6.2.1 Conductor resistance

The measurement of the conductor resistance shall be in accordance with IEC 60189-1:2018, 8.1.

NOTE For resistance, general information can be found in IEC TR 61156-1-6.

6.2.2 Resistance unbalance

6.2.2.1 General requirement

The measurement of the resistance unbalance and the accuracy of the measurement equipment shall be in accordance with IEC 60708.

NOTE For resistance unbalance, general information can be found in IEC TR 61156-1-6.

6.2.2.2 Resistance unbalance within a pair

The resistance unbalance between conductors of a pair or on the same side of a quad is given by

$$\Delta R = \frac{(R_{max} - R_{min})}{(R_{max} + R_{min})} \times 100\% \qquad (1)$$

where

ΔR is the conductor resistance unbalance (%);

R_{max} is the resistance for the conductor with the highest resistance value (Ω);

R_{min} is the resistance for the conductor with the lowest resistance value (Ω).

6.2.2.3 Resistance unbalance between pairs

The resistance unbalance between pairs or sides of quads is given by

$$\Delta RP_{i,k} = \frac{\left| R_{\max i} \times R_{\min i} \left(R_{\max k} + R_{\min k} \right) - R_{\max k} \times R_{\min k} \left(R_{\max i} + R_{\min i} \right) \right|}{R_{\max i} \times R_{\min i} \left(R_{\max k} + R_{\min k} \right) + R_{\max k} \times R_{\min k} \left(R_{\max i} + R_{\min i} \right)} \times 100\% \qquad (2)$$

where

$\Delta RP_{i,k}$ is the resistance unbalance between pair i and pair k (%);

R_{max} is the resistance of the wire with the highest resistance of a pair (Ω);

R_{min} is the resistance of the wire with the lowest resistance of a pair (Ω);

i,k $i \neq k$ where i = 1 to n and k = 1 to n for n = number of pairs.

6.2.3 Dielectric strength

This measurement shall be carried out before the measurement of insulation resistance described in 6.2.4.

The measurement of dielectric strength shall be in accordance with IEC 61196-1-105 for conductor/conductor, conductor/screen (if present) and screen/screen (if present).

NOTE This test is important to ensure safety is not contravened in remote powering installations.

6.2.4 Insulation resistance

This measurement shall be carried out after the dielectric strength test described in 6.2.3.

The measurement of insulation resistance between conductor/conductor, conductor/ screen and screen/screen shall be in accordance with IEC 60189-1:2018, 8.3. The test voltage shall be between 100 V and 500 V DC unless otherwise specified in the detail specification.

6.2.5 Mutual capacitance

The measurement of the mutual capacitance of pairs in a multipair or quad cable shall be in accordance with IEC 60189-1:2018, 8.4.

6.2.6 Capacitance unbalance to earth

The measurement of the capacitance unbalance in a multipair or quad cable shall be in accordance with IEC 60189-1:2018, 8.5.

The capacitance unbalance to earth of a pair or one side of a quad is given by

$$\Delta C_e = C_1 - C_2 \qquad (3)$$

where

ΔC_e is the pair-to-earth capacitance unbalance (pF/km);

C_1 is the capacitance between conductor "a" and conductor "b", with conductor "b" connected to all other conductors, to the screen (if present) and to earth (pF/km);

C_2 is the capacitance between conductor "b" and conductor "a", with conductor "a" connected to all other conductors, to the screen (if present) and to earth (pF/km).

The test result of the capacitance unbalance to earth shall be corrected:

– for pair-to-earth and side-to-earth by

$$\Delta C_e = C_{meas} \times \frac{1000}{L} \quad (4)$$

where

ΔC_e is the capacitance unbalance to earth (pF/km);

C_{meas} is the measured capacitance (pF/km);

L is the length of cable under test (m).

If required, the test result of capacitance unbalance for pair-to-pair and side-to-side shall be specified in the detailed specification.

6.2.7 Transfer impedance

The measurement of the transfer impedance shall be in accordance with IEC 62153-4-3. All of the screens shall be connected together at the ends of the test specimen. The transfer impedance shall be measured over the frequency range indicated in the relevant sectional specification.

6.2.8 Coupling attenuation

The test method of the coupling attenuation shall be in accordance with IEC 62153-4-5 or IEC 62153-4-9. All of the screens shall be connected together at the ends of the test specimen. The coupling attenuation of all pairs within the specimen shall be measured over the frequency range indicated in the relevant sectional specification.

IEC 62153-4-9 shall be the referee test method to resolve doubts or dispute.

6.2.9 Current-carrying capacity

If required, the test method for current carrying capacity is described in IEC 61156-1-4. As the current carrying capacity is significantly determined by the installation conditions, general guidance of ISO/IEC TS 29125 should be considered.

NOTE The minimum conductor size (maximum resistance) will be used in the calculation of each cable being considered for its maximum current carrying capacity as batch deliveries can vary.

6.3 Transmission characteristics

6.3.1 General requirements

Transmission measurements are in the balanced mode with measuring equipment (network analyzer or signal generator and receiver) and baluns to connect the cable to the equipment. The baluns shall be selected to match the test equipment to the cable nominal impedance and shall have the relevant performance characteristics given in Table 1.

All the tests shall be carried out over the whole specified frequency range and at the same frequency points of the calibration procedure. A full two-port calibration shall be done to get the best accuracy, and the length of the cable for a through calibration should be as short as possible.

All the tests shall be carried out in both directions or at both ends.

An alternative to balun measurement method is the balunless measurement method which is specified in IEC TR 61156-1-2. For frequencies higher than 1 GHz, the balunless measurement method is recommended.

The length of cable under test shall be 100 m, unless otherwise specified.

6.3.2 Velocity of propagation (phase velocity)

The velocity of propagation shall be determined by radian frequency and phase constant.

The test equipment schematic is given in Figure 2.

The velocity of propagation is given by

$$v_{(f)} = \frac{\omega_{(f)}}{\beta_{(f)}} = \frac{2\pi f}{\beta_{(f)}} \tag{5}$$

where

f is the frequency (Hz);

$v_{(f)}$ is the phase velocity at frequency f (m/s);

$\beta_{(f)}$ is the phase constant (rad/m);

$\omega_{(f)}$ is the radian frequency.

In the high frequency, the cable's propagation velocity is approximately constant, so the phase velocity may be assessed by the group velocity for an easier measurement. When signals with multiple frequency components propagate along a cable, if these frequencies are very close and their differences are much smaller than the central frequency, the group velocity is determined from Formula (6). Δf is the frequency interval, for which the phase of the output signal makes a 2π radians rotation in comparison with the input signal.

$$v_{(G)} = L \times \Delta f \tag{6}$$

where

$v_{(G)}$ is the group velocity (m/s);

L is the length of the cable under test (m);

Δf is the frequency interval (Hz).

In order to evaluate Δf with sufficient accuracy, the frequency difference $\Delta f'$ for n rotations of 2π radians can be measured as

$$\Delta f = \Delta f'/n \tag{7}$$

where

Δf is the frequency interval (Hz);

$\Delta f'$ is the frequency difference for n rotations(Hz);

n is the number of rotations ≤ 10.

Detailed information of phase velocity and group velocity can be found in IEC TR 61156-1-2.

6.3.3 Phase delay and differential delay (delay skew)

The phase delay is determined from the phase velocity:

$$\tau_{\mathrm{p}} = \frac{L}{v_{\mathrm{p}}} \tag{8}$$

where

τ_{p} is the phase delay (s);

v_{p} is the phase velocity (m/s);

L is the cable length under test (m).

The differential phase delay (delay skew) is determined from

$$\Delta\tau_{\mathrm{p}} = L \times \left| \frac{1}{v_{\mathrm{p},1}} - \frac{1}{v_{\mathrm{p},2}} \right| \tag{9}$$

where

$\Delta\tau_{\mathrm{p}}$ is the differential phase delay (delay skew) (s);

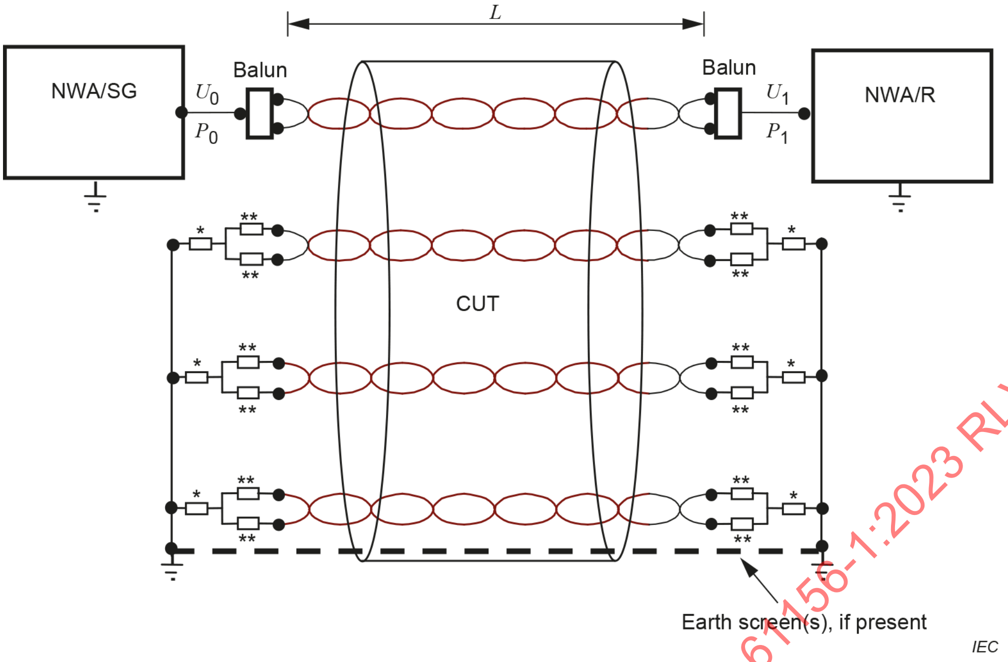
$v_{\mathrm{p},1}$ is the phase velocity of one pair (m/s);

$v_{\mathrm{p},2}$ is the phase velocity of another pair (m/s).

6.3.4 Attenuation

6.3.4.1 Attenuation at 20 °C operating temperature

The measurement shall be over the frequency range indicated in the relevant sectional specification. The test schematic is given in Figure 2.



Key

CUT	cable under test
NWA/SG	network analyzer port or signal generator
NWA/R	network analyzer port or receiver
*	common-mode termination resistor
**	differential-mode termination resistor (matched in pairs)
L	length of cable under test (m)
U_0	voltage at network analyzer port or signal generator (V)
U_1	voltage at network analyzer port or receiver (V)
P_0	power at network analyzer port or signal generator (W)
P_1	power at network analyzer port or receiver (W)

Figure 2 – Test set-up for the measurement of attenuation, velocity of propagation and phase delay

The measurements are made at ambient temperature, and attenuation for 100 m length of cable is given by Formula (10).

$$\alpha = \left|\frac{100}{L}\right| \times 10\lg\left|\frac{P_0}{P_1}\right| \tag{10}$$

where

α is the attenuation in 100 m (dB/100 m) and is corrected to 20 °C as follows.

$$\alpha_{20} = \frac{\alpha}{1+\delta_{\text{cable}} \times (T-20)} \tag{11}$$

where

α_{20} is the attenuation corrected to 20 °C (dB/100 m);

δ_{cable} is the attenuation temperature coefficient (%/°C);

T is the ambient temperature (°C).

Attenuation temperature coefficient values are given in the relevant sectional specification.

6.3.4.2 Attenuation at elevated ambient temperatures

6.3.4.2.1 Test chamber

The test chamber shall be either an air-circulating oven or an environmental chamber. The test chamber shall be capable of maintaining the required test temperature, ±2 °C, for the duration of the test. The chamber dimensions shall be adequate to contain the sample and fixtures as required to support the sample. The chamber shall be provided with access ports for connecting the sample to the test equipment. The maximum length of the cable ends extending out of the test chamber shall be 1 m.

6.3.4.2.2 Sample preparation and test configuration

The sample may be loosely coiled with a minimum diameter of 18 cm and placed in the chamber. In this configuration the wraps of the coil may be in close proximity and inter-winding coupling may appear in the test results for unscreened cable.

Alternatively, the sample may be wound on a non-metallic drum with adjacent wraps separated by a minimum of 2,5 cm which will eliminate inter-winding coupling for unscreened cable.

6.3.4.2.3 Test procedure

The attenuation of the sample shall be measured at ambient temperature in accordance with 6.3.4.1 after conditioning in the chamber for at least 4 h.

The temperature in the chamber shall be maintained at the required temperature, and the attenuation of the sample shall be measured again after a time duration of between 4 h and 24 h. The test signal shall be low enough to avoid any temperature increase.

A mathematical smoothing algorithm that can be applied to the measured attenuation data to correct for inter-winding coupling is given by the following:

$$\alpha_{sm} = a \times \sqrt{f} + b \times f + c / \sqrt{f} + d \quad (12)$$

where

α_{sm} is the smoothed attenuation data (dB/100 m);

a, b, c, d are the regression coefficients;

f is the frequency (Hz).

6.3.4.3 Attenuation temperature coefficient

The attenuation temperature coefficient is given by Formula (13).

$$\delta_{\text{cable}} = \frac{\alpha_{T2} - \alpha_{T1}}{\alpha_{T1} \times (T_2 - T_1)} \times 100\% \tag{13}$$

where

δ_{cable} is the attenuation temperature coefficient (%/°C);

α_{T1} is the attenuation at temperature T_1 (dB/100 m);

α_{T2} is the attenuation at temperature T_2 (dB/100 m);

T_1 is the reference or ambient temperature (°C);

T_2 is the elevated temperature (°C).

NOTE The calculation according to Formula (13) is applicable to both the measured and the smoothed attenuation data.

6.3.5 Unbalance attenuation

6.3.5.1 Equipment

a) A defined return (common-mode) path shall be created for unbalanced attenuation measurement. This is normally achieved by earthing all other pairs and screen(s) if present in common to the balun earth. The pairs shall be terminated with differential-mode and common-mode terminations and earthed at near and far ends. However, the cable under test may be wound onto an earthed metal drum. The drum surface may have a suitable groove, wide enough to contain the cable and shall be adequate to hold 100 m of cable in one layer.

b) Both the balun method and the balunless method are permitted, in order to do a measure for unbalance attenuation. For the balun measurement method, the baluns shall have a common-mode port and the characteristics given in Table 1. For the balunless measurement method, the equipment shall comply with IEC TR 61156-1-2.

c) A vector network analyzer or generator and receiver combination suitable for the required frequency and dynamic range can be used.

d) A time domain reflectometer or a VNA having a time domain analysis function by using inverse discrete Fourier transformation can be used as optional equipment.

Table 1 – Test balun performance characteristics

Parameter	Class A-500 1 MHz to 500 MHz	Class A-1 000 1 MHz to 1 000 MHz	Class A-2 000 1 MHz to 2 000 MHz
Impedance, primary [a]	50 Ω unbalanced	50 Ω unbalanced	50 Ω unbalanced
Impedance, secondary	Matched balanced [d]	Matched balanced [d]	Matched balanced [d]
Insertion loss, maximum	2,0 dB	3,0 dB	4,5 dB
Return loss, secondary, minimum	12 dB min., 1 MHz to 15 MHz 20 dB min., 15 MHz to 500 MHz	12 dB, 4 MHz to 15 MHz 20 dB, 15 MHz to 550 MHz 17,5 dB, 550 MHz to 600 MHz 10 dB, 600 MHz to 1 000 MHz	8 dB, 1 MHz to 3 MHz 12 dB, 3 MHz to 15 MHz 20 dB, 15 MHz to 1 000 MHz 18 dB, 1 000 MHz to 2 000 MHz

Parameter	Class A-500 1 MHz to 500 MHz	Class A-1 000 1 MHz to 1 000 MHz	Class A-2 000 1 MHz to 2 000 MHz
Return loss, common mode [b], minimum	15 dB min., 1 MHz to 15 MHz 20 dB min., 15 MHz to 400 MHz 15 dB min., 400 MHz to 500 MHz	15 dB, 4 MHz to 15 MHz 20 dB, 15 MHz to 400 MHz 15 dB, 400 MHz to 600 MHz 10 dB, 600 MHz to 1 000 MHz	6 dB, 1 MHz to 3 MHz 10 dB, 3 MHz to 500 MHz ffs., 500 MHz to 2 000 MHz
Power rating	0,1 W min.	0,1 W	0,1 W min.
Longitudinal balance [c], minimum	60 dB min., 1 MHz to 100 MHz 50 dB min., 100 MHz to 500 MHz	60 dB, 4 MHz to 350 MHz 50 dB, 350 MHz to 600 MHz 40 dB, 600 MHz to 1 000 MHz	60 dB, 1 MHz to 100 MHz 50 dB, 100 MHz to 500 MHz 42 dB, 500 MHz to 1 000 MHz 34 dB, 1 000 MHz to 2 000 MHz
Output signal balance[c], minimum	50 dB,minumum	60 dB, 4 MHz to 350 MHz 50 dB, 350 MHz to 600 MHz 40 dB, 600 MHz to 1 000 MHz	Under considerartion
Common-mode rejection[c], minimum	50 dB	50 dB, 4 MHz to 600 MHz 40 dB, 600 MHz to 1 000 MHz	50 dB, 1 MHz to 500 MHz 42 dB, 500 MHz to 1 000 MHz 34 dB, 1 000 MHz to 2 000 MHz

Special guidelines for the use of baluns

1) For tests up to 500 MHz, class A-500 baluns should be used.
2) For tests up to 1 000 MHz, class A-1000 baluns should be used.
3) For tests up to 2 000 MHz, the balunless test method is preferred. See IEC TR 61156-1-2 for detailed information on the balunless test method.
4) Common mode port of baluns are optional in 6.3 except for unbalance attenuation measurement.

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

[b] Measured by connecting the balanced output terminals together and measuring the return loss. The unbalanced balun input terminal shall be terminated by a 50 Ω load.

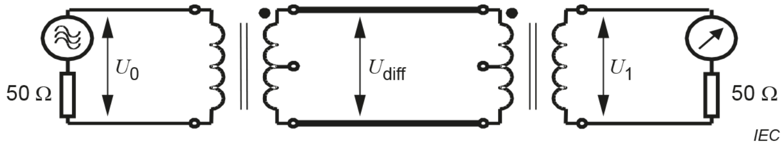
[c] Measured according to ITU T Recommendation G.117 and ITU-T Recommendation O.9.

[d] For 120 Ω cables, 120 Ω baluns will be used only in cases where it is requested by the user. Usually 100 Ω baluns will be used.

6.3.5.2 Balun calibration

a) The reference line calibration (0 dB line) shall be determined by connecting coaxial cables between the analyzer input and output. The same coaxial cables shall also be used for the balun loss measurements. The calibration shall be established over the whole frequency range specified in the relevant cable specification. This calibration method is valid for closely matched baluns that satisfy the characteristics of Table 1.

b) Figure 3 gives the schematic for the measurement of the differential-mode loss of the baluns. Two baluns are connected back to back on the symmetrical output side and their attenuation measured over the specified frequency range. The connection between the two baluns shall be made with negligible loss.



Key

U_0 voltage at network analyzer port or signal generator (V);

U_1 voltage at network analyzer port or receiver (V);

U_{diff} voltage at symmetrical port of baluns (V).

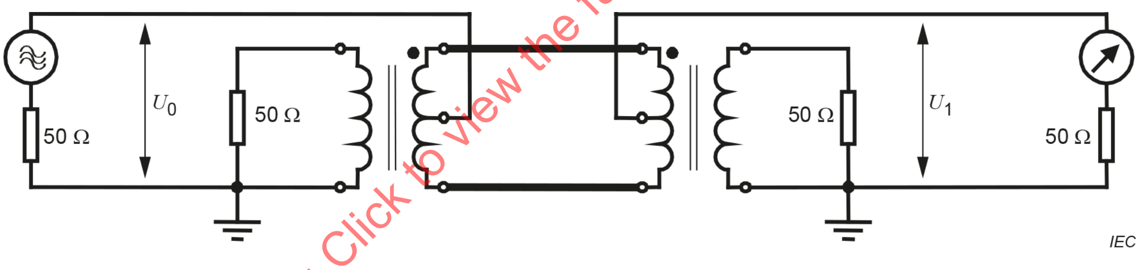
Figure 3 – Test set-up for the measurement of the differential-mode loss of the baluns

The differential-mode loss of the single balun is given by

$$\alpha_{diff} = 0,5 \times \left(20\lg\left|\frac{U_0}{U_1}\right| \right) = -\,0,5 \times \left(20\lg\left|S_{21}\right| \right) \tag{14}$$

where α_{diff} is the differential-mode loss of the single balun (dB).

c) Figure 4 gives the schematic for the measurement of the common-mode loss of the baluns. The baluns used in b) are connected together; the unbalanced balun ports are terminated with the nominal test equipment impedance, and the test equipment is connected to the common-mode port (centre tap) of the baluns.



Key

U_0 voltage at network analyzer port or signal generator (V);

U_1 voltage at network analyzer port or receiver (V).

Figure 4 – Test set-up for the measurement of the common-mode loss of the baluns

The common-mode loss of the single balun is given by

$$\alpha_{com} = 0,5 \times \left(20\lg\left|\frac{U_0}{U_1}\right| \right) = -\,0,5 \times \left(20\lg\left|S_{21}\right| \right) \tag{15}$$

where α_{com} is the common-mode loss of the single balun (dB).

d) The operational attenuation of the balun α_{balun} takes into account the common-mode and differential-mode losses of the balun:

$$\alpha_{balun} = \alpha_{diff} + \alpha_{com} \tag{16}$$

where α_{balun} is the operational attenuation or intrinsic loss of the balun (dB).

NOTE More precise results can be obtained using either poling of the baluns for α_{diff} and α_{com} and averaging the results or using three baluns. In the latter case, the assumption of identical baluns is not required.

e) The voltage ratio of the balun can be expressed by the turns ratio of the balun and the operational attenuation of the balun:

$$\begin{aligned} 20\lg\left|\frac{U_{diff}}{U_0}\right| &= 10\lg\left|\frac{Z_{diff}}{Z_0}\right| - \alpha_{balun} \\ 20\lg\left|\frac{U_{diff}}{U_1}\right| &= 10\lg\left|\frac{Z_{diff}}{Z_1}\right| - \alpha_{balun} \end{aligned} \tag{17}$$

where

U_{diff} is the differential-mode voltage at the input of the cable under test (V);

U_0 is the voltage at the network analyzer port or signal generator (V);

U_1 is the voltage at the input of the load (V);

Z_{diff} is the characteristic impedance of the differential-mode circuit (Ω);

Z_0 is the output impedance of the network analyzer or signal generator (Ω);

Z_1 is the input impedance of the load (Ω).

6.3.5.3 Measurements

6.3.5.3.1 Sample preparation

The ends of the CUT shall be prepared so that the twisting of the pairs/quads is maintained up to the terminals of the test equipment. If not otherwise specified, the CUT shall have a length of 100 m ± 1 m. All pairs not under test shall be connected to earth through differential-mode and common-mode terminations at the near and far end.

The impedance of the common-mode circuit Z_{com} can be measured more precisely either with a time domain reflectometer (TDR) or a network analyzer. The two conductors of the pair are connected together at both ends and the impedance is measured between these conductors and the return path.

If not otherwise specified, the common-mode terminations should be 50 Ω. The screens, if any, shall be connected to earth at both ends of the cable.

6.3.5.3.2 Test set-up for unbalance measurements

Figure 5 gives a schematic of the measurement for unbalance attenuation at the near end.

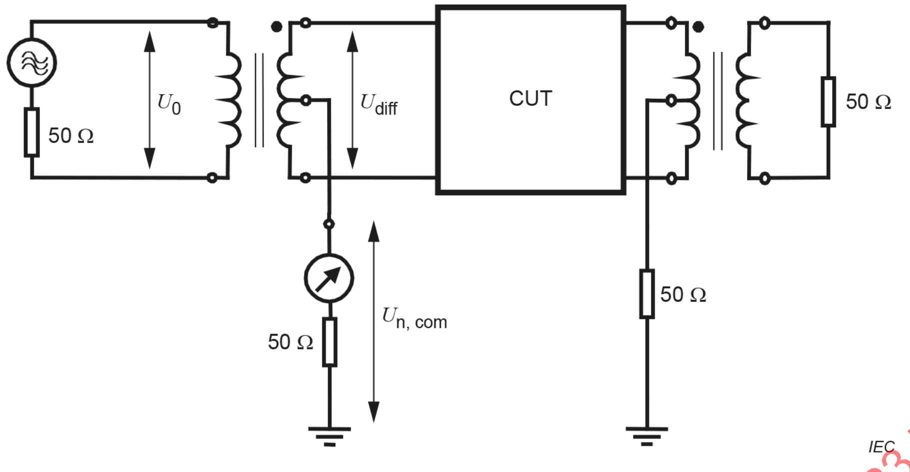


Figure 5 – Test set-up for unbalance attenuation at near end (TCL)

$$\alpha_{meas} = 20\lg\left|\frac{U_0}{U_{n,com}}\right| = -20\lg|S_{21}| \quad (18)$$

where

α_{meas} is the measured attenuation (dB);

$U_{n,com}$ is the voltage in the common-mode circuit at the near end balun (V);

U_0 is the voltage in the primary (unbalanced) circuit at the near end balun (V).

Figure 6 gives a schematic of the measurement for unbalance attenuation at the far end.

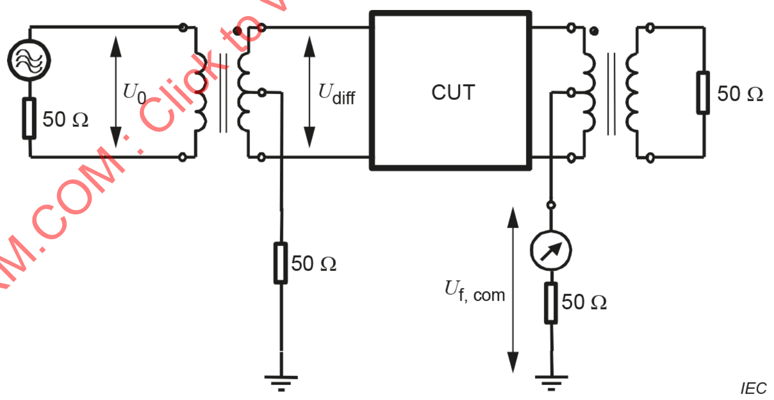


Figure 6 – Test set-up for unbalance attenuation at far end (TCTL)

$$\alpha_{meas} = 20\lg\left|\frac{U_0}{U_{f,com}}\right| \quad (19)$$

where

α_{meas} is the measured attenuation (dB);

$U_{f,com}$ is the voltage in the common-mode circuit at the far end balun (V);

U_0 is the voltage in the primary (unbalanced) circuit at the near end balun (V).

6.3.5.3.3 Expression of test result

The unbalance attenuation is defined as the logarithmic ratio of the common-mode power to the differential-mode power.

$$\alpha_{\substack{u,n\\u,f}} = 10\lg\left|\frac{P_{diff}}{P_{\substack{n,com\\f,com}}}\right| = 20\lg\left|\frac{U_{diff}}{U_{\substack{n,com\\f,com}}}\right| + 10\lg\left|\frac{Z_{com}}{Z_{diff}}\right| \tag{20}$$

where

α_u is the unbalance attenuation (dB);

P_{com} is the matched common-mode power (W);

P_{diff} is the matched differential-mode power (W);

n, f are the near end and far end, respectively;

Z_{diff} is the characteristic impedance of the differential-mode circuit (Ω);

Z_{com} is the characteristic impedance of the common-mode circuit (Ω).

When measuring with S-parameter test-sets, the output voltage of the generator is measured instead of the differential-mode voltage in the cable under test. Taking the operational attenuation of the balun into account, the formula for the unbalance attenuation near or far end is:

$$\begin{aligned} \alpha_{\substack{u,n\\u,f}} &= 10\lg\left|\frac{P_{diff}}{P_{\substack{n,com\\f,com}}}\right| = \\ & 10\lg\left|\frac{P_0}{P_{\substack{n,com\\f,com}}}\right| - \alpha_{balun} = \\ & \alpha_{meas} + 10\lg\left|\frac{Z_0}{Z_{com}}\right| - \alpha_{balun} = \\ & -20\lg|S_{21}| + 10\lg\left|\frac{Z_0}{Z_{com}}\right| - \alpha_{balun} \end{aligned} \tag{21}$$

The equal level unbalance attenuation at the far end is then

$$\begin{aligned} EL\ \alpha_{u,f} &= \alpha_{meas} + 10\lg\left|\frac{Z_0}{Z_{com}}\right| - \alpha_{balun} - \alpha_{cable} = \\ & -20\lg|S_{21}| + 10\lg\left|\frac{Z_0}{Z_{com}}\right| - \alpha_{balun} - \alpha_{cable} \end{aligned} \tag{22}$$

where

$EL\ \alpha_{u,f}$ is the equal level unbalance attenuation at the far end (EL TCTL) (dB);

α_{cable} is the attenuation of the pair under test (dB);

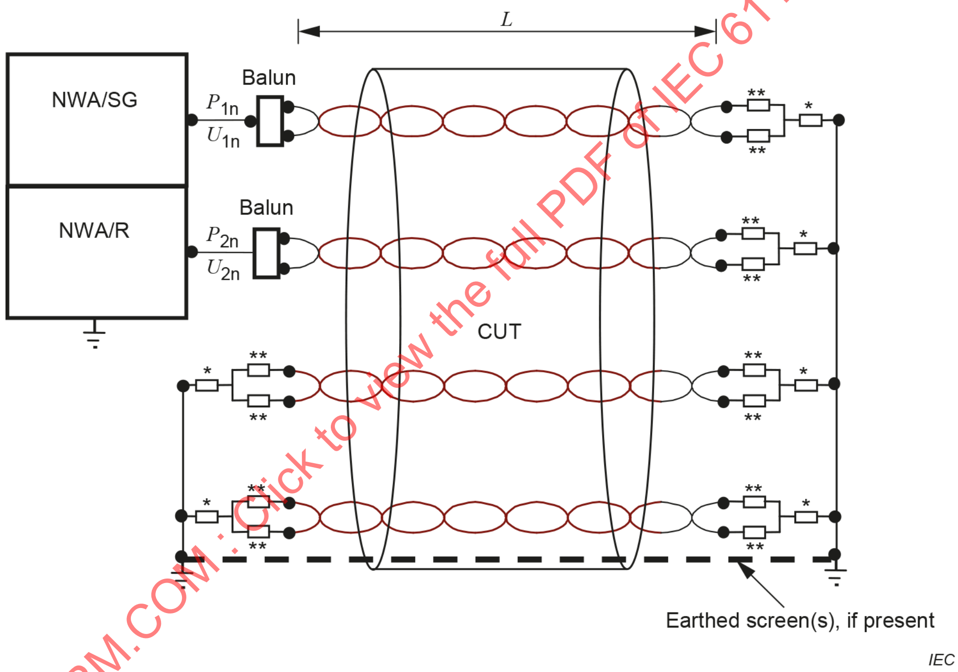
Z_0 is the output impedance of the network analyzer or signal generator (Ω);

Z_{com} is the operational impedance of the common-mode circuit, 50 Ω.

6.3.6 Near-end crosstalk

Figure 7 gives the schematic for the measurement of near-end crosstalk. The near-end crosstalk shall be measured using a network analyzer or equivalent measuring equipment over the frequency range indicated in the relevant sectional specification. One end of the pairs under test shall be connected to baluns, the other end shall be connected to earth through appropriate common-mode (see 6.1) and differential-mode terminations.

All pairs not under test shall be connected to earth through appropriate common-mode (see 6.1) and differential-mode terminations at the near and far end. The screens, if any, shall be connected to earth at both ends of the cable. End effect couplings shall be minimized. When the cable sheath is removed, the pairs shall maintain their twist and shall be well separated.



Key

CUT cable under test

NWA/SG network analyzer port or signal generator

NWA/R network analyzer port or receiver

* common-mode termination resistor (see 6.1)

** differential-mode termination resistor (matched in pairs)

L length of cable under test (m)

Figure 7 – Test set-up for near-end crosstalk

Near-end crosstalk loss NEXT is given by

$$\begin{aligned} NEXT &= 10\lg\left|\frac{P_{1n}}{P_{2n}}\right| = \\ &20\lg\left|\frac{U_{1n}}{U_{2n}}\right| + 10\lg\left|\frac{Z2}{Z1}\right| = \\ &-20\lg\left|S_{21}\right| + 10\lg\left|\frac{Z2}{Z1}\right| \end{aligned} \tag{23}$$

where

$NEXT$ is the near-end crosstalk (dB);

P_{1n} is the input power of the disturbing pair at the near end (W);

P_{2n} is the output power of the disturbed pair at the near end (W);

U_{1n} is the input voltage of the disturbing pair at the near end (V);

U_{2n} is the output voltage of the disturbed pair at the near end (V);

Z_1 is the characteristic impedance of the disturbing pair (Ω);

Z_2 is the characteristic impedance of the disturbed pair (Ω).

Measurements shall be on a length of at least 100 m. For a length greater than 100 m, the measured value may be corrected to 100 m using the following correction formula:

$$NEXT_{100} = NEXT - 10\lg\left[\left(1-10^{-\left(\frac{\alpha}{5}\right)\text{x}\left(\frac{100}{L}\right)}\right)\Big/\left(1-10^{-\left(\frac{\alpha}{5}\right)}\right)\right] \tag{24}$$

where

$NEXT_{100}$ is the near-end crosstalk corrected to a length of 100 m (dB);

$NEXT$ is the near-end crosstalk on the measured cable length (dB);

α is the attenuation of the measured cable length (dB).

The power sum near-end crosstalk PS NEXT is calculated from

$$PS\ NEXT_j = -10\lg\sum_{\substack{i=1\\ i\neq j}}^{m}\left(10^{\frac{-NEXT_{i,j}}{10}}\right) \tag{25}$$

where

$PS\ NEXT_j$ is the power sum of the pair j (dB);

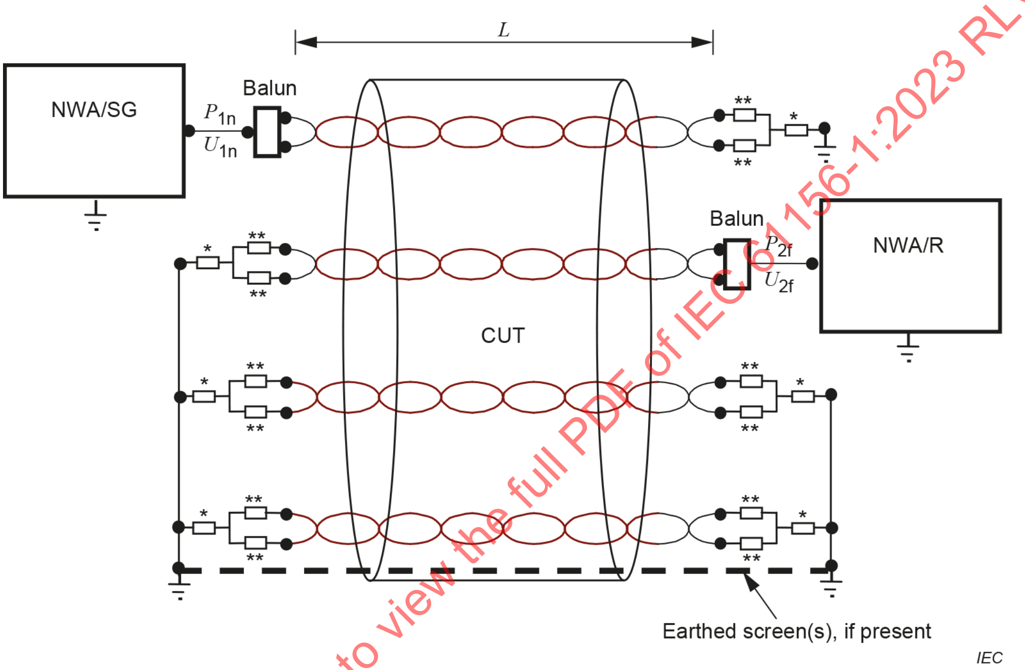
$NEXT_{i,j}$ is the crosstalk coupled from the pairs i into the pair j (dB);

m is the number of pairs contained within the cable.

6.3.7 Far-end crosstalk

Figure 8 gives the schematic for the measurement of far-end crosstalk. The far-end crosstalk shall be measured using a network analyzer or equivalent measuring equipment over the frequency range indicated in the relevant sectional specification. One end of the pairs under test shall be connected to baluns, the other end shall be connected to earth through appropriate common-mode (see 6.1) and differential-mode terminations.

All pairs not under test shall be connected to earth through appropriate common-mode (see 6.1) and differential-mode terminations at the near and far end. The screens, if any, shall be connected to earth at both ends of the cable. End effect couplings shall be minimized. When the cable sheath is removed, the pairs shall maintain their twist and shall be well separated.



Key

CUT cable under test

NWA/SG network analyzer port or signal generator

NWA/R network analyzer port or receiver

* common-mode termination resistor (see 6.1)

** differential-mode termination resistor (matched in pairs)

L length of cable under test (in m)

Figure 8 – Test set-up for far-end crosstalk

The measurement shall be carried on a length of at least 100 m.

Far-end crosstalk is given by

$$\begin{aligned} FEXT &= 10\lg\left|\frac{P_{1n}}{P_{2f}}\right| = \\ &20\lg\left|\frac{U_{1n}}{U_{2f}}\right| + 10\lg\left|\frac{Z_2}{Z_1}\right| = \\ &-20\lg\left|S_{21}\right| + 10\lg\left|\frac{Z_2}{Z_1}\right| \end{aligned} \tag{26}$$

where

$FEXT$ is the far-end crosstalk (dB);

P_{1n} is the input power of the disturbing pair at the near end (W);

P_{2f} is the output power of the disturbed pair under test at the far end (W);

U_{1n} is the input voltage of the disturbing pair at the near end (V);

U_{2f} is the output voltage of the disturbed pair at the far end (V);

Z_1 is the characteristic impedance of the disturbing pair (Ω);

Z_2 is the characteristic impedance of the disturbed pair (Ω).

Equal level far-end crosstalk loss is given by Formula (28) and related to FEXT by the attenuation of the disturbing pair in the measured cable length:

$$\begin{aligned} EL\,FEXT &= 10\lg\left|\frac{P_{1f}}{P_{2f}}\right| = \\ &10\lg\left|\frac{P_{1n}}{P_{2f}}\right| - 10\lg\left|\frac{P_{1n}}{P_{1f}}\right| = \\ &FEXT - \alpha_1 \end{aligned} \tag{27}$$

where

$EL\ FEXT$ is the equal level far-end crosstalk (dB);

$FEXT$ is the far-end crosstalk (dB);

P_{1f} is the output power of the disturbing pair at the far end (W);

P_{2f} is the output power of the disturbed pair under test at the far end (W);

P_{1n} is the input power of the disturbing pair at the near end (W);

α_1 is the attenuation of the disturbing pair (dB).

It is recommended that the maximum cable length to be measured be limited to 305 m in order to minimize errors resulting from the noise floor of the testing equipment. For lengths greater than 100 m, the measured values of FEXT and the calculated values of the EL FEXT shall be corrected to a length of 100 m as follows:

$$FEXT_{100} = FEXT + 10\lg\left(\frac{L}{100}\right) + \alpha_1 \times \left(\frac{100}{L} - 1\right) \tag{28}$$

$$EL\ FEXT_{100} = EL\ FEXT + 10\lg\left(\frac{L}{100}\right) \quad (29)$$

where

$FEXT_{100}$	is the far-end crosstalk corrected to a length of 100 m (dB);
$FEXT$	is the measured far-end crosstalk (dB);
$EL\ FEXT_{100}$	is the equal level far-end crosstalk corrected to a length of 100 m (dB);
$EL\ FEXT$	is the equal level far-end crosstalk (dB);
L	is the measured cable length (m);
α_1	is the measured attenuation of disturbing pair (dB).

The power sum far-end crosstalk PS EL FEXT is calculated from

$$PS\ EL\ FEXT_j = -10\lg\sum_{\substack{i=1\\ i\neq j}}^{m} 10^{\frac{-EL\ FEXT_{i,j}}{10}} \quad (30)$$

where

$PS\ EL\ FEXT_j$	is the power sum of the pair j (dB);
$EL\ FEXT_{i,j}$	is the crosstalk coupled from the pairs i into the pair j (dB);
m	is the number of pairs contained within the cable.

The attenuation-to-crosstalk ratio far end is defined as the ratio of the attenuation of the disturbed pair to the far-end crosstalk, both in nepers, or the difference of the far-end crosstalk and the attenuation of the disturbed pair if both are expressed in dB. Hence:

$$ACR - F_j = FEXT_{i,j} - \alpha_j \quad (31)$$

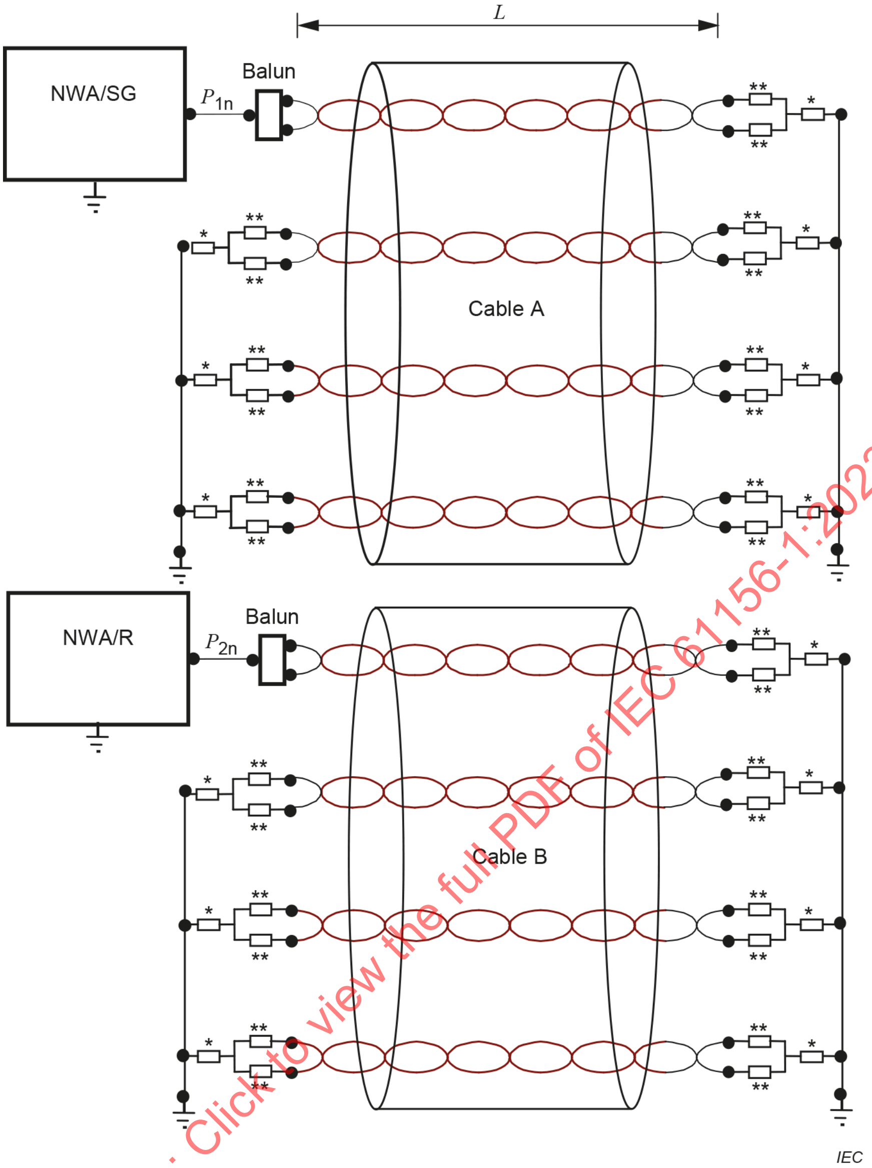
where

$ACR - F_j$	is the attenuation to crosstalk ratio far-end in (dB);
α_j	is the attenuation of the disturbed pair $_j$ in (dB);
$FEXT_{i,j}$	is the far-end crosstalk coupled from the pair i into the disturbed pair j.

6.3.8 Alien (exogenous) near-end crosstalk

6.3.8.1 General

Figure 9 gives the schematic for the measurement of alien (exogenous) near-end crosstalk, ANEXT. The same test equipment and sample-end preparation considerations relevant to the measurement of NEXT are relevant to the measurement of ANEXT. The cable fan-out shall not be greater than 1 m. The measurement shall be over the frequency range indicated in the relevant sectional specification.



Key

Cable A, B two cables in the test assembly configuration (other cables in the assembly are not shown)

NWA/SG network analyzer port or signal generator

NWA/R network analyzer port or receiver

* common mode termination resistor (see 6.1)

** differential mode termination resistor (matched in pairs)

L length of test assembly under test (in m)

Figure 9 – Test set-up for alien (exogenous) near-end crosstalk

Alien near-end crosstalk (ANEXT) given by

$$ANEXT = 10\lg\left|\frac{P_{1n}}{P_{2n}}\right| \quad (32)$$

where

$ANEXT$ is the alien (exogenous) near-end crosstalk (dB);

P_{1n} is the input power of the disturbing pair at the near end (W);

P_{2n} is the output power of the disturbed pair at the near end (W).

The disturbing and disturbed pairs are contained within different cables.

For near-end and far-end alien (exogenous) crosstalk the power sum is defined as:

$$PS\ AX-talk_j = -10\lg\left(\sum_{l=1}^{N}\sum_{i=1}^{n}10^{-\frac{AX-talk_{i,j,l}}{10}}\right) \tag{33}$$

where

$PS\ AX-talk_j$ is the power sum of pair j (dB);

$AX\text{-}talk_{i,j,l}$ is the crosstalk between pair j of a given cable and pair i of a neighbouring cable (dB);

j is the number of the disturbed pair;

i is the current number of a disturbing pair in a disturbing cable;

l is the number of the disturbing cable;

N is the total number of disturbing cables;

n is the total number of disturbing pairs.

The cables to be tested are mounted into a configuration as specified in the relevant sectional specification.

The test method configuration involves six cables around one cable.

The cable arrangement shall be a bundle.

6.3.8.2 Six cables around one cable

The seven cables to be tested are mounted into the test assembly configuration shown in the cross-section in Figure 10. The test assembly length shall be specified in the relevant sectional specification. The assembly cross-section shall be maintained, without longitudinal twist, throughout the assembly length by means of suitable non-metallic binder material. The binder material may be applied as discrete straps such as tie wraps and self-clinging or adhesive straps. The binder material may be applied helically about the cables in the form of a continuous thread or tape. The binder material shall not visibly compress or deform the cross-section. The spacing of the discrete binder and the pitch of the continuous binder shall be adequate to maintain the cable components in close proximity, without visible spacing, as depicted in Figure 10. The test assembly shall be laid out as depicted in Figure 11 (with serpentine looping as necessary) in a loop in such a way that a minimum separation of 10 cm is maintained between sections of the loop. A non-metallic floor is suitable for laying out the test assembly.

The crosstalk from each pair of cables 1 through 6 to each of the pairs of cable 7 shall be measured across the frequency range specified in the relevant sectional specification.

The power sum alien (exogenous) near-end crosstalk, PS ANEXT, shall be calculated from the measured values according to Formula (33).

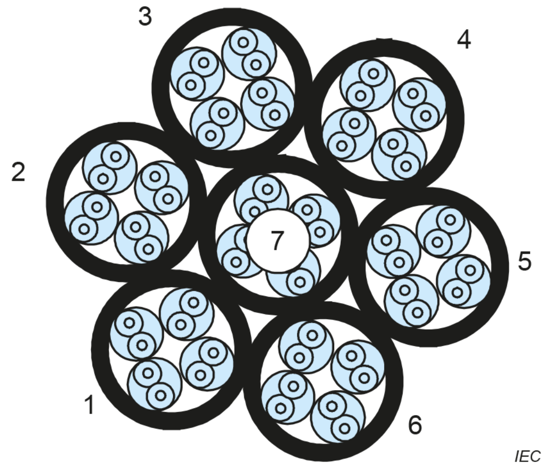


Figure 10 – Test assembly cross-section: six cables around one cable

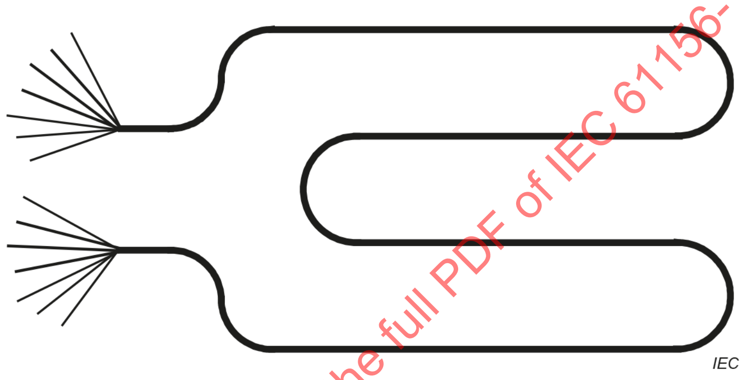


Figure 11 – Test assembly layout: six cables around one cable

6.3.9 Alien (exogenous) far-end crosstalk

Measurement of alien (exogenous) far-end crosstalk, AFEXT, involves the same test equipment and sample-end preparation considerations relevant to the measurement of FEXT. The cables to be tested are mounted into a configuration, as specified in the relevant sectional specification and as described in 6.3.8.2 for six cables around one.

The PS AFEXT shall be calculated from the measured values according to Formula (33).

PS AFEXT requirements may be given in terms of PS AACR-F where AACR-F shall be calculated from the measured values according to Formula (34).

$$AACR\text{-}F = AFEXT - \alpha \tag{34}$$

where

$AACR\text{-}F$ is the attenuation alien (exogenous) crosstalk ratio at the far end (dB);

$AFEXT$ is the alien (exogenous) far-end crosstalk (dB);

α is the attenuation of the disturbed pair (dB).

6.3.10 Alien (exogenous) crosstalk of bundled cables

Alien (exogenous) crosstalk, (ANEXT and AFEXT), is measured directly on the bundled cable and does not require the preparation of a specific test assembly configuration.

The bundled cable shall be laid out as depicted in Figure 11 (with serpentine looping as necessary) in a loop in such a way that a minimum separation of 10 cm is maintained between sections of the loop. A non-metallic floor is suitable for laying out the test assembly.

The near-end (NEXT) and far-end (FEXT) crosstalk of each pair of one disturbed cable due to all pairs in the surrounding disturbing cables shall be measured across the frequency range specified in the relevant sectional specification.

Each cable of the bundle shall in turn be treated as the disturbed cable and the near-end (NEXT) and far-end (FEXT) crosstalk due to all pairs in the surrounding disturbing cables shall be measured across the frequency range specified in the relevant sectional specification.

The power sum alien (exogenous) crosstalk, PS ANEXT and PS AFEXT, shall be calculated from the measured values according to Formula (33).

6.3.11 Impedance

6.3.11.1 Preparation of cable under test

Both ends of the cable under test shall be prepared to minimize end effects. For frequencies of measurements greater than or equal to 1 000 MHz, it is recommended that no more than 20 mm of jacket should be removed from pairs; for frequencies of measurements lower than 1 000 MHz, it is recommended that no more than 40 mm jacket should be removed from the pairs. When the cable sheath is removed, the pairs shall maintain their twist and shall be well separated.

Unscreened cables shall be suspended or laid on a non-conducting surface so that multiple traversals are separated by a minimum of 25 mm.

6.3.11.2 Measurement

The measurement is in a balanced configuration with a network analyzer (together with an S-parameter unit) or an impedance meter. The balun shall have the relevant characteristics given in Table 1 corresponding to the measurement frequency range; for this measurement, the common-mode balun ports in Table 1 are optional. The measurement schematic is given in Figure 12.

A three-step calibration procedure (using open-, short- and load-circuit terminations) is performed at the secondary side of the balun before the measurement.

For improvement of impedance measurement uncertainty, IEC TR 61156-1-5 should be considered.

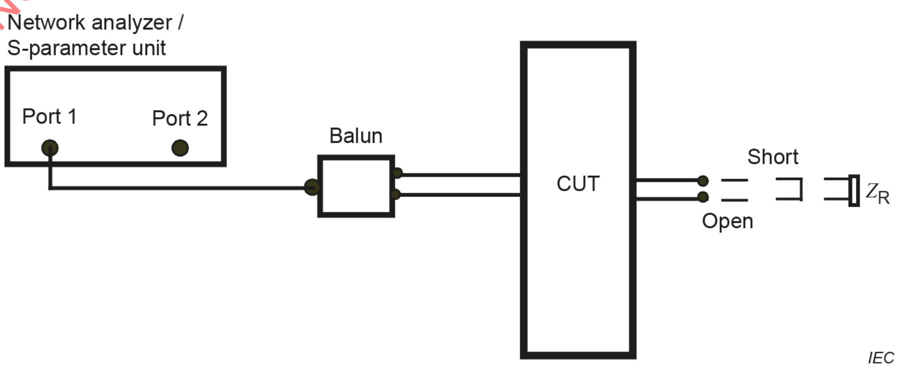


Figure 12 – Test set-up for characteristic impedance, terminated input impedance, and return loss

6.3.11.3 Characteristic impedance

A three-step calibration procedure (using open, short and load circuit terminations) is performed at the secondary side of the balun before the measurement.

The near end of the cable under test shall be connected to the test equipment via balun, the far end shall be terminated by the open circuit termination and short circuit termination. The scattering parameter S_{xx} shall be measured to obtain characteristic impedance values. The impedance is calculated from the measured S_{xx} parameters.

$$Z_{\text{meas}} = Z_{\text{R}} \times \left| \frac{1+S_{\text{xx}}}{1-S_{\text{xx}}} \right| \tag{35}$$

where

Z_{meas} is the impedance for open-circuit termination or short-circuit termination (Ω);

Z_{R} is the system nominal impedance (Ω);

S_{xx} is the measured wave scattering parameter for open circuit termination and short circuit termination, x is the vector network analyzer port number.

The characteristic impedance is calculated as the square root of the product of the open circuit and short circuit measured values and is given by

$$Z_{\text{C}} = \sqrt{\left| Z_{\text{OC}} \cdot Z_{\text{SC}} \right|} \tag{36}$$

where

Z_{C} is the characteristic impedance (Ω);

Z_{OC} is the measured open circuit impedance (Ω);

Z_{SC} is the measured short circuit impedance (Ω).

6.3.11.4 Terminated input impedance

A single terminated impedance measurement at the near end can be made to get the terminated input impedance. In this condition, the far end of the cable under test is terminated by a load impedance in place of the open circuit termination and short circuit termination; the load impedance value should be equal to the nominal impedance Z_{R}. Z_{in} is calculated from the measured S_{xx} parameter.

$$Z_{\text{in}} = Z_{\text{R}} \times \left| \frac{1+S_{xx}}{1-S_{xx}} \right| \tag{37}$$

where

Z_{in} is the terminated input impedance (Ω);

Z_{R} is the system nominal impedance (Ω);

S_{xx} is the measured wave scattering parameter for load circuit termination, and x is the vector network analyzer port number.

6.3.11.5 Fitted characteristic impedance

Function fitting is used for computing a smoothed characteristic impedance when the cable exhibits significant structural effects.

The fitting function is given by

$$|Z_m| = k_0 + \frac{k_1}{f^{1/2}} + \frac{k_2}{f} + \frac{k_3}{f^{3/2}} \qquad (38)$$

where

$|Z_m|$ is the magnitude of the fitted characteristic impedance (Ω);

k_0, k_1, k_2, k_3 are the least squares coefficients;

f is the frequency (Hz).

NOTE More details of how to calculate the least squares coefficients can be found in IEC TR 61156-1-2.

6.3.11.6 Mean characteristic impedance

Mean characteristic impedance is calculated using the formula

$$Z_\infty = \tau / C \qquad (39)$$

where

Z_∞ is the mean characteristic impedance (Ω);

τ is the time delay (s);

C is the mutual capacitance (F).

This method shall only be applied to cables having a mutual capacitance which does not change over frequency. The measurement shall be done at frequencies over 100 MHz where the phase delay approaches an asymptotic value.

6.3.12 Return loss

6.3.12.1 Preparation of cable under test

The cable under test shall be prepared in accordance with 6.3.11.1.

6.3.12.2 Measurement

The measurement is in a balanced configuration with a network analyzer (together with a wave scattering parameter unit). The balun shall have the relevant characteristics given in Table 1 corresponding to the measurement frequency range. For return loss measurement, the common-mode port of the balun in Table 1 is optional. The measurement schematic is given in Figure 12. The load termination value shall be equal to the nominal impedance (Z_R).

The measurement shall be done at the frequency, or in the whole frequency range, indicated in the relevant sectional specification.

6.3.12.3 Procedure

A three-step calibration procedure (using open, short and load circuit terminations) is performed at the secondary side of the balun before the measurement.

The near end of the cable under test shall be connected to the test equipment via balun, and the far end shall be terminated by the load circuit termination. Return loss is given by the wave scattering parameter directly from the network analyzer as follows.

$$RL = -20\lg\left|S_{xx}\right| \tag{40}$$

where

RL is the return loss (dB);

S_{xx} is the measured wave scattering parameter for load circuit termination, and x is the vector network analyzer port number.

6.4 Mechanical and dimensional characteristics and requirements

6.4.1 Measurement of dimensions

Determination of insulation thickness and sheath thickness shall be in accordance with IEC 60811-201 and IEC 60811-202, respectively, and the measurement of overall dimensions shall be in accordance with IEC 60811-203.

6.4.2 Elongation at break of the conductor

Determination of the elongation at the break of the conductor is described in IEC 60189-1:2018, 6.3.

6.4.3 Tensile strength of the insulation

Determination of the tensile strength of the insulation is described in IEC 60811-501.

6.4.4 Elongation at break of the insulation

Determination of the elongation at the break of the insulation is described in IEC 60811-501.

6.4.5 Adhesion of the insulation to the conductor

Determination of the adhesion of the insulation to the conductor is described in IEC 60189-1:2018, 6.4.

6.4.6 Elongation at break of the sheath

Determination of the elongation at the break of the sheath is described in IEC 60811-501.

6.4.7 Tensile strength of the sheath

Determination of the tensile strength of the sheath is described in IEC 60811-501.

6.4.8 Crush test of the cable

Determination of the crush of the cable is described in IEC 62012-1:2002, 3.3.6.

6.4.9 Cold Impact test of the cable

Determination of the impact test of the cable is described in IEC 60811-506.

6.4.10 Bending under tension

6.4.10.1 Equipment

The apparatus consists of

a) a tensile power device with a maximum error of ±3 %;
b) if required for a particular user application, a measuring apparatus for the determination of change in the transmission performance;
c) for the U-bend test: one roller with radius, r, as given in the relevant sectional specification and as shown in Figure 13;
d) for the S-bend test: two rollers each with a radius, R, and separated by distance Y, as given in the relevant sectional specification and as shown in Figure 14;
e) a reference frame that shall be provided for locating the test sample sheath marks that are applied at points A and B as shown in Figure 13 and Figure 14.

6.4.10.2 Test sample

The test sample shall be taken from one end of a finished cable. Both ends of the specimen shall be terminated in such a way that the specified load can be applied and any specified transmission tests can be carried out.

The sample shall be marked at points A and B as shown in Figure 13 and Figure 14. The total length of the test sample and the length between points A and B shall be as given in the relevant sectional specification, taking into account the length needed to carry out the specified transmission tests.

6.4.10.3 Procedure

6.4.10.3.1 General

The test shall be carried out at ambient temperature. If specified in the relevant sectional specification, the transmission performance shall be recorded before the load is applied, and after the test when the load is zero. One of the two following tests shall be used, as indicated in the relevant sectional specification.

6.4.10.3.2 U-bend test

The cable shall be moved around the roller through a minimum of 180° (U-bend) as shown in Figure 13.

The tension shall be continuously increased to the value given in the relevant sectional specification.

Moving the sample from point A to point B (see Figure 13) and then returning to point A is considered to be one cycle. The sample shall be subjected to bending under tension with the speed of movement and number of cycles given in the relevant sectional specification.

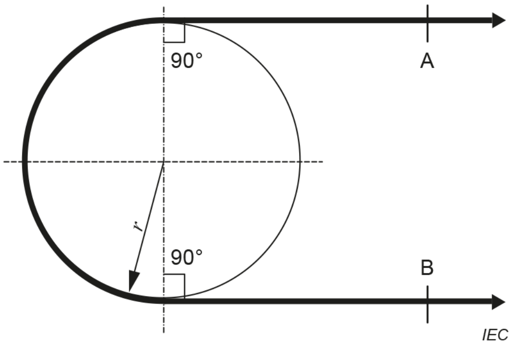


Figure 13 – U-bend test configuration

6.4.10.3.3 S-bend test

The cable shall be moved around two rollers in an S form manner (S-bend), as shown in Figure 14.

The tension shall be continuously increased to the value given in the relevant sectional specification.

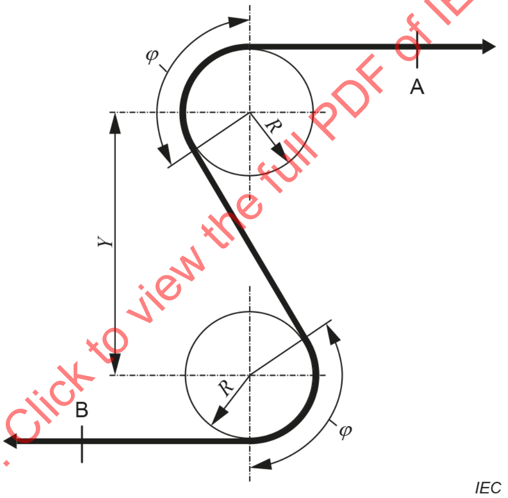


Figure 14 – S-bend test configuration

Moving the sample from point A to point B (see Figure 14) and then returning to point A is considered to be one cycle. The sample shall be subjected to bending under tension with the speed of movement and number of cycles given in the relevant sectional specification.

6.4.10.3.4 Dielectric strength and insulation resistance

After completing the bending test, the sample shall be tested for conductor/conductor and conductor/screen dielectric strength and insulation resistance. The magnitude of the voltage and the test duration shall be as given in the relevant sectional specification.

6.4.10.4 Test report

The test report shall give the following test conditions:

- bending test used (U-bend or S-bend);
- length of the test sample and the length between the sheath marks at points A and B;
- end preparation;

- tension device;
- radius, r, of rollers in the U-bend test;
- radius, R, of rollers in the S-bend test;
- roller separation, Y, in the S-bend test;
- bending angle, φ, in the S-bend test;
- speed of movement;
- number of moving cycles;
- applied voltage and duration of the dielectric strength and insulation resistance test;
- maximum tension applied during test;
- test temperature.

The pass or fail conditions shall be recorded as required by the relevant sectional specification.

6.4.11 Repeated bending of the cable

6.4.11.1 Equipment

The apparatus shall permit a sample to be bent backwards and forwards through angles up to 180°, the two extreme positions making an angle of 90° on both sides of the vertical, whilst being subjected to a tensile load. A suitable apparatus is shown in Figure 15. Other equivalent apparatus may be used.

The bending arm shall have an adjustable clamp or fixture to hold the test sample securely during the entire test.

The apparatus shall be capable of cycling. Displacing the sample from the vertical position to the extreme right position, then oscillating to the extreme left position and returning to the original vertical position is considered to be one cycle. Unless otherwise specified in the relevant sectional specification, the bending rate shall be approximately one cycle in 2 s.

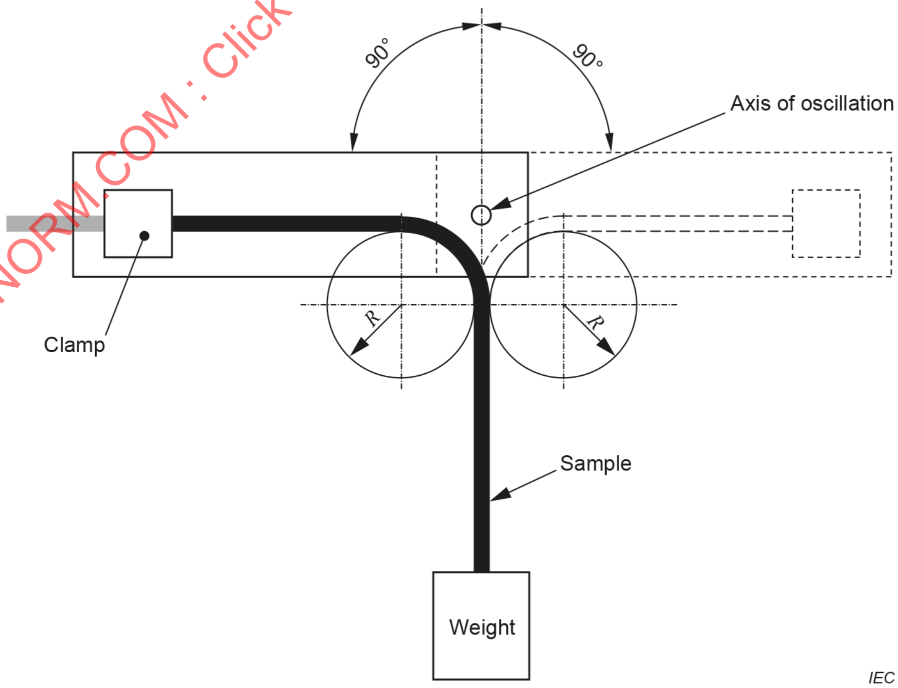


Figure 15 – Repeated bending test configuration

The apparatus shall include any test equipment needed to measure the changes in transmission performance requested in the relevant sectional specification.

6.4.11.2 Test sample length

The sample length shall be sufficient to carry out the testing specified. When only physical damage is to be evaluated, the length may range from 1 m (for example, for small diameter patch cords) to 5 m (for larger diameter cables). Longer lengths can be necessary to permit transmission measurements.

The length of the test sample shall be indicated in the relevant sectional specification.

6.4.11.3 Procedure

The following procedure shall be followed.

a) Precondition the sample at ambient temperature for 24 h.
b) Fix the sample to the apparatus as shown in Figure 15.
c) Apply the weight of mass as shown in the relevant sectional specification.
d) Measure the acceptance criteria parameters to establish baseline values.
e) Carry out repeated bending for the number of cycles specified in the relevant sectional specification.
f) Carry out acceptance criteria parameter measurements. If necessary, the sample may be removed from the apparatus for visual examination.

6.4.11.4 Requirements

The acceptance criteria for the test shall be stated in the relevant sectional specification. Typical failure modes include loss of transmission performance, loss of continuity or physical damage to the cable.

6.4.11.5 Test report

The test report shall give the following test conditions:

- angle of displacement;
- number of cycles;
- mass of the weight;
- bending radius, R;
- test temperature.

The pass/fail conditions shall be recorded as required in the relevant sectional specification.

6.4.12 Tensile performance of the cable

The method of measuring the tensile performance of the cable is described in IEC 60794-1-21:2015, method E1.

6.4.13 Shock test of the cable

The method of measuring the shock performance of the cable is described in IEC 62012-1:2002, 3.4.4.

6.4.14 Bump test of the cable

The method of measuring the bump performance of the cable is described in IEC 62012-1:2002, 3.4.3.

6.4.15 Vibration test of the cable

The method of measuring the vibration performance of the cable is described in IEC 62012-1:2002, 3.4.2.

6.5 Environmental characteristics

6.5.1 Shrinkage of the insulation

The method of measuring the shrinkage of the insulation is described in IEC 60811-502.

6.5.2 Wrapping test of the insulation after thermal ageing

The method of measuring the ageing performance of the insulation is described in IEC 60811-510.

6.5.3 Bending test of the insulation at low temperature

The method of measuring the cold bend test performance is described in IEC 60811-504.

6.5.4 Elongation at break of the sheath after ageing

Samples of sheath are prepared and tested in accordance with IEC 60811-501 after ageing, in accordance with IEC 60811-401, for a time and temperature described in the relevant sectional specification.

6.5.5 Tensile strength of the sheath after ageing

Samples of sheath are prepared and tested in accordance with IEC 60811-501 after ageing, in accordance with IEC 60811-401, for a time and temperature described in the relevant sectional specification.

6.5.6 Sheath pressure test at high temperature

The method of measuring the sheath pressure test is described in IEC 60811-508.

6.5.7 Cold bend test of the cable

6.5.7.1 Equipment

The cold bend test apparatus shall be in accordance with IEC 60811-504 with a mandrel diameter as specified in the relevant sectional specification.

6.5.7.2 Test sample

The sample shall be taken from one end of the finished cable. The length shall be approximately 120 × cable diameter and it shall be coiled to a diameter not less than 30 × cable diameter.

6.5.7.3 Procedure

The sample and test apparatus shall be cooled in a cold chamber in accordance with test Ab of IEC 60068-2-1:2007 for a period of not less than 4 h at the temperature specified in the relevant sectional specification.

If the mandrel is metal, it shall be conditioned at the same time as the sample.

After the cooling period and while still in the cold chamber, the sample shall be wrapped three times around the mandrel at a wrapping velocity of approximately 1 turn per 4 s. Alternatively, the sample may be removed from the chamber after conditioning and wound around the mandrel provided the test is completed within 30 s after removal from the chamber.

After completing the cold bend test, the sample shall be tested for conductor/conductor and conductor/screen dielectric strength and insulation resistance. The magnitude of the voltage and the test duration shall be as given in the relevant sectional specification.

After the dielectric strength test, the sample shall be stripped into its component elements.

6.5.7.4 Test report

The test report shall give the following test conditions:

- cable diameter;
- coiling diameter;
- mandrel diameter;
- applied voltage and duration of the dielectric strength test and insulation resistance;
- test temperature;

and record the pass/fail conditions as required in the relevant sectional specification.

6.5.8 Heat shock test

The method of measuring the heat shock is described in IEC 60811-509.

6.5.9 Damp heat, steady state

The method of measuring the damp-heat steady-state performance of the cable is described in IEC 62012-1:2002, 3.5.2.

6.5.10 Solar radiation

Samples of the cable sheath shall be conditioned in a carbon-arc or xenon-arc weatherometer for a specified period of time. At the end of the conditioning period, the elongation and tensile strength of the specimens shall be measured, respectively, in accordance with 6.4.6 and 6.4.7. The results shall be compared to those obtained on unconditioned specimens.

6.5.11 Solvents and contaminating fluids

The method of measuring the solvents and contaminating fluids performance of the cable is described in IEC 62012-1:2002, 3.6.1.

6.5.12 Salt mist and sulphur dioxide

The method of measuring the salt mist and sulphur dioxide performance of the cable is described in IEC 62012-1:2002, 3.6.2.

6.5.13 Water immersion

A 100 m sample of the completed cable shall be immersed in water for a specified period of time at a temperature of 20 °C ± 3 °C. At the end of the immersion period and while still immersed in the water, the insulation resistance of the conductors shall be measured in accordance with 6.2.4.

6.5.14 Hygroscopicity

The material is considered to be non-hygroscopic when a dry sample of the material is placed in an environment of 65 % ± 5 % relative humidity and 20 °C ± 1 °C for 3 h and the amount of moisture gained does not exceed 1 % by weight.

6.5.15 Wicking

6.5.15.1 Equipment

The following equipment shall be used in 6.5.15.2.

a) Beaker: 500 ml to 1 000 ml.
b) Laboratory stand: with movable crossbar.
c) Weight: 25 g, lead sinker type (3).
d) Fluorescein dye solution: 0,1 g/l of water.
e) Filter paper 25 mm × 25 mm (3 pieces).

6.5.15.2 Procedure

The following procedure shall be used.

a) Cut three (3) lengths of material, approximately 450 mm long, to be tested and attach lead sinker type weights to one end of each sample.
b) Attach the opposite end of each sample length to the crossbar with a minimum space of 25 mm between samples. See Figure 16.
c) Attach one section of filter paper to each sample with a paper clip, approximately 75 mm above the weight.
d) Fill the beaker with the fluorescein solution to a depth of about 75 mm.
e) Position the crossbar with attached, hanging samples in place directly over the filled beaker. Lower the crossbar so that the weighted sample end enters the solution positioning the bottom of the filter paper 25 mm above the surface. Record time of entry.

The sample shall be considered "non-wicking" if the solution does not wick and wet the lower edge of the filter paper within 6 h.

Dimensions in millimetres

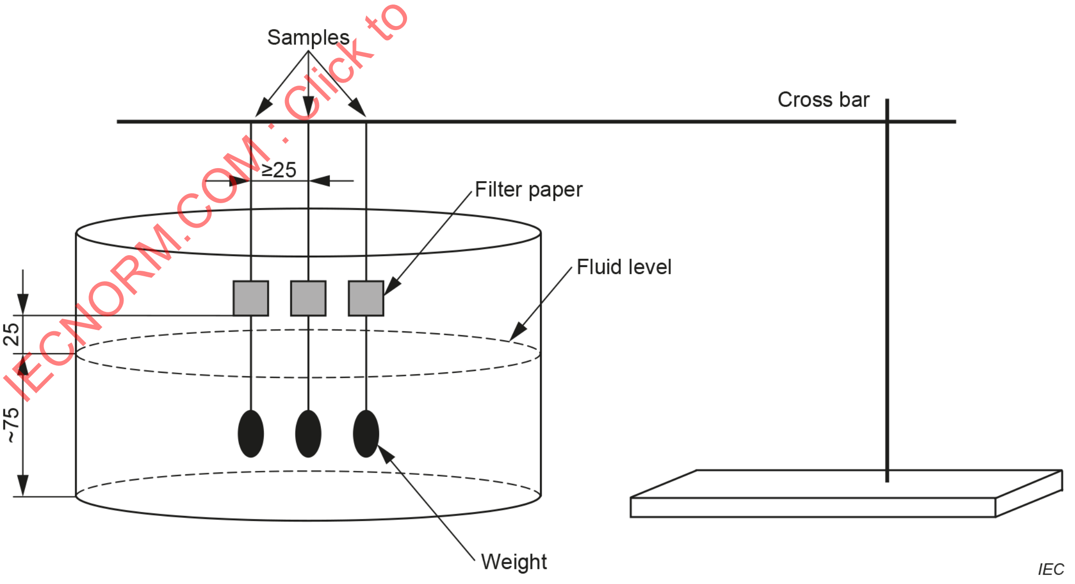


Figure 16 – Wicking test configuration

6.5.16 Flame propagation characteristics of a single cable

The method of measuring the burning performance of a single cable is specified in IEC 60332-1-2. When this method is not suitable because a small conductor can melt under the application of the flame, the cable shall be tested in accordance with IEC 60332-2-2.

6.5.17 Flame propagation characteristics of bunched cables

If not specified differently in the relevant detail specification or by local regulations (e.g. European Construction Products Regulation), the method of measuring the burning performance of bunched cables is specified either in IEC 60332-3-24 or IEC 60332-3-25, or both, depending on the overall dimensions of the cable.

6.5.18 Resistance to fire test method

Under consideration.

6.5.19 Halogen gas evolution

The method of measuring the evolution of halogen gas is specified in IEC 60754-2.

6.5.20 Smoke generation

The method of measuring the amount of smoke generated is specified in IEC 61034 (all parts).

6.5.21 Toxic gas emission

Under consideration.

6.5.22 Integrated fire test method for cables in environmental air handling spaces

The method of testing the combined flame and smoke for cables in environmental air handling spaces is described in IEC 62012-1:2002, Annex A.

Annex A
(informative)

Acronyms for common cable constructions

The acronym structure for the cable name is defined in Table A.1. Some common cable construction examples are given in Figure A.1.

Table A.1 – Cable construction acronyms

Acronym		
XX / ABB		
XX – Overall screen	**A – Cable element screen**	**BB – Cable element type**
U – Unscreened F – Foil screened S – Braid screened SF – Braid and foil screened	U – Unscreened F – Foil screened	TP – Twisted pair TQ – Twisted quad

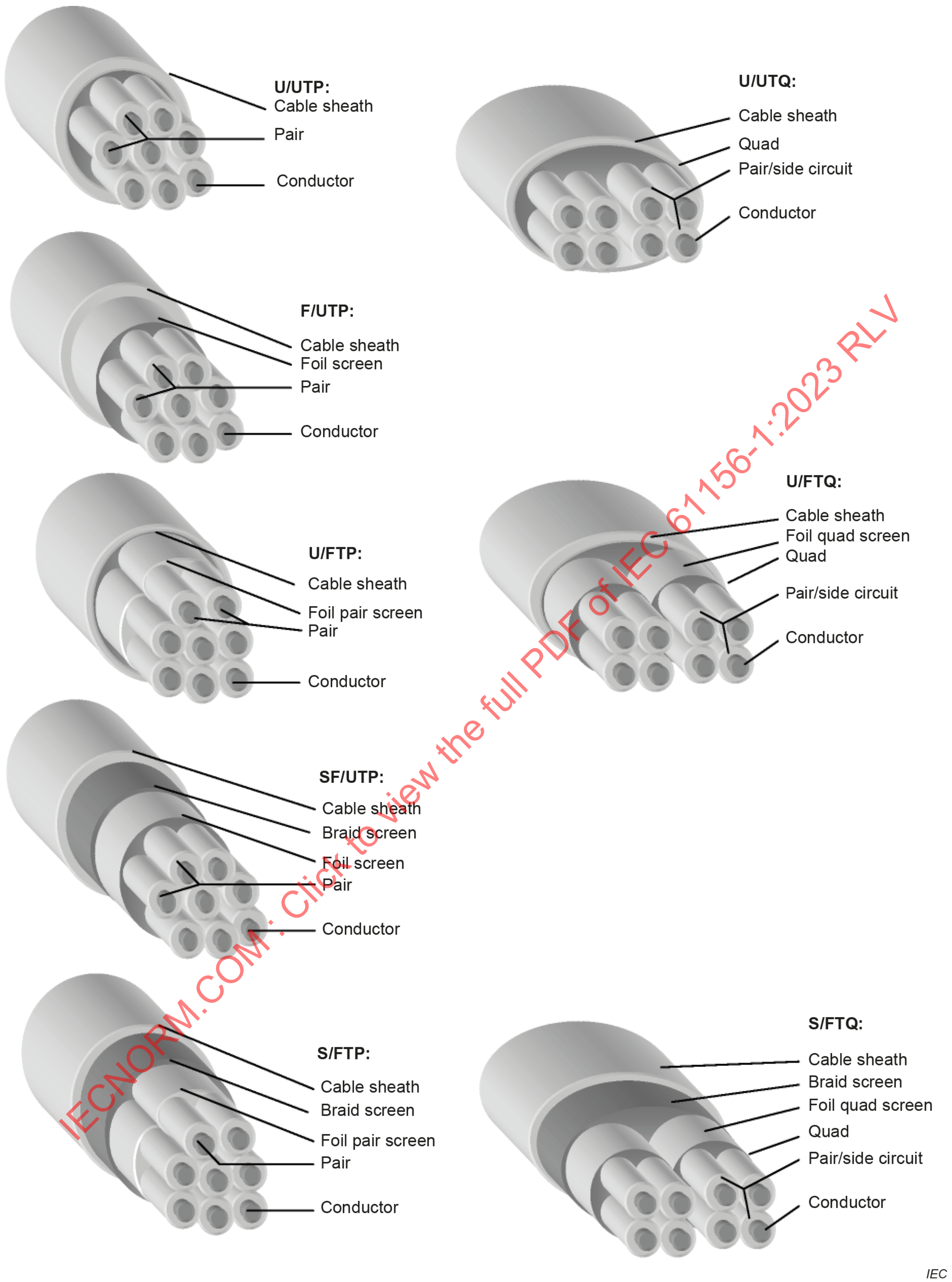


Figure A.1 – Common cable construction examples

Bibliography

IEC 60050-195, *International Electrotechnical Vocabulary (IEV) – Part 195: Earthing and protection against electric shock*

IEC 60050-726, *International Electrotechnical Vocabulary (IEV) – Part 726: Transmission lines and wave guides*

IEC 60364-7-716[2], *Low-voltage electrical installations – Part 7-716: Requirements for special installations or locations – DC power distribution over information technology cable infrastructure*

IEC 61156-1-4, *Multicore and symmetrical pair/quad cables for digital communications – Part 1-4: Assessment of conductor heating in bundled cables due to the deployment of remote powering*

IEC TR 61156-1-6, *Multicore and symmetrical pair/quad cables for digital communications – Part 1-6: Nominal DC-resistance values of floor-wiring and work-area cables for digital communications*

IEC TR 62152, *Transmission properties of cascaded two-ports or quadripols – Background of terms and definitions*

IEC 62153-4-7:2021, *Metallic cables and other passive components test methods – Part 4-7: Electromagnetic compatibility (EMC) –Test method for measuring of transfer impedance Z_T and screening attenuation a_S or coupling attenuation a_C of connectors and assemblies – Triaxial tube in tube method*

ISO/IEC 11801 (all parts), *Information technology – Generic cabling for customer premises*

ISO/IEC 11801-4:2017, *Information technology – Generic cabling for customer premises – Part 4: Single-tenant homes*

ISO/IEC/IEEE 8802-3, *Telecommunications and exchange between information technology systems – Requirements for local and metropolitan area networks – Part 3: Standard for Ethernet*

ITU-T Recommendation G.117:1996, *Transmission aspects of unbalance about earth*

ITU-T Recommendation O.9:1999, *Measuring arrangements to assess the degree of unbalance about earth*

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2 Under preparation. Stage at the time of publication: IEC CDV 60364-7-716:2022.

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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CÂBLES MULTICONDUCTEURS À PAIRES SYMÉTRIQUES ET QUARTES POUR TRANSMISSIONS NUMÉRIQUES –

Partie 1: Spécification générique

AVANT-PROPOS

L'IEC 61156-1 a été établie par le sous-comité 46C: Câbles symétriques et fils, du comité d'études 46 de l'IEC: Câbles, fils, guides d'ondes, connecteurs, composants passifs pour micro-onde et accessoires. Il s'agit d'une Norme internationale.

Cette quatrième édition annule et remplace la troisième édition parue en 2007 et son Amendement 1 paru en 2009. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) modification du domaine d'application à l'Article 1 et mise à jour des documents de "Références normatives" à l'Article 2;

b) ajout de définitions liées au PoE à l'Article 3;

c) clarification des résistances en mode différentiel et en mode commun, correction des formules et ajout de la méthode d'essai de l'IEC 62153-4-9 pour l'affaiblissement de couplage à l'Article 6;

d) introduction de la méthode de mesure sans symétriseur en 6.3.1, modification des exigences de l'équipement relatives à l'affaiblissement de symétrie en 6.3.5 et mise à jour du fonctionnement du symétriseur dans le Tableau 1;

e) suppression de la méthode "trois couches de câbles sur un touret" de mesure de paradiaphonie exogène (due aux câbles voisins) en 6.3.8 et ajout de l'impédance d'entrée adaptée en 6.3.11.4.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
46C/1242/FDIS	46C/1249/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

Les langues employées pour l'élaboration de cette Norme internationale sont l'anglais et le français.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

Une liste de toutes les parties de la série IEC 61156, publiées sous le titre général *Câbles multiconducteurs à paires symétriques et quartes pour transmissions numériques*, se trouve sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera:

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

IMPORTANT – Le logo "colour inside" qui se trouve sur la page de couverture de ce document indique qu'elle contient des couleurs qui sont considérées comme utiles à une bonne compréhension de son contenu. Les utilisateurs devraient, par conséquent, imprimer cette publication en utilisant une imprimante couleur.

CÂBLES MULTICONDUCTEURS À PAIRES SYMÉTRIQUES ET QUARTES POUR TRANSMISSIONS NUMÉRIQUES –

Partie 1: Spécification générique

1 Domaine d’application

La présente partie de l’IEC 61156 spécifie les définitions, les exigences et les méthodes d’essai des câbles multiconducteurs, à paires symétriques et à quartes.

Le présent document est applicable aux systèmes de transmission tels que les réseaux locaux (LAN) et les câbles de transmission de données. Il est aussi applicable aux câbles utilisés pour les applications industrielles, le câblage des locaux des clients et le câblage générique comprenant des câbles d’installation et des câbles destinés au câblage d’espaces de travail qui sont définis dans l’ISO/IEC 11801 (toutes les parties).

Les câbles couverts par le présent document sont destinés à être exploités sous des tensions et courants rencontrés conventionnellement dans les systèmes de communication. Bien que ces câbles ne soient pas destinés à être utilisés en conjonction avec des sources de basse impédance, par exemple les alimentations électriques des réseaux de services publics, ils sont destinés à être utilisés pour prendre en charge les applications de téléalimentation basse tension, y compris notamment l’alimentation par Ethernet, comme spécifié dans l’ISO/IEC/IEEE 8802-3. L’IEC 61156-1-4, l’IEC TR 61156-1-6 et l’ISO/IEC TS 29125 fournissent davantage d’informations sur la capacité à prendre en charge ces applications en fonction des pratiques de pose.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu’ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l’édition citée s’applique. Pour les références non datées, la dernière édition du document de référence s’applique (y compris les éventuels amendements).

IEC 60028, *Spécification internationale d’un cuivre-type recuit*

IEC 60068-2-1:2007, *Essais d’environnement – Partie 2-1: Essais – Essai A: Froid*

IEC 60189-1:2018, *Low-frequency cables and wires with PVC insulation and PVC sheath – Part 1: General test and measuring methods* (disponible en anglais seulement)

IEC 60304, *Couleurs de référence de l’enveloppe isolante pour câbles et fils pour basses fréquences*

IEC 60332-1-2, *Essais des câbles électriques et à fibres optiques soumis au feu – Partie 1-2: Essai de propagation verticale de la flamme sur conducteur ou câble isolé – Procédure pour flamme à prémélange de 1 kW*

IEC 60332-2-2, *Essais des câbles électriques et à fibres optiques soumis au feu – Partie 2-2: Essai de propagation verticale de la flamme sur conducteur ou câble isolé de petite section – Procédure pour une flamme de type à diffusion*

IEC 60332-3-24, *Essais des câbles électriques et des câbles à fibres optiques soumis au feu – Partie 3-24: Essai de propagation verticale de la flamme des fils ou câbles montés en nappes en position verticale – Catégorie C*

IEC 60332-3-25, *Essais des câbles électriques et des câbles à fibres optiques soumis au feu – Partie 3-25: Essai de propagation verticale de la flamme des fils ou câbles montés en nappes en position verticale – Catégorie D*

IEC 60708, *Câbles pour basses fréquences à isolation polyoléfine et gaine polyoléfine à barrière d'étanchéité*

IEC 60754-2, *Essai sur les gaz émis lors de la combustion des matériaux prélevés sur câbles – Partie 2: Détermination de la conductivité et de l'acidité (par mesure du pH)*

IEC 60794-1-21:2015, *Câbles à fibres optiques – Partie 1-21: Spécification générique – Procédures fondamentales d'essais des câbles optiques – Méthodes d'essai mécanique*

IEC 60811-201, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 201: Essais généraux – Mesure de l'épaisseur des enveloppes isolantes*

IEC 60811-202, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 202: Essais généraux – Mesure de l'épaisseur des gaines non métalliques*

IEC 60811-203, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 203: Essais généraux – Mesure des dimensions extérieures*

IEC 60811-401, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 401: Essais divers – Méthodes de vieillissement thermique – Vieillissement en étuve à air*

IEC 60811-501, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 501: Essais mécaniques – Détermination des propriétés mécaniques des mélanges pour les enveloppes isolantes et les gaines*

IEC 60811-502, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 502: Essais mécaniques – Essai de rétraction des enveloppes isolantes*

IEC 60811-504, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 504: Essais mécaniques – Essai d'enroulement à basse température pour les enveloppes isolantes et les gaines*

IEC 60811-506, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 506: Essais mécaniques – Essai de choc à basse température pour les enveloppes isolantes et les gaines*

IEC 60811-508, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non métalliques – Partie 508: Essais mécaniques – Essai de pression à température élevée pour les enveloppes isolantes et les gaines*

IEC 60811-509, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 509: Essais mécaniques – Essai de résistance à la fissuration des enveloppes isolantes et des gaines (essai de choc thermique)*

IEC 60811-510, *Câbles électriques et à fibres optiques – Méthodes d'essai pour les matériaux non-métalliques – Partie 510: Essais mécaniques – Méthodes spécifiques pour les mélanges polyéthylène et polypropylène – Essai d'enroulement après vieillissement thermique dans l'air*

IEC 61034 (toutes les parties), *Mesure de la densité de fumées dégagées par des câbles brûlant dans des conditions définies*

IEC TR 61156-1-2 [1], *Multicore and symmetrical pair/quad cables for digital communications – Part 1-2: Electrical transmission characteristics and test methods of symmetrical pair/quad cables* (disponible en anglais seulement)

IEC TR 61156-1-5, *Multicore and symmetrical pair/quad cables for digital communications – Part 1-5: Correction procedures for the measurement results of return loss and input impedance* (disponible en anglais seulement)

IEC 61196-1-105, *Câbles coaxiaux de communication – Partie 1-105: Méthodes d'essai électrique – Essai pour la tension de tenue du diélectrique du câble*

IEC 62012-1:2002, *Câbles multiconducteurs à paires symétriques et quartes pour transmissions numériques utilisés en environnements sévères – Partie 1: Spécification générique*

IEC 62153-4-3:2013, *Metallic communication cables test methods – Part 4-3: Electromagnetic compatibility (EMC) – Surface transfer impedance – Triaxial method* (disponible en anglais seulement)

IEC 62153-4-5, *Méthodes d'essai des câbles métalliques de communication – Partie 4-5: Compatibilité électromagnétique (CEM) – Affaiblissement d'écran ou de couplage – Méthode de la pince absorbante*

IEC 62153-4-9, *Méthodes d'essai des câbles métalliques de communication – Partie 4-9: Compatibilité électromagnétique (CEM) – Affaiblissement de couplage des câbles symétriques écrantés, méthode triaxiale*

IEC 62255 (toutes les parties), *Câbles multiconducteurs à paires symétriques et quartes pour transmissions numériques large bande (réseau d'accès télécommunications numériques à haut débit) – Câbles pour installations extérieures*

ISO/IEC TS 29125:2017, *Technologies de l'information – Exigences de câblage des télécommunications pour téléalimentation d'équipement terminal*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

1 L'IEC TR 61156-1-2 est censée devenir une TS en 2023.

3.1
déséquilibre de résistance
différence de résistance entre conducteurs dans une paire ou un circuit d'une quarte, ou entre paires ou quartes

Note 1 à l'article: Le déséquilibre de résistance est exprimé en pourcentage (%).

3.2
capacité mutuelle
paramètre de stockage de charge électrique d'une paire de conducteurs (ou d'un même circuit d'une quarte)

Note 1 à l'article: La capacité mutuelle est l'un des quatre paramètres primaires d'une ligne de transmission: capacité mutuelle, inductance mutuelle, résistance et conductance.

Note 2 à l'article: La capacité mutuelle est exprimée en pF/m.

3.3
déséquilibre de capacité par rapport à la terre
différence arithmétique de capacité par rapport à la terre des conducteurs d'une paire ou d'un même circuit d'une quarte

Note 1 à l'article: Le déséquilibre de capacité est exprimé en pF/m.

3.4
écran
couche conductrice continue ou ensemble de couches conductrices ayant pour fonction de réduire la pénétration d'un champ électrique, magnétique ou électromagnétique dans une région déterminée

[SOURCE: IEC 60050-195:2021,195-02-37, modifié, "couche conductrice continue ou ensemble de couches conductrices ayant pour fonction de réduire" a remplacé "dispositif destiné à réduire"]

3.5
symétriseur
dispositif fournissant une transformation d'impédance entre des composants symétriques et asymétriques

[SOURCE: ISO/IEC 11801-4:2017, 3.1.2]

3.6
sans symétriseur
symétriseur virtuel remplaçant les transformateurs physiques, obtenu par un algorithme mathématique et calculé à partir de paramètres à constantes localisées ou d'un réseau de paramètres à constantes réparties

3.7
impédance de transfert
Z_{T}
quotient de la tension longitudinale d'un câble uniforme électriquement court, induite dans le circuit extérieur, formé par l'écran en essai et le gabarit de mesure, et du courant injecté dans le circuit intérieur, le câble en essai proprement dit ou vice versa, rapporté à l'unité de longueur

Note 1 à l'article: L'impédance de transfert est exprimée en mΩ/m.

[SOURCE: IEC 62153-4-3:2013, 3.3, modifié, "d'un câble uniforme électriquement court" a été ajouté, "circuit extérieur" a remplacé "circuit extérieur adapté", "le câble en essai proprement dit" a été ajouté, "rapporté à l'unité de longueur" a remplacé "(voir Figure 1)"]

3.8
affaiblissement de couplage
a_C
pour un câble symétrique écranté, somme des effets de l'affaiblissement de symétrie, a_U, de la paire symétrique et de l'affaiblissement d'écran, a_s, de l'écran du câble en essai

Note 1 à l'article: Pour les dispositifs électriquement longs, c'est-à-dire au-delà de la fréquence de coupure, l'affaiblissement de couplage, a_C, est défini comme le rapport logarithmique de la puissance d'alimentation, P_1, et des valeurs maximales périodiques de la puissance couplée, $P_{r,\ max}$, dans le circuit externe.

Note 2 à l'article: L'affaiblissement de symétrie est exprimé en dB.

[SOURCE: IEC 62153-4-7:2021, 3.4, modifié, "câble" a remplacé "dispositif", "somme des effets" a remplacé "somme", la Note 2 a été ajoutée]

3.9
courant maximal admissible
courant maximal qu'un circuit de câble (un ou plusieurs conducteurs) peut supporter avec une augmentation spécifiée de la température de surface du conducteur au-delà de la température ambiante, et ne dépassant pas la température maximale de fonctionnement admissible du câble

3.10
vitesse de propagation
vitesse de phase
vitesse à laquelle un signal sinusoïdal se propage sur une paire dans le câble

Note 1 à l'article: La vitesse de propagation est exprimée en m/s.

3.11
temps de propagation de phase
temps de propagation
durée entre les instants où le front d'onde d'une onde progressive sinusoïdale, définie par une phase spécifiée, passe en deux points spécifiés dans un câble

Note 1 à l'article: Le temps de propagation de phase est exprimé en s/m.

3.12
temps de propagation différentiel
distorsion
différence en temps de propagation de phase entre deux paires quelconques dans le câble

Note 1 à l'article: Le temps de propagation différentiel (distorsion) est exprimé en s.

3.13
affaiblissement
diminution en grandeur de la puissance d'un signal qui se propage le long d'une paire d'un câble

Note 1 à l'article: L'affaiblissement est exprimé en dB/m.

3.14
température ambiante
température de la pièce ou de l'espace dans lequel se trouve le câble

Note 1 à l'article: La température ambiante est exprimée en degrés Celsius (°C).

3.15
température de fonctionnement
température à la surface du conducteur du câble

Note 1 à l'article: La température de fonctionnement du câble est la somme de la température ambiante et de l'augmentation de température causée par la puissance transportée.

Note 2 à l'article: La température de fonctionnement est exprimée en degrés Celsius (°C).

3.16
affaiblissement de symétrie
UA
rapport logarithmique de la puissance en mode différentiel à la puissance en mode commun dans une ligne symétrique, oui vice versa

Note 1 à l'article: L'affaiblissement de symétrie est exprimé en dB.

Note 2 à l'article: L'affaiblissement de symétrie est aussi souvent appelé perte de conversion: TCL (perte de conversion transverse), TCTL (perte de transfert de conversion transverse), LCL (perte de conversion longitudinale), LCTL (perte de transfert de conversion longitudinale), EL TCTL (perte de transfert de conversion transverse à niveau égal) et EL LCTL (perte de transfert de conversion longitudinale à niveau égal).

Note 3 à l'article: L'abréviation "UA" est dérivée du terme anglais développé correspondant "Unbalance Attenuation".

3.17
perte de conversion transverse
TCL
rapport logarithmique de la puissance du circuit en mode différentiel à l'extrémité proche et de la puissance de couplage en mode commun mesurée à l'extrémité proche

Note 1 à l'article: L'abréviation "TCL" est dérivée du terme anglais développé correspondant "Transverse Conversion Loss".

3.18
perte de transfert de conversion transverse à niveau égal
EL TCTL
mesure de sortie à sortie du rapport logarithmique de la puissance du circuit en mode différentiel à l'extrémité proche et de la puissance de couplage en mode commun mesurée à l'extrémité éloignée

Note 1 à l'article: EL TCTL est calculée par la différence entre la TCTL mesurée et les pertes d'insertion en mode différentiel de la paire perturbée.

Note 2 à l'article: L'abréviation "EL TCTL" est dérivée du terme anglais développé correspondant "Equal Level Transverse Conversion Transfer Loss".

3.19
paradiaphonie
NEXT
grandeur de la puissance d'un signal d'une paire perturbatrice à l'extrémité proche induite dans une paire perturbée mesurée à l'extrémité proche

Note 1 à l'article: La paradiaphonie est exprimée en dB.

Note 2 à l'article: L'abréviation "NEXT" est dérivée du terme anglais développé correspondant "Near-End CROSSTalk".

3.20
télédiaphonie
FEXT
grandeur de la puissance d'un signal d'une paire perturbatrice à l'extrémité proche induite dans une paire perturbée mesurée éloignée

Note 1 à l'article: La télédiaphonie est exprimée en dB.

Note 2 à l'article: L'abréviation "FEXT" est dérivée du terme anglais développé correspondant "Far-End CROSSTalk".

3.21
sommation en puissance de la diaphonie
PS
sommation de la puissance de diaphonie de toutes les paires perturbatrices vers une paire perturbée

Note 1 à l'article: La sommation est applicable à la paradiaphonie et à la télédiaphonie.

Note 2 à l'article: La sommation en puissance de la diaphonie est exprimée en dB.

Note 3 à l'article: L'abréviation "PS" est dérivée du terme anglais développé correspondant "Power Sum".

3.22
rapport affaiblissement à diaphonie, en extrémité éloignée
ACR-F
différence arithmétique entre la télédiaphonie et l'affaiblissement d'une paire perturbée

Note 1 à l'article: Le rapport affaiblissement à diaphonie, en extrémité éloignée, est exprimé en dB.

Note 2 à l'article: L'abréviation "ACR-F" est dérivée du terme anglais développé correspondant "Attenuation to Crosstalk Ratio, Far-end".

3.23
paradiaphonie exogène (due aux câbles voisins)
ANEXT
paradiaphonie où les paires perturbatrice et perturbée sont contenues dans des câbles différents

Note 1 à l'article: La paradiaphonie exogène (due aux câbles voisins) est exprimée en dB.

Note 2 à l'article: L'abréviation "ANEXT" est dérivée du terme anglais développé correspondant "Alien (exogenous) Near-End CROSSTalk".

3.24
télédiaphonie exogène (due aux câbles voisins)
AFEXT
télédiaphonie où les paires perturbatrice et perturbée sont contenues dans des câbles différents

Note 1 à l'article: La télédiaphonie exogène (due aux câbles voisins) est exprimée en dB.

Note 2 à l'article: L'abréviation "AFEXT" est dérivée du terme anglais développé correspondant "Alien (exogenous) Far-End CROSSTalk".

3.25
télédiaphonie exogène (due aux câbles voisins)
AACR-F
télédiaphonie où les paires perturbatrice et perturbée sont contenues dans des câbles différents

Note 1 à l'article: La télédiaphonie exogène (due aux câbles voisins) est exprimée en dB.

Note 2 à l'article: L'abréviation "AACR-F" est dérivée du terme anglais développé correspondant "Attenuation Alien (exogenous) Crosstalk Ratio at the Far end".

3.26
sommation en puissance de la paradiaphonie exogène (due aux câbles voisins)
PS ANEXT
sommation de la puissance de paradiaphonie exogène (due aux câbles voisins) de toutes les paires perturbatrices induite vers une paire perturbée dans des câbles différents

Note 1 à l'article: La sommation en puissance de la paradiaphonie exogène (due aux câbles voisins) est exprimée en dB.

Note 2 à l'article: L'abréviation "PS ANEXT" est dérivée du terme anglais développé correspondant "Power Sum of Alien (exogenous) Near-End CROSSTalk".

3.27
sommation en puissance de la télédiaphonie exogène (due aux câbles voisins)
PS AACR-F
sommation de la puissance de diaphonie exogène (due aux câbles voisins) de toutes les paires perturbatrices induite vers une paire perturbée dans des câbles différents

Note 1 à l'article: La sommation en puissance de la télédiaphonie exogène (due aux câbles voisins) est exprimée en dB.

Note 2 à l'article: L'abréviation "PS AACR-F" est dérivée du terme anglais développé correspondant "Power Sum of Alien (exogenous) Far-end CRosstalk".

3.28
impédance caractéristique
Z_C
impédance à l'entrée d'une ligne homogène de longueur infinie

Note 1 à l'article: valeur d'impédance exprimée en Ω, calculée, aux fréquences appropriées, comme la racine carrée du produit de l'impédance mesurée à l'extrémité proche (entrée) d'une paire de câbles, l'extrémité éloignée étant terminée d'abord par un circuit ouvert, puis par un court-circuit.

Note 2 à l'article: La valeur asymptotique aux hautes fréquences est dénotée Z_∞.

Note 3 à l'article: L'impédance caractéristique d'une paire homogène de câbles est donnée par le quotient d'une onde de tension et d'une onde de courant qui propagent dans le même sens, soit en avant, soit en arrière.

Note 4 à l'article: Pour les câbles idéaux homogènes, cette méthode d'essai rapporte une courbe lisse plate sur la plage de fréquences entière. Les câbles réels comportant des déformations donnent des courbes irrégulières.

3.29
impédance d'entrée adaptée
Z_{in}
valeur d'impédance, exprimée en Ω, aux fréquences appropriées, mesurée à l'extrémité proche (entrée) quand l'extrémité lointaine est terminée avec l'impédance nominale du système, Z_R

3.30
impédance caractéristique ajustée
Z_m
valeur d'impédance, exprimée en Ω, calculée au moyen d'un algorithme utilisant la fonction des moindres carrés appliquée aux valeurs de l'impédance caractéristique mesurée

3.31
impédance caractéristique moyenne
Z_∞
valeur asymptotique vers laquelle tend l'impédance caractéristique aux hautes fréquences (≈ 100 MHz) et telle que la partie imaginaire (angle de phase) soit insignifiante

Note 1 à l'article: Normalement mesurée à partir de la capacité et du décalage de temps.

Note 2 à l'article: Applicable aux câbles avec indépendance en fréquence de la capacité mutuelle.

3.32
affaiblissement de réflexion
RL
rapport de la puissance réfléchie à la puissance d'entrée aux bornes d'entrée d'une paire d'un câble

Note 1 à l'article: L'affaiblissement de réflexion est exprimé en dB.

Note 2 à l'article: L'abréviation "RL" est dérivée du terme anglais développé correspondant "Return Loss".

3.33
câble en faisceau
groupage ou réunion de plusieurs câbles élémentaires qui sont systématiquement rassemblés

Note 1 à l'article: Les assemblages de câbles se réfèrent aussi aux faisceaux avec attaches rapides, et divers câbles sanglés entre eux.

3.34
téléalimentation
fourniture d'énergie à des équipements spécifiques à l'application par un câblage symétrique

[SOURCE: ISO/IEC TS 29125:2017, 3.1.5]

3.35
très basse tension de sécurité
TBTS
tension n'excédant pas 50 V efficaces en courant alternatif ou 120 V en courant continu lissé entre conducteurs ou entre un conducteur quelconque et la terre dans un circuit dont la séparation galvanique du réseau d'alimentation électrique est assurée par des moyens tels qu'un transformateur à enroulements séparés

Note 1 à l'article: Une tension maximale inférieure à 50 V en courant alternatif ou 120 V en courant continu lissé peut être spécifiée dans des exigences particulières, plus spécialement lorsque le contact direct avec des parties actives est possible.

Note 2 à l'article: Lorsque la source est un transformateur de sécurité, il convient que la limite de tension ne soit pas dépassée à toute charge comprise entre la pleine charge et à vide.

Note 3 à l'article: "Lissé" se dit par convention d'une tension en courant continu lorsque le rapport de la valeur efficace de l'ondulation à la composante continue ne dépasse pas 10 %. La valeur de crête maximale ne dépasse pas 140 V pour un système en courant continu lissé de tension nominale 120 V et 70 V pour un système en courant continu lissé de tension nominale 60 V.

3.36
température de fonctionnement continu
COT
température maximale qui assure la stabilité et l'intégrité du matériau pendant la durée de vie prévue de l'équipement, ou de la pièce, dans l'application prévue

Note 1 à l'article: L'abréviation "COT" est dérivée du terme anglais développé correspondant "Continuous Operating Temperature".

3.37
caractère hygroscopique
caractéristique d'un matériau à absorber l'humidité de l'atmosphère

3.38
effet de mèche
écoulement longitudinal d'un liquide dans un matériau dû à l'action de capillarité

4 Considérations d'installation

Les câbles doivent être conçus pour satisfaire aux conditions d'installation rencontrées dans chaque zone, comme suit.

a) Câbles d'équipement

   Câbles utilisés entre les postes de travail et les équipements périphériques (par exemple imprimante).

b) Câbles de zone de travail

   Câbles utilisés entre le poste de travail et les prises de télécommunications.

c) Câbles capillaires

Câbles utilisés entre la prise de télécommunications de la zone de travail et le coffret de télécommunications.

d) Câbles de colonne et câbles de dorsale d'immeuble

Câbles utilisés pour installation horizontale ou verticalement entre étages.

e) Câbles de campus

Câbles utilisés pour interconnecter des bâtiments et devant être appropriés pour installation extérieure. Les câbles doivent être gainés et protégés conformément à l'IEC 62255 (toutes les parties).

f) Fourniture d'énergie

Pour les câbles fourniture d'énergie utilisant uniquement des systèmes TBTS pour la téléalimentation, la COT doit être prise en compte.

NOTE Le document connexe est l'IEC 60364-7-716.

5 Matériaux et construction du câble

5.1 Remarques générales

Le choix des matériaux et de la construction du câble doit convenir à l'application et l'installation envisagées pour le câble. Il convient de tenir compte de toutes les exigences spéciales relatives à la CEM (compatibilité électromagnétique), la tenue au feu ou la TBTS.

5.2 Constructions du câble

5.2.1 Généralités

La construction des câbles doit être conforme aux détails et aux dimensions donnés dans la spécification particulière applicable.

5.2.2 Conducteur

Le conducteur doit être en cuivre recuit, de qualité uniforme et exempt de défauts. Les propriétés du cuivre doivent être en conformité avec l'IEC 60028.

Le conducteur peut être massif ou câblé. Le conducteur massif doit être de section circulaire et peut être nu ou avec revêtement métallique. Le conducteur massif doit être tréfilé d'un seul tenant. Des soudures sur le conducteur massif sont permises, pourvu que la résistance à la rupture d'une soudure ne soit pas inférieure à 85 % de la résistance à la rupture d'un conducteur sans soudure.

Le conducteur câblé doit être constitué de brins de section circulaire et sans isolation entre eux, assemblés en concentrique ou en tordon.

NOTE L'utilisation de tordon n'est pas recommandée pour l'application de connexion par déplacement d'isolant (IDC).

Les brins élémentaires du conducteur peuvent être nus ou avec revêtement métallique.

Des soudures sur les brins élémentaires sont permises, pourvu que la résistance à la traction d'une soudure ne soit pas inférieure à 85 % de la résistance à la rupture d'un brin élémentaire sans soudure. Des soudures sur le conducteur câblé complet ne sont pas permises sauf dérogation dans la spécification particulière applicable.

Le conducteur des câbles de zone de travail et des câbles d'équipement peut être constitué d'un ou plusieurs éléments de rubans minces en cuivre ou alliage de cuivre qui doivent être appliqués en hélice sur une mèche fibreuse. Des soudures sur l'élément complet ne sont pas permises.

5.2.3 Isolation

5.2.3.1 Exigences générales

L'enveloppe isolante du conducteur est composée d'un ou plusieurs matériaux diélectriques appropriés. L'isolation peut être massive, cellulaire ou composite (par exemple une couche cellulaire sous une couche massive).

L'enveloppe isolante doit être continue et d'épaisseur uniforme.

L'enveloppe isolante doit être appliquée de façon à adhérer étroitement au conducteur.

Les conducteurs isolés peuvent être identifiés par couleurs, marquage additionnel par anneaux ou symboles obtenus en utilisant une enveloppe isolante colorée ou par coloration en surface à partir d'extrusion, d'impression ou de peinture. Les couleurs doivent être facilement identifiables et doivent correspondre raisonnablement aux couleurs de référence de l'IEC 60304.

5.2.3.2 Code de couleurs

Le code de couleurs de l'enveloppe isolante est donné dans la spécification particulière applicable.

5.2.4 Élément de câble

5.2.4.1 Généralités

L'élément de câble est:

– une paire constituée de deux conducteurs isolés torsadés ensemble et désignés respectivement comme conducteur "a" et conducteur "b"; ou
– une quarte constituée de quatre conducteurs isolés torsadés ensemble et désignés respectivement comme conducteur "a", conducteur "c", conducteur "b" et conducteur "d", dans l'ordre de rotation.

Le choix de la longueur moyenne maximale du pas dans le câble terminé doit être effectué eu égard aux exigences spécifiées pour la diaphonie, au comportement en manipulation et à l'intégrité de la paire ou de la quarte.

NOTE La formation de l'élément avec un pas variable peut conduire à un pas maximal dépassant la valeur spécifiée, situation peu fréquente, mais acceptable.

5.2.4.2 Écran de l'élément de câble

Lorsqu'un écran est exigé sur la paire ou la quarte, il peut comporter ce qui suit:

a) un ruban métallique contrecollé à un ruban plastique;
b) un ruban métallique contrecollé à un ruban plastique et un fil de continuité en cuivre nu ou avec revêtement métallique par lequel le ruban métallique est en contact avec le fil de continuité;
c) une tresse métallique;
d) un ruban métallique contrecollé à un ruban plastique et une tresse métallique.

Il convient de considérer des revêtements ou d'autres méthodes de protection pour empêcher toute interaction galvanique lorsque des matériaux dissemblables sont mis en contact les uns avec les autres.

Un rubanage de protection peut être appliqué soit sous l'écran, soit sur celui-ci ou encore les deux à la fois.

5.2.5 Constitution du câble

Les éléments de câble peuvent être assemblés en couches concentriques ou en faisceaux. L'assemblage peut être protégé par un rubanage non hygroscopique, exempt d'effet de mèche.

NOTE 1 Des bourrages peuvent être utilisés pour maintenir une formation circulaire.

NOTE 2 La formation de l'élément avec un pas variable peut conduire à un pas maximal dépassant la valeur spécifiée, situation peu fréquente, mais acceptable.

5.2.6 Écran d'assemblage

Les éléments du câble peuvent comporter un écran faisant partie du système de blindage et de mise à la terre du câblage. Conception possible:

a) un ruban métallique contrecollé à un ruban plastique qui peut être collé à la gaine, par exemple structure F/UTP;
b) un ruban métallique contrecollé à un ruban plastique et un fil de continuité en cuivre nu ou avec revêtement métallique par lequel le ruban métallique est en contact avec le fil de continuité, par exemple structure F/UTP;
c) une tresse métallique, par exemple structure S/UTP;
d) un ruban métallique contrecollé à un ruban plastique et une tresse métallique, par exemple structure SF/UTP;
e) un ruban en cuivre nu ou en aluminium, par exemple structure F/UTP.

Un ruban métallique non contrecollé est également admissible s'il peut satisfaire aux exigences de performance, par exemple rigidité diélectrique.

Il convient de considérer des revêtements ou d'autres méthodes de protection pour empêcher toute interaction galvanique lorsque des matériaux dissemblables sont mis en contact les uns avec les autres.

Un rubanage de protection peut être appliqué soit sous l'écran, soit sur celui-ci ou encore les deux à la fois. L'Annexe A énumère les conceptions habituelles et leurs dénominations.

5.2.7 Gaine

La gaine doit être constituée d'un matériau polymère.

La gaine doit être continue et d'épaisseur uniforme.

La gaine doit être appliquée de façon à adhérer étroitement aux éléments du câble. Dans le cas des câbles avec écran, la gaine ne doit pas adhérer à l'écran sauf lorsqu'elle est intentionnellement collée à lui.

La couleur de la gaine peut être spécifiée dans la spécification particulière applicable.

5.2.8 Identification

5.2.8.1 Marquage de câble

Chaque longueur de câble doit porter le nom du fournisseur et le type de câble et, lorsqu'elle est fournie, l'année de fabrication en utilisant l'une des méthodes suivantes:

a) des filins colorés ou rubans;
b) un ruban imprimé;

c) une impression sur le rubanage de l'assemblage;

d) un marquage sur la gaine.

Des marquages supplémentaires, par exemple tension maximale, température assignée, etc. peuvent être stipulés sur la gaine comme indiqué dans la spécification particulière applicable.

5.2.8.2 Étiquetage

Les informations suivantes doivent être fournies, soit sur une étiquette annexée à chaque longueur de câble terminé, soit à l'extérieur de l'emballage du produit:

a) le type de câble;

b) le nom du fournisseur ou son logo;

c) l'année de fabrication;

d) la longueur du câble en mètres.

5.2.9 Câble terminé

Le câble terminé doit avoir une protection adéquate pour le stockage et l'expédition.

6 Caractéristiques et exigences

6.1 Remarques générales – Configurations d'essai

Sauf spécification contraire, tous les essais doivent être réalisés en présumant que la température de fonctionnement est de 20 °C. La température du câble doit être stabilisée à 20 °C et le signal d'essai doit être suffisamment faible pour éviter toute augmentation de température.

NOTE Un échauffement est prévu lors des essais pour l'application du câble dans les installations de téléalimentation.

Les exigences calculées, arrondies à une décimale, doivent être utilisées pour déterminer la conformité.

Les configurations d'essai typiques pour l'éprouvette sont les suivantes:

a) disposée sur une surface non métallique à 25 mm au moins d'une surface conductrice;

b) maintenue en portées aériennes de sorte qu'il y ait une séparation minimale de 25 mm entre enroulements;

c) enroulée en une seule hélice à spires non serrées sur un touret avec 25 mm au moins entre tours.

Les configurations a), b) et c) ne sont pas nécessaires pour les câbles avec écran.

Les paramètres de capacité mutuelle, diaphonie, impédance caractéristique et affaiblissement présentent quelquefois des valeurs mesurées jusqu'à 10 % plus élevées lorsque le câble est mesuré dans son emballage. Cette différence se produit du fait d'un conditionnement dense et serré, et d'un effet entre spires. L'emballage en caisse peut également affecter négativement les caractéristiques du câble affaiblissement de réflexion, diaphonie et impédance caractéristique, avec rétablissement total ou partiel des performances du câble après installation.

En cas de doute, les mesures de capacité mutuelle, impédance, affaiblissement et diaphonie doivent être effectuées sur un échantillon de câble retiré de son emballage.

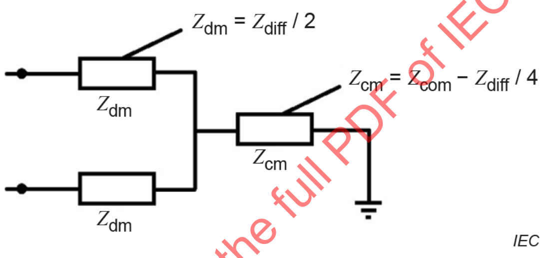
Les procédures de mesure pour la diaphonie exogène (due aux câbles voisins) spécifient les configurations d'essai spéciales pour le montage des câbles.

Il convient d'utiliser les résistances de terminaison en mode différentiel et en mode commun pour équiper les paires inactives et les extrémités opposées des paires actives pour les essais de paradiaphonie et de télédiaphonie (voir Figure 1). Pour les câbles ayant une impédance nominale (Z_{diff}) de 100 Ω, l'impédance en mode commun (Z_{com}) est égale à:

– environ 75 Ω pour les câbles à paires sans écran contenant jusqu'à 25 paires;
– environ 50 Ω pour les câbles à paires avec écran collectif et pour les câbles à paires sans écran contenant plus de 25 paires;
– environ 25 Ω pour les câbles à paires écrantées individuellement.

En principe, pour les mesures avec symétriseur, l'essai doit être effectué à condition que l'impédance en mode différentiel (Z_{diff}) et l'impédance en mode commun (Z_{com}) de l'éprouvette soient adaptées respectivement par le symétriseur et l'analyseur de réseau vectoriel (ou des instruments équivalents).

Mais en pratique, sachant que l'analyseur de réseau vectoriel (ou l'instrument équivalent) utilisé pour la mesure est équipé d'accès 50 Ω en général et que l'impédance en mode commun du symétriseur est également de 50 Ω, l'impédance en mode commun de la terminaison doit être de 50 Ω, sauf spécification contraire. Cela permet de simplifier les mesures lorsque l'impédance en mode commun de l'éprouvette varie de 25 Ω à 75 Ω.



Légende

Z_{dm} est la résistance de terminaison en mode différentiel (Ω)

Z_{cm} est la résistance de terminaison en mode commun (Ω)

Z_{diff} est l'impédance du câble en mode différentiel (Ω)

Z_{com} est l'impédance du câble en mode commun (Ω)

Figure 1 – Résistances de terminaison pour les mesures avec symétriseur

L'IEC TR 61156-1-2 fournit les valeurs des résistances de terminaison pour les mesures sans symétriseur.

6.2 Caractéristiques électriques et essais

6.2.1 Résistance du conducteur

La mesure de la résistance du conducteur doit être conforme à l'IEC 60189-1:2018, 8.1.

NOTE L'IEC TR 61156-1-6 fournit des informations générales concernant la résistance.

6.2.2 Déséquilibre de résistance

6.2.2.1 Exigence générale

La mesure du déséquilibre de résistance et la précision de l'équipement de mesure doivent être en conformité avec l'IEC 60708.

NOTE L'IEC TR 61156-1-6 fournit des informations générales concernant le déséquilibre de résistance.

6.2.2.2 Déséquilibre de résistance dans une paire

Le déséquilibre de résistance entre conducteurs d'une paire ou d'un même circuit d'une quarte est donné par:

$$\Delta R = \frac{(R_{\text{max}} - R_{\text{min}})}{(R_{\text{max}} + R_{\text{min}})} \times 100\% \qquad (1)$$

où

ΔR est le déséquilibre de résistance entre conducteurs (%);

R_{max} est la résistance pour le conducteur ayant la valeur de résistance la plus élevée (Ω);

R_{min} est la résistance pour le conducteur ayant la valeur de résistance la plus faible (Ω).

6.2.2.3 Déséquilibre de résistance entre paires

Le déséquilibre de résistance entre paires ou entre circuits de quartes est donné par:

$$\Delta RP_{i,k} = \frac{\left| R_{\text{max}\,i} \times R_{\text{min}\,i}\left(R_{\text{max}\,k} + R_{\text{min}\,k}\right) - R_{\text{max}\,k} \times R_{\text{min}\,k}\left(R_{\text{max}\,i} + R_{\text{min}\,i}\right)\right|}{R_{\text{max}\,i} \times R_{\text{min}\,i}\left(R_{\text{max}\,k} + R_{\text{min}\,k}\right) + R_{\text{max}\,k} \times R_{\text{min}\,k}\left(R_{\text{max}\,i} + R_{\text{min}\,i}\right)} \times 100\% \qquad (2)$$

où

$\Delta RP_{i,k}$ est le déséquilibre de résistance entre la paire i et la paire k (%);

R_{max} est la résistance du conducteur ayant la valeur de résistance la plus élevée d'une paire (Ω);

R_{min} est la résistance du conducteur ayant la valeur de résistance la plus faible d'une paire (Ω);

i,k $i \neq k$ où i = 1 à n et k = 1 à n pour n = nombre de paires.

6.2.3 Rigidité diélectrique

Cette mesure doit être effectuée avant la mesure de la résistance d'isolement décrit en 6.2.4.

La mesure de la rigidité diélectrique doit être en conformité avec l'IEC 61196-1-105 entre conducteurs, entre les conducteurs et l'écran (le cas échéant) et entre les écrans (le cas échéant).

NOTE Cet essai permet de s'assurer que la sécurité n'est pas compromise dans les installations de téléalimentation.

6.2.4 Résistance d'isolement

Cette mesure doit être effectuée après l'essai de rigidité diélectrique décrit en 6.2.3.

La mesure de la résistance d'isolement entre conducteurs, conducteur/écran et écran/écran doit être conforme à l'IEC 60189-1:2018, 8.3. La tension d'essai doit être comprise entre 100 V et 500 V en courant continu, sauf indication contraire dans la spécification particulière.

6.2.5 Capacité mutuelle

La mesure de la capacité mutuelle des paires dans un câble multipaire ou à quartes doit être conforme à l'IEC 60189-1:2018, 8.4.

6.2.6 Déséquilibre de capacité par rapport à la terre

La mesure du déséquilibre de capacité dans un câble multipaire ou à quartes doit être conforme à l'IEC 60189-1:2018, 8.5.

Le déséquilibre de capacité par rapport à la terre d'une paire ou d'un circuit d'une quarte est donné par:

$$\Delta C_e = C_1 - C_2 \qquad (3)$$

où

ΔC_e est le déséquilibre de capacité de la paire par rapport à la terre (pF/km);

C_1 est la capacité entre le conducteur "a" et le conducteur "b" avec le conducteur "b" connecté à tous les autres conducteurs, à l'écran (s'il existe) et à la terre (pF/km);

C_2 est la capacité entre le conducteur "b" et le conducteur "a" avec le conducteur "a" connecté à tous les autres conducteurs, à l'écran (s'il existe) et à la terre (pF/km).

Le résultat d'essai de déséquilibre de capacité par rapport à la terre doit être corrigé:

– pour le déséquilibre paire-terre et réel-terre par:

$$\Delta C_e = C_{meas} \times \frac{1000}{L} \qquad (4)$$

où

ΔC_e est le déséquilibre de capacité par rapport à la terre (pF/km);

C_{meas} est la capacité mesurée (pF/km);

L est la longueur du câble en essai (m).

Si cela est exigé, le résultat d'essai de déséquilibre de capacité pour le déséquilibre entre paires et réel-réel doit être spécifié dans la spécification particulière.

6.2.7 Impédance de transfert

L'impédance de transfert doit être mesurée conformément à l'IEC 62153-4-3. Tous les écrans doivent être connectés ensemble aux extrémités de l'éprouvette. L'impédance de transfert doit être mesurée sur toute la plage de fréquences indiquée dans la spécification intermédiaire applicable.

6.2.8 Affaiblissement de couplage

La méthode d'essai de l'affaiblissement de couplage doit se faire conformément à l'IEC 62153-4-5 ou l'IEC 62153-4-9. Tous les écrans doivent être connectés ensemble aux extrémités de l'éprouvette. L'affaiblissement de couplage de toutes les paires dans l'éprouvette doit être mesuré sur toute la plage de fréquences indiquée dans la spécification intermédiaire applicable.

L'IEC 62153-4-9 doit être la méthode d'essai de référence pour résoudre les doutes ou les litiges.

6.2.9 Courant maximal admissible

Si cela est exigé, la méthode d'essai du courant maximal admissible est décrite dans l'IEC 61156-1-4. Comme le courant maximal admissible est déterminé de manière significative par les conditions d'installation, il convient de prendre en compte les recommandations générales de l'ISO/IEC TS 29125.

NOTE La section minimale des conducteurs (résistance maximale) est utilisée dans le calcul de chaque câble considéré pour son courant maximal admissible, car les livraisons par lots peuvent varier.

6.3 Caractéristiques de transmission

6.3.1 Exigences générales

Les mesures de transmission sont effectuées en condition équilibrée, avec équipement de mesure (analyseur de réseau ou générateur de signal et récepteur) et transformateurs symétriseurs pour connecter le câble à l'équipement. Les symétriseurs doivent être sélectionnés pour adapter l'équipement d'essai à l'impédance nominale du câble et doivent avoir les caractéristiques de fonctionnement appropriées données dans le Tableau 1.

Tous les essais doivent être effectués sur l'ensemble de la plage de fréquences spécifiée et aux mêmes points de fréquence de la procédure d'étalonnage. Un étalonnage complet des 2 accès doit être effectué pour obtenir la meilleure précision et il convient que la longueur du câble pour un étalonnage complet soit aussi courte que possible.

Tous les essais doivent être effectués dans les deux sens ou aux deux extrémités.

Une alternative à la méthode de mesure avec symétriseur est la méthode de mesure sans symétriseur qui est spécifiée dans l'IEC TR 61156-1-2. Pour les fréquences supérieures à 1 GHz, la méthode de mesure sans symétriseur est recommandée.

La longueur du câble en essai doit être égale à 100 m, sauf spécification contraire.

6.3.2 Vitesse de propagation (vitesse de phase)

La vitesse de propagation doit être déterminée en fonction de la vitesse angulaire et la constante de phase.

Le schéma de l'équipement d'essai est donné à la Figure 2.

La vitesse de propagation est donnée par:

$$v_{(f)} = \frac{\omega_{(f)}}{\beta_{(f)}} = \frac{2\pi f}{\beta_{(f)}} \tag{5}$$

où

f est la fréquence (Hz);

$v_{(f)}$ est la vitesse de phase à la fréquence f (m/s);

$\beta_{(f)}$ est la constante de phase (rad/m);

$\omega_{(f)}$ est la vitesse angulaire.

Aux hautes fréquences, la vitesse de propagation du câble est approximativement constante, de sorte que la vitesse de phase peut être évaluée par la vitesse de groupe pour faciliter la mesure. Lorsque des signaux à composantes de fréquences multiples se propagent le long d'un câble, si ces fréquences sont très proches et que leurs différences sont beaucoup plus petites que la fréquence centrale, la vitesse de groupe est déterminée à l'aide de la Formule (6). Δf est l'intervalle de fréquence pour lequel la phase du signal de sortie présente une rotation de 2π radians par rapport au signal d'entrée:

$$v_{(G)} = L \times \Delta f \qquad (6)$$

où

$v_{(G)}$ est la vitesse de groupe (m/s);

L est la longueur du câble en essai (m);

Δf est l'intervalle de fréquence (Hz).

Afin d'évaluer Δf avec suffisamment de précision, la différence de fréquence, $\Delta f'$, pour n rotations de 2π radians peut être mesurée comme:

$$\Delta f = \Delta f' / n \qquad (7)$$

où

Δf est l'intervalle de fréquence (Hz);

$\Delta f'$ est la différence de fréquence pour n rotations(Hz);

n est le nombre de rotations ≤ 10.

L'IEC TR 61156-1-2 fournit des informations détaillées de la vitesse de phase et de la vitesse de groupe.

6.3.3 Temps de propagation de phase et temps de propagation différentiel (distorsion)

Le temps de propagation de phase est déterminé à partir de la vitesse de phase:

$$\tau_{\mathrm{p}} = \frac{L}{v_{\mathrm{p}}} \qquad (8)$$

où

τ_{p} est le temps de propagation de phase (s);

v_{p} est la vitesse de phase (m/s);

L est la longueur du câble en essai (m).