

INTERNATIONAL STANDARD



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



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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- withdrawn,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.

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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 60189-1:1986/2018, *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 61156-1-2², *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 62012-1:20042002, *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 α_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 a_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 a_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~~ 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~~ 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 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~~

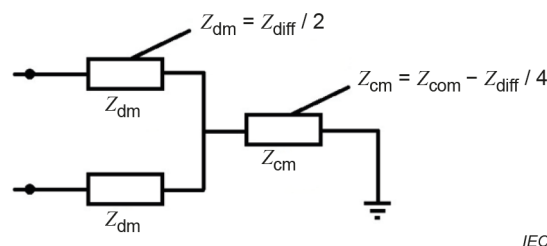
- ~~— 0 Ω for individually screened pair cables;~~
- ~~— 25 Ω for overall screened cables;~~
- ~~— 45 Ω to 50 Ω for unscreened cables.~~

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

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

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

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

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

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

$$\Delta C_e = C_1 - C_2 \quad (3)$$

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~~

~~$$C_{\text{corr}} = \frac{C_{\text{meas}}}{0,5 \times (L/500 + \sqrt{L/500})} \quad (4)$$~~

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

~~$$C_{\text{corr}} = \frac{C_{\text{meas}}}{L/500} \quad (5)$$~~

~~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

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

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~~

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

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

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

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.

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

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

$$\Delta f = \Delta f' / n \quad (7)$$

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:

$$\tau_p = \frac{L}{v_p} \quad (8)$$

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

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

where

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

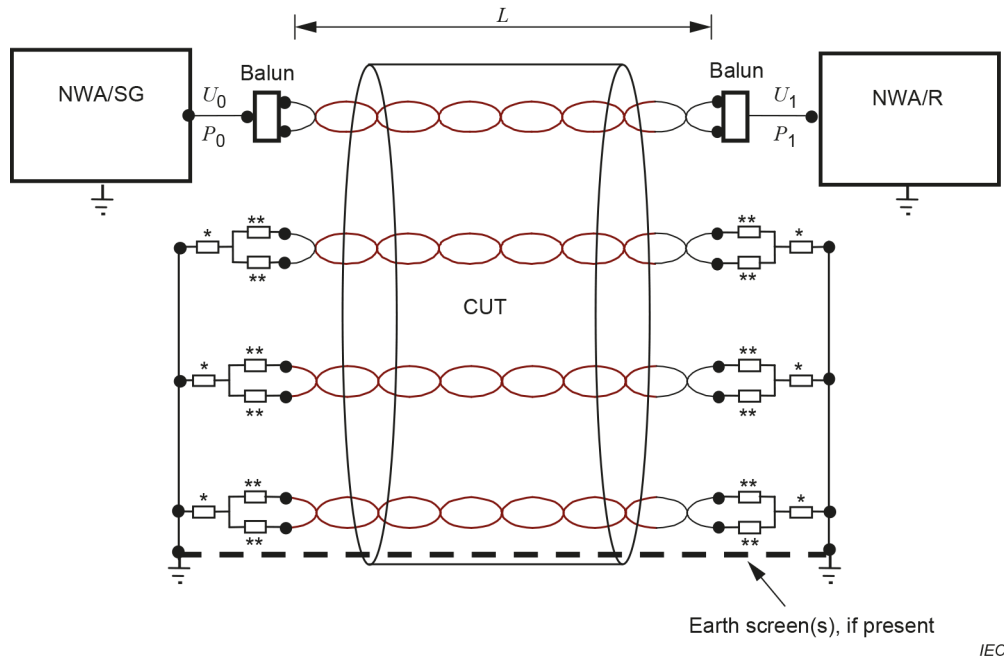
$v_{p,1}$ is the phase velocity of one pair (m/s);

$v_{p,2}$ 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.~~

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

where

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

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

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:

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

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

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).

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

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.
- ~~e) 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

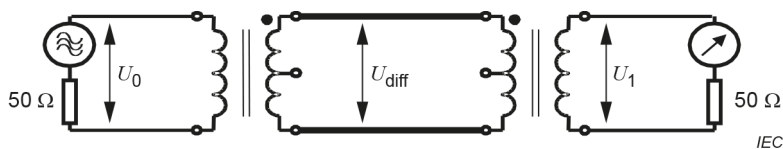
Parameter	Class A-250 value	Class A-600 value	Class B value
Impedance, primary ^a	50 Ω unbalanced	50 Ω unbalanced	50 Ω unbalanced
Impedance, secondary	Matched balanced	Matched balanced	Matched balanced
Insertion loss	3 dB max.	3 dB max.	10 dB max.
Return loss, secondary	20 dB min.	12 dB min., 5-15 MHz 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, minimum	60 dB, 4 MHz to 350 MHz 50 dB, 350 MHz to 600 MHz 40 dB, 600 MHz to 1 000 MHz	Under consideration

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
<p>Special guidelines for the use of baluns</p> <p>1) For best accuracy, the baluns should be supplied with connectors (for example, with IEC 60169-22 connectors).</p> <p>2) For tests up to 250 MHz, class A-250 baluns should be used.</p> <p>3) For tests up to 600 MHz, class A-600 baluns should be used.</p> <p>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.</p> <p>1) For tests up to 500 MHz, class A-500 baluns should be used.</p> <p>2) For tests up to 1 000 MHz, class A-1000 baluns should be used.</p> <p>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.</p> <p>4) Common mode port of baluns are optional in 6.3 except for unbalance attenuation measurement.</p>			
<p>^a Primary impedance may differ, if necessary, to accommodate analyzer outputs other than 50 Ω.</p> <p>^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.</p> <p>^c Measured according to ITU T Recommendation G.117 and ITU-T Recommendation O.9.</p> <p>^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.</p>			

6.3.5.2 Balun calibration

- 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.
- 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

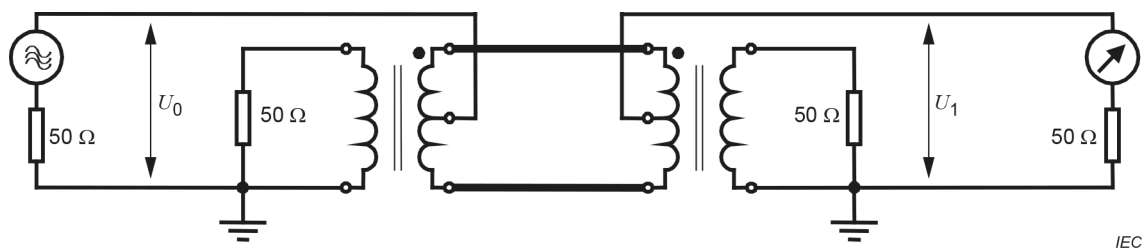
The differential-mode loss of the ~~single~~ baluns is given by

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

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

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

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

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

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:

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

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:

$$\begin{aligned} 20 \times \log_{10} \left| \frac{U_{\text{diff}}}{U_0} \right| &= 10 \times \log_{10} \left| \frac{Z_{\text{diff}}}{Z_0} \right| - \alpha_{\text{balun}} \\ 20 \times \log_{10} \left| \frac{U_{\text{diff}}}{U_1} \right| &= 10 \times \log_{10} \left| \frac{Z_{\text{diff}}}{Z_1} \right| - \alpha_{\text{balun}} \end{aligned} \quad (17)$$

$$\begin{aligned} 20 \lg \left| \frac{U_{\text{diff}}}{U_0} \right| &= 10 \lg \left| \frac{Z_{\text{diff}}}{Z_0} \right| - \alpha_{\text{balun}} \\ 20 \lg \left| \frac{U_{\text{diff}}}{U_1} \right| &= 10 \lg \left| \frac{Z_{\text{diff}}}{Z_1} \right| - \alpha_{\text{balun}} \end{aligned} \quad (17)$$

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 $\pm$ 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.

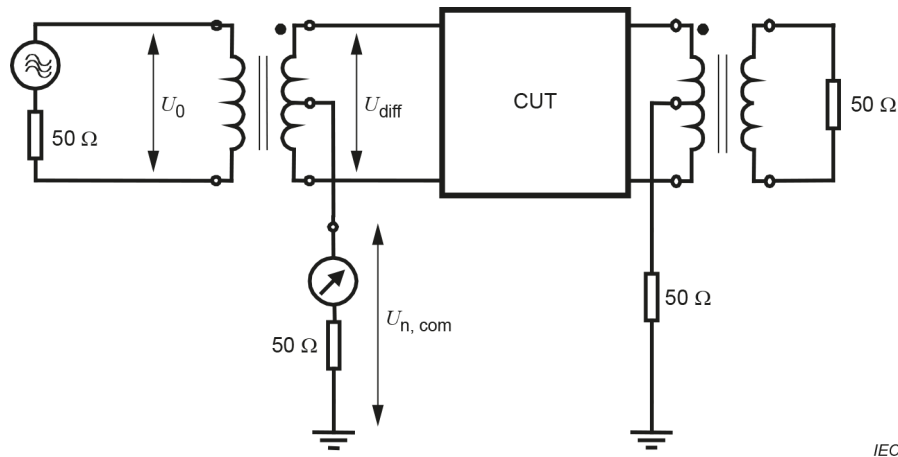


Figure 5 – Test set-up for unbalance attenuation at near end (TCL)

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

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

where

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

$U_{n, \text{com}}$ 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.~~

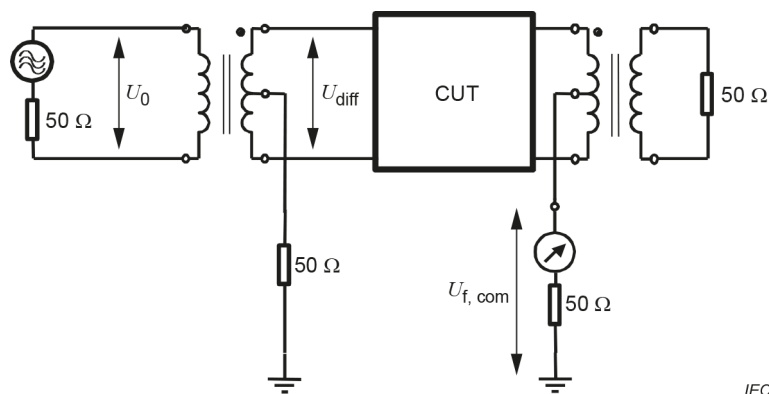


Figure 6 – Test set-up for unbalance attenuation at far end (TCTL)

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

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

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.

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

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

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:

$$\begin{aligned} \alpha_{u, n} &= 10 \times \log_{10} \left| \frac{P_{n, \text{com}}}{P_{\text{diff}}} \right| = 10 \times \log_{10} \left| \frac{P_{n, \text{com}}}{P_0} \right| - \alpha_{\text{balun}} \\ &= 20 \times \log_{10} \left| \frac{U_{n, \text{com}}}{U_0} \right| + 10 \times \log_{10} \left| \frac{Z_0}{Z_{\text{com}}} \right| - \alpha_{\text{balun}} \end{aligned} \quad (21)$$

~~$$\alpha_{u, n} = \alpha_{\text{meas}} + 10 \times \log_{10} \left| \frac{Z_0}{Z_{\text{com}}} \right| - \alpha_{\text{balun}} \quad (22)$$~~

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

The equal level unbalance attenuation at the far end is then

~~$$EL \alpha_{u, f} = \alpha_{\text{meas}} + 10 \times \log_{10} \left| \frac{Z_0}{Z_{\text{com}}} \right| - \alpha_{\text{balun}} - \alpha_{\text{cable}} \quad (23)$$~~

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

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);

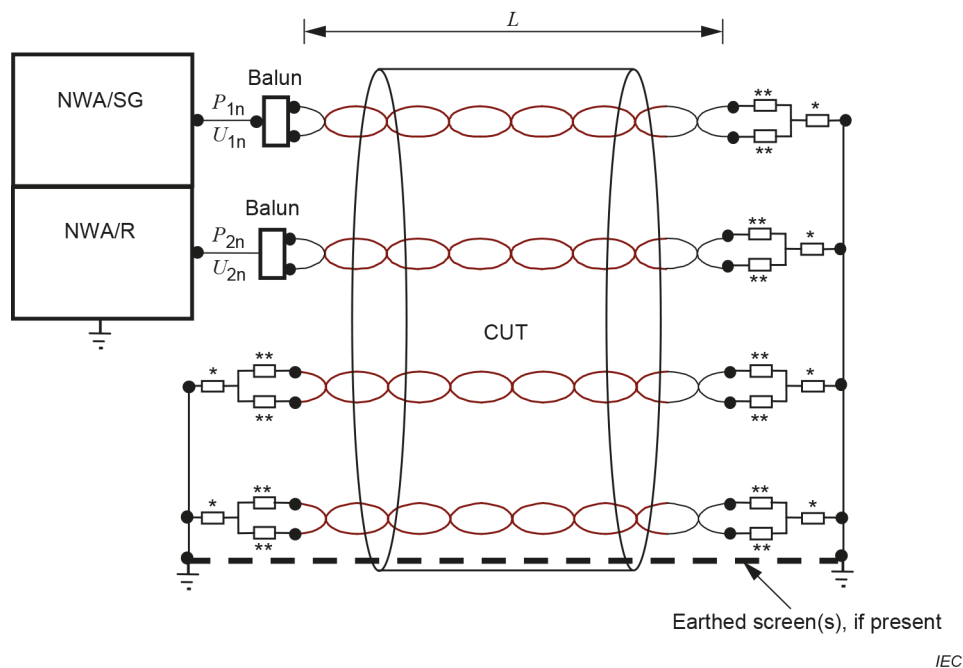
Z_{com} is the operational impedance of the common-mode circuit, 50 Ω .

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

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

$$\begin{aligned} \text{NEXT} &= 10 \lg \left| \frac{P_{1n}}{P_{2n}} \right| = \\ &= 20 \lg \left| \frac{U_{1n}}{U_{2n}} \right| + 10 \lg \left| \frac{Z_2}{Z_1} \right| = \\ &= -20 \lg |S_{21}| + 10 \lg \left| \frac{Z_2}{Z_1} \right| \end{aligned} \quad (23)$$

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:

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

$$\text{NEXT}_{100} = \text{NEXT} - 10 \lg \left[\frac{\left(1 - 10^{-\left(\frac{\alpha}{5} \right) \times \left(\frac{100}{L} \right)} \right)}{\left(1 - 10^{-\left(\frac{\alpha}{5} \right)} \right)} \right] \quad (24)$$

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

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

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

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);

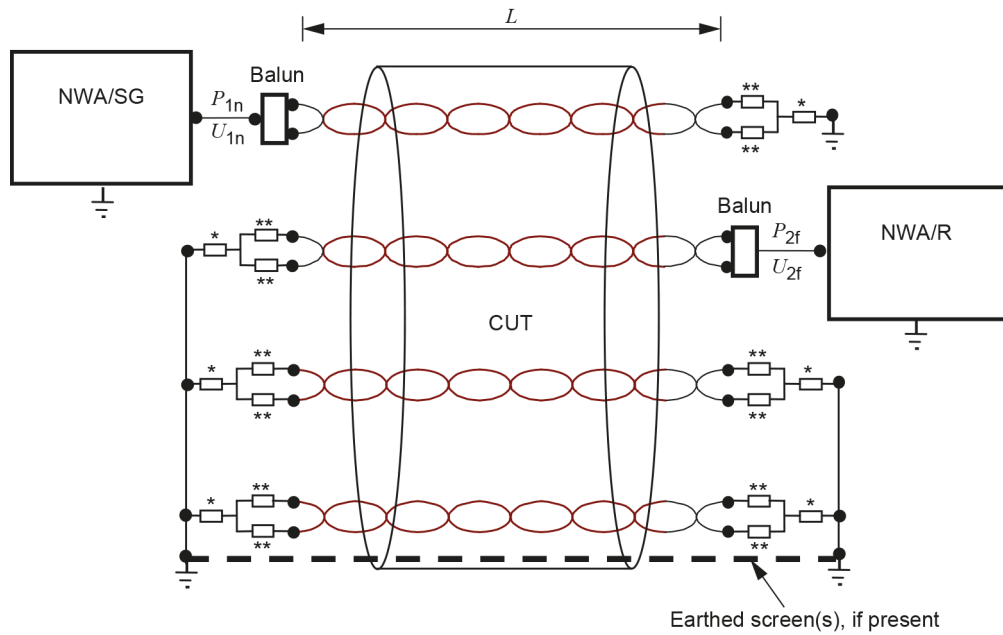
m is the number of pairs contained within the cable.

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.



IEC

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

$$FEXT = 10 \times \log_{10} \left| \frac{P_{1n}}{P_{2f}} \right|$$

$$= 20 \times \log_{10} \left| \frac{U_{1n}}{U_{2f}} \right| + 10 \times \log_{10} \left| \frac{Z_1}{Z_2} \right|$$

(27)

$$FEXT = 10 \lg \left| \frac{P_{1n}}{P_{2f}} \right| =$$

$$20 \lg \left| \frac{U_{1n}}{U_{2f}} \right| + 10 \lg \left| \frac{Z_2}{Z_1} \right| =$$

$$- 20 \lg |S_{21}| + 10 \lg \left| \frac{Z_2}{Z_1} \right|$$

(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:

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

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:~~

$$\del{EL\ FEXT = FEXT - \alpha_1} \quad (29)$$

where

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

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

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:

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

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

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

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

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

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

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

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);

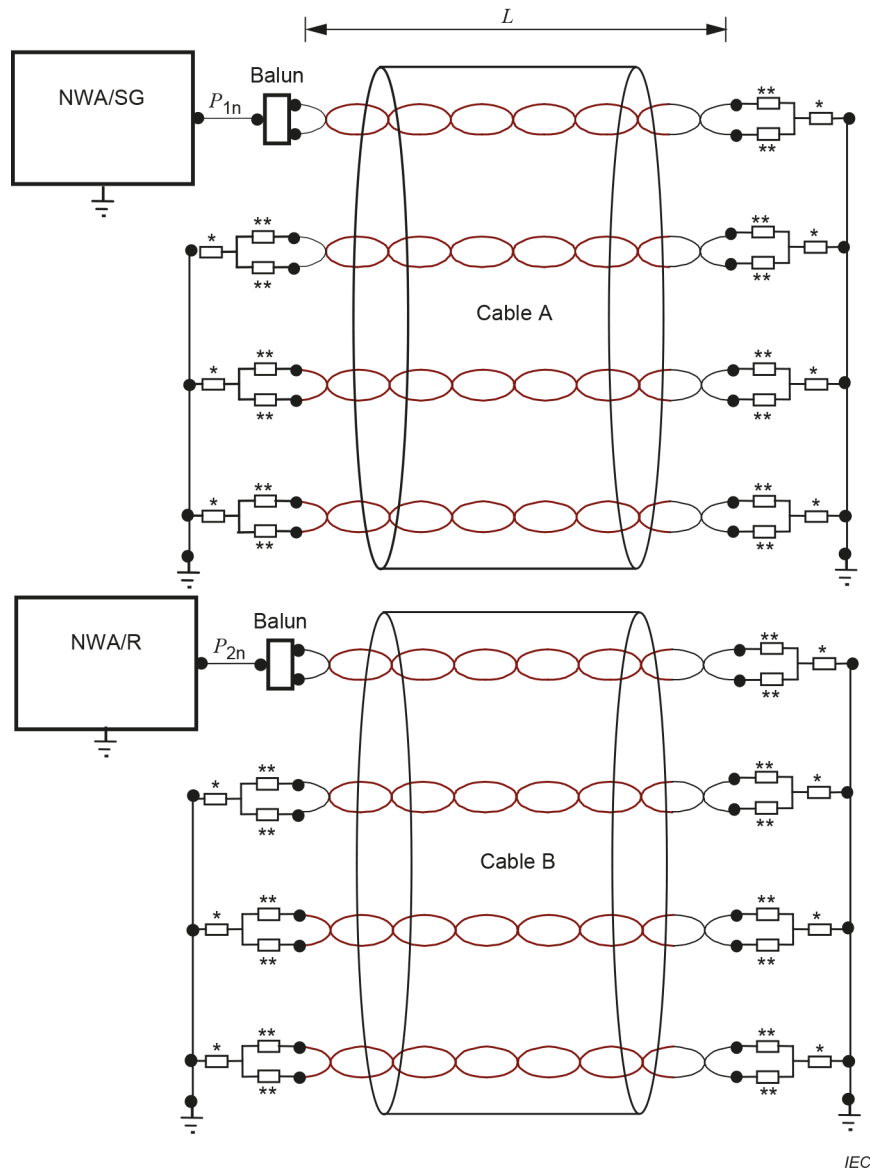
α_j is the attenuation of the disturbed pair j in (dB);

$FEXT_{i,j}$ 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

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

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

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:

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

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

where

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

$AX - talk_{i,j,l}$ 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).

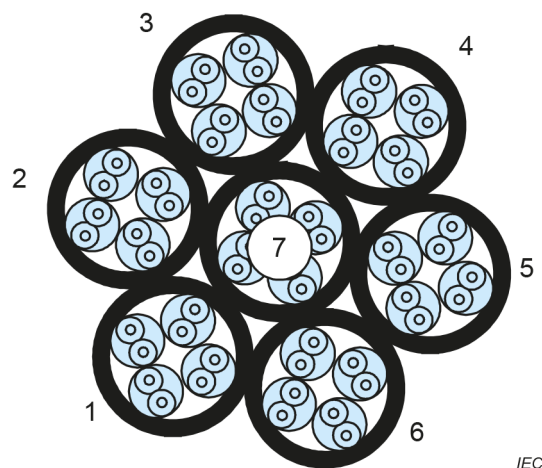


Figure 10 – Test assembly cross-section: six cables around one cable

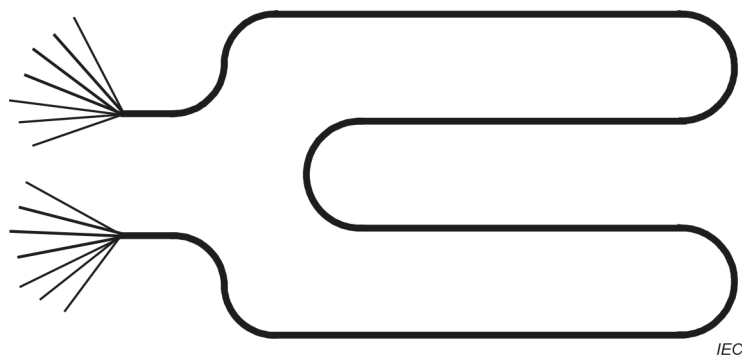


Figure 11 – Test assembly layout: six cables around one cable

~~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.

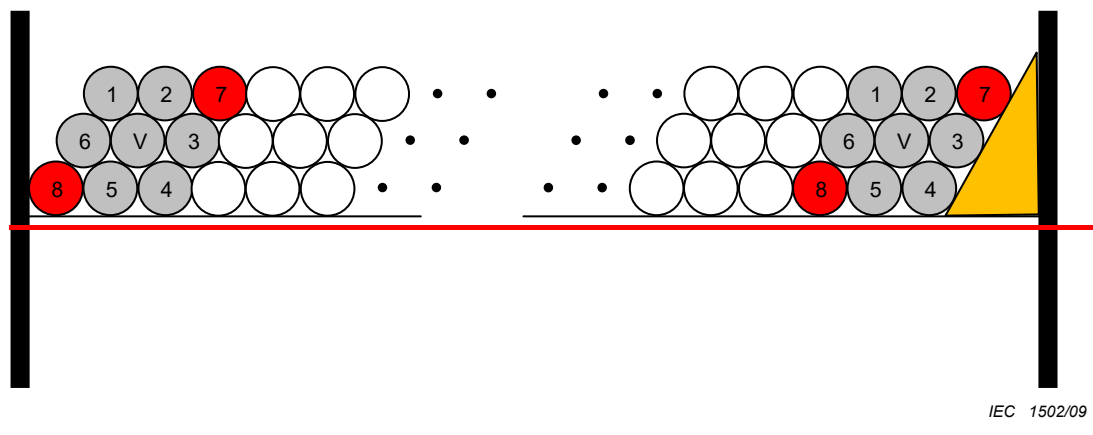
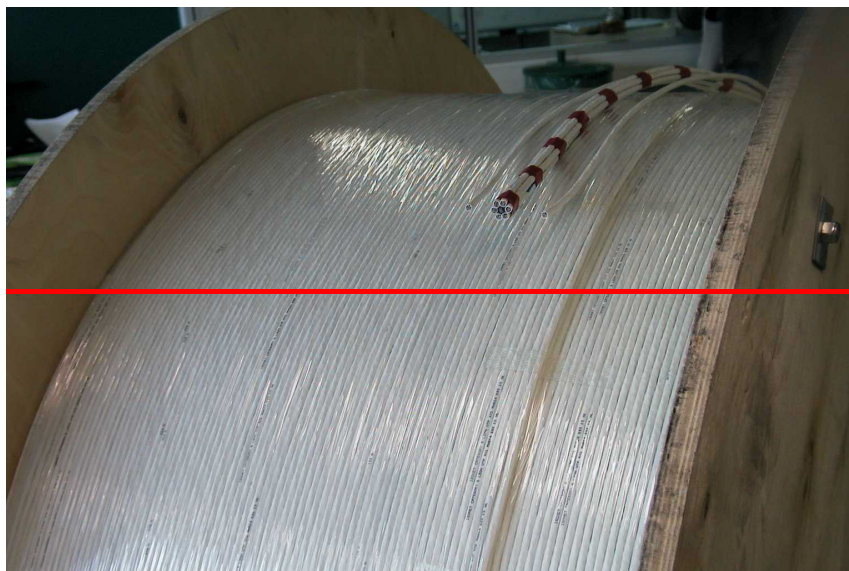


Figure 18 — Schematic diagram representing the position of the 9 cables on a wooden drum

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.



IEC 1503/09

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.

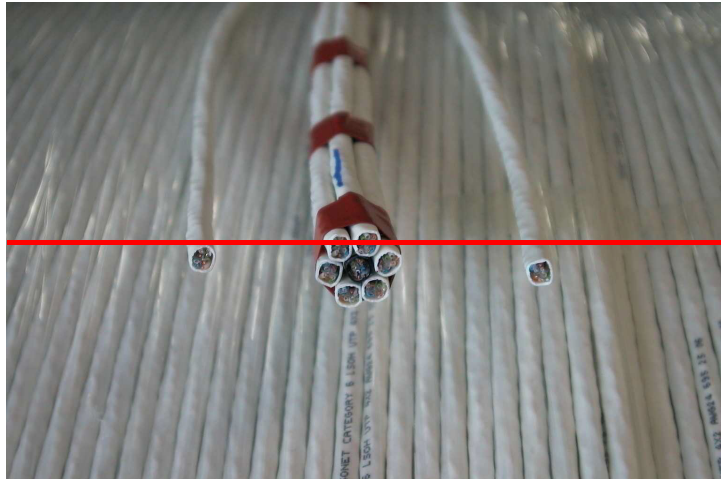


Figure 20 — Preparation of one end

IEC 1504/09

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).

$$AACR-F = AFEXT - \alpha \quad (34)$$

where

$AACR-F$ 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 (~~AFEXT~~) 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 (~~AFEXT~~) 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.

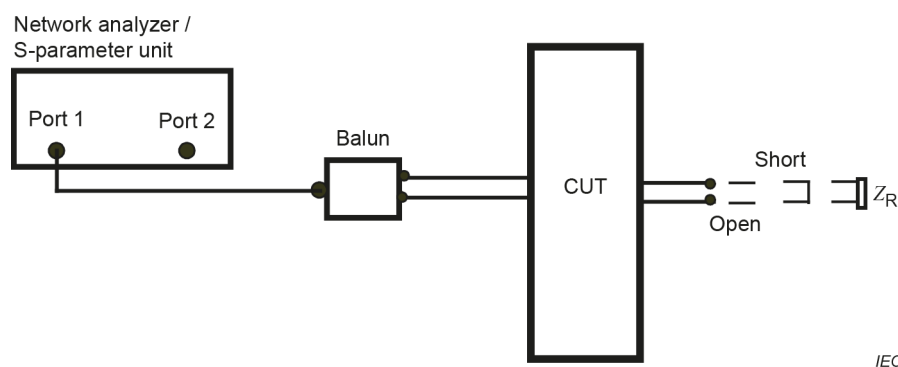


Figure 12 – Test set-up for characteristic impedance, terminated input impedance, and return loss

~~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.~~

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

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.

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

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

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

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.