

Australian/New Zealand Standard™

**Specification for the testing of balanced
and coaxial information technology
cabling**

**Part 1: Installed balanced cabling as
specified in ISO/IEC 11801 and related
standards
(IEC 61935-1, Ed.3.0 (2009) MOD)**



AS/NZS IEC 61935.1:2012

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee CT-001, Communications Cabling. It was approved on behalf of the Council of Standards Australia on 30 May 2012 and on behalf of the Council of Standards New Zealand on 27 August 2012.

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This Standard was issued in draft form for comment as DR AS/NZS IEC 61935.1.

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Specification for the testing of balanced and coaxial information technology cabling

Part 1: Installed balanced cabling as specified in ISO/IEC 11801 and related standards (IEC 61935-1, Ed.3.0 (2009) MOD)

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee CT-001, Communications Cabling to supersede AS/NZS IEC 61935.1:2006, *Testing of balanced communication cabling in accordance with ISO/IEC 11801*, Part 1: *Installed cabling*.

The objective of this Standard is to provide information about the test equipment and methodology for in-field testing of cabling systems in accordance with AS/NZS 3080, *Telecommunications installations—Generic cabling for customer premises (ISO/IEC 11801, Ed.2.2 (2011) MOD)**. This edition differs from the previous edition in that it includes test methods for exogenous (alien) crosstalk. It also includes a new annex for uncertainty and variability of field test results. Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

This Standard is an adoption with national modifications and has been reproduced from IEC 61935-1, Ed. 3.0 (2009), *Specification for the testing of balanced and coaxial information technology cabling—Part 1: Installed balanced cabling as specified in ISO/IEC 11801 and related standards* and has been varied to take account of Australian/New Zealand conditions.

Variations to IEC 61935-1 are listed in Appendix ZZ.

As this Standard is reproduced from an International Standard, the following applies:

- (a) Its number appears on the cover and title page while the International Standard number appears only on the cover.
- (b) In the source text ‘this part of IEC 61935’ should read ‘this Australian/New Zealand Standard’.
- (c) A full point substitutes for a comma when referring to a decimal marker.

References to International Standards should be replaced by references to Australian or Australian/New Zealand Standards, as follows:

<i>Reference to International Standard</i>		<i>Australian/New Zealand Standard</i>	
ISO/IEC		AS/NZS	
11801	Information technology—Generic cabling for customer premises	3080	Telecommunications installations—Generic cabling for customer premises (ISO/IEC 11801, Ed.2.2 (2011) MOD)*

Only international references that have been adopted as Australian/Australian/New Zealand Standards have been listed.

Variations made to IEC 61935-1, Ed. 3.0 (2009) form the Australian/New Zealand variations for the purposes of the CB scheme for recognition of testing to standards for safety of electrical equipment. They are listed in Appendix ZZ.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the annex and appendix to which they apply. A ‘normative’ annex and appendix is an integral part of a Standard, whereas an ‘informative’ annex and appendix is only for information and guidance.

* To be published.

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INTRODUCTION

Telecommunication cabling, once specified uniquely by each telecommunications application, has evolved into a generic cabling system. Telecommunications applications now use the ISO/IEC 11801 cabling standard to meet their cabling requirements. Formerly, connectivity tests and visual inspection were deemed sufficient to verify a cabling installation. Now users need more comprehensive testing in order to ensure that the link will support telecommunications applications that are designed to operate on the generic cabling system. This part of IEC 61935 addresses reference laboratory and field test methods and provides a comparison of these methods.

Transmission performance depends on cable characteristics, connecting hardware, patch cords and cross-connect cabling, the total number of connections, and the care with which they are installed and maintained. This standard provides test methods for installed cabling and pre-fabricated cable assemblies. These test methods, where appropriate, are based on those used for components of the cable assembly.

This Part 1 contains the test methods required for installed cabling. Part 2 contains the test methods required for patch cords and work area cables.

NOTES

AUSTRALIAN/NEW ZEALAND STANDARD

Specification for the testing of balanced and coaxial information technology cabling**Part 1:**

Installed balanced cabling as specified in ISO/IEC 11801 and related standards (IEC 61935-1, Ed.3.0 (2009) MOD)

1 Scope

This part of IEC 61935 specifies reference measurement procedures for cabling parameters and the requirements for field tester accuracy to measure cabling parameters identified in ISO/IEC 11801. References in this standard to ISO/IEC 11801 mean ISO/IEC 11801 or equivalent cabling standards.

This International Standard applies when the cable assemblies are constructed of cables complying with the IEC 61156 family of standards, and connecting hardware as specified in IEC 60603-7 family of standards or IEC 61076-3-104 and IEC 61076-3-110. In the case where cables and/or connectors do not comply with these standards, then additional tests may be required.

This standard is organized as follows:

- reference laboratory measurement procedures on cabling topologies are specified in Clause 4. In some cases, these procedures may be used in the field;
- descriptions and requirements for measurements in the field are specified in Clause 5;
- performance requirements for field testers and procedures to verify performance are specified in Clause 6.

NOTE 1 This standard does not include tests that are normally performed on the cables and connectors separately. These tests are described in IEC 61156-1 and IEC 60603-7 or IEC 61076-3-104 and IEC 61076-3-110 respectively.

NOTE 2 Wherever possible, cables and connectors used in cable assemblies, even if they are not described in IEC 61156 or IEC 60603-7, IEC 61076-3-104 or IEC 61076-3-110, are tested separately according to the tests given in the relevant generic specification. In this case, most of the environmental and mechanical tests described in this standard may be omitted.

NOTE 3 Users of this standard are advised to consult with applications standards, equipment manufacturers and system integrators to determine the suitability of these requirements for specific networking applications.

This standard relates to performance with respect to 100 Ω cabling. For 120 Ω or 150 Ω cabling, the same principles apply but the measurement system should correspond to the nominal impedance level.

Field tester types include certification, qualification and verification. Certification testing is performed for the rigorous needs of commercial/industrial buildings to this standard. Qualification testing is described in IEC 61935-3. Qualification testing determines whether the cabling will support certain network technologies (e.g., 1000BASE-T, 100BASE-TX, IEEE 1394b¹⁾). Qualification testers do not have traceable accuracy to national standards and provide confidence that specific applications will work. Verification testers only verify connectivity.

Throughout this document, 4-pair cabling is assumed. The test procedures described in this standard may also be used to evaluate 2-pair balanced cabling. However, 2-pair cabling links that share the same sheath with other links are tested as 4-pair cabling.

¹⁾ IEEE 1394b: 2002, *High Performance Serial Bus (High Speed Supplement)*

2 Normative references

The following referenced documents are indispensable for the application 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 60169-22, *Radio-frequency connectors – Part 22: R.F. two-pole bayonet coupled connectors for use with shielded balanced cables having twin inner conductors (Type BNO)*

IEC 60512-25-9, *Connectors for electronic equipment – Tests and measurements – Part 25-9: Signal integrity tests – Test 25i: Alien crosstalk*

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

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

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

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

IEC 61076-3-104, *Connectors for electronic equipment – Product requirements – Part 3-104: Detail specification for 8-way, shielded free and fixed connectors for data transmissions with frequencies up to 1 000 MHz*

IEC 61076-3-110, *Connectors for electronic equipment – Product requirements – Part 3-110: Rectangular connectors - Detail specification for shielded, free and fixed connectors for data transmission with frequencies up to 1 000 MHz*

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

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

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

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

IEC 61156-8, *Multicore and symmetrical pair/quad cables for digital communications – Part 8: Symmetrical pair/quad cables with transmission characteristics up to 1 200 MHz – Work area wiring – Sectional specification*

ISO/IEC 11801, *Information technology – Generic cabling for customer premises*

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

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*

EN 50289-1-15, *Communication cables – Specifications for test methods – Part 1-15: Electromagnetic performance – Coupling attenuation of links and channels (Laboratory conditions)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply, in addition to the definitions included in ISO/IEC 11801.

3.1

cable assembly

combination of cable(s) and connector(s) with specified performance, used as a single unit intended to be a part of a cabling link as defined in ISO/IEC 11801 (or equivalent)

NOTE Examples are: patch cord, work area cable, link.

3.2

certification

measurements of installed cabling specified in ISO/IEC 11801 (e.g., class D, class E, class E_A, class F, class F_A)

This requires field testers with traceable accuracy to national standards.

3.3

comparative test

test that is performed to check the deviation between the results obtained with the reference test method and those obtained with another test set-up (i.e. field test equipment)

3.4

d.c. resistance

measure of the sum total of the d.c. resistance of the wires of a pair

3.5

delay skew

worst case value of the phase delay difference between any pair in the same cable assembly

3.6

electrical length

equivalent free-space length of the cable assembly

3.7

far-end cross-talk

FEXT

decrease in magnitude of power of a signal that propagates between disturbing and disturbed pairs contained within the same link measured at the far end

NOTE 1 When the power decrease is referenced to the near end of the disturbing pair, the characteristic is named input output crosstalk (IO FEXT).

NOTE 2 When the power decrease is referenced to the far end of the disturbing pair, the characteristic is named equal level far end crosstalk (ELFEXT).

NOTE 3 When the power decrease is referenced to the far end of the disturbed pair, the characteristic is named attenuation-to-crosstalk ratio, far end (ACR-F).

NOTE 4 FEXT is expressed in dB.

3.8**near-end cross-talk***NEXT*

near end measurement of square root of signal power coupling from one circuit to another within a cable assembly when a square root of signal power is fed and measured at the same end

It is expressed in dB relative to the incident square root of signal power.

3.9**nominal impedance**

impedance for which the system is designed; the nominal impedance is resistive

3.10**output signal balance***OSB*

ratio of the output common mode voltage to the output differential voltage generated by a source port

3.11**power sum (*NEXT* and *FEXT* and *ELFEXT*)**

the combined cross-talk on a receiving pair from all disturbing links operating simultaneously

3.12**propagation delay**

phase delay at each frequency in the frequency range of interest for the propagation of a transverse electromagnetic mode (TEM) wave between the reference planes of the cable assembly, expressed in nanoseconds per metre (ns/m)

3.13**qualification**

measurements of installed cabling for specific network technologies (e.g., 100BASE-T, IEEE802.3 1000BASE-T, IEEE 1394b)

The measurement accuracy of field testers for qualification tests does not need to be traceable to national standards.

3.14**reference plane**

reference position of the cabling under test or necessary mating connector at which the performance requirements are specified

3.15**reflection coefficient**

ratio of the complex square root of wave amplitude of the reflected wave to the complex square root of wave amplitude of the incident wave at a port or transverse cross section of a cable assembly when the cable assembly is terminated with its application or nominal impedances, Z_{nom} .

$$C_r = \left(\frac{|Z_{\text{in}} - Z_{\text{nom}}|}{|Z_{\text{in}} + Z_{\text{nom}}|} \right) \quad (1)$$

3.16**return loss***RL*

ratio of the power delivered to a cable assembly terminated at the far end with its nominal characteristic impedance, to the reflected power at the input port of the cable assembly

$$RL=20 \times \log_{10} \left(\frac{u_i}{u_r} \right) \quad \text{or} \quad RL= -20 \times \log_{10} \left(\frac{|Z_{in} - Z_{nom}|}{|Z_{in} + Z_{nom}|} \right) \quad (2)$$

where

u_i is the incident voltage;

u_r is the reflection voltage.

3.17

screening attenuation (of the cable assembly)

ratio of the common mode square root of power wave inside a screened cable assembly to the total square root of power that radiates outside the cable assembly

3.18

unbalance attenuation

ratio of the common mode square root of signal power to the differential mode square root of signal power in a pair due to unbalanced properties of the given pair

3.19

verification

measurements of installed cable or cabling for continuity

No other transmission performance parameters other than connectivity are measured.

4 Reference measurement procedures for electrical properties

4.1 General

This clause describes reference measurement procedures for electrical parameters. The measurement procedures are intended to be used in a laboratory environment using laboratory equipment. In some cases, a measurement procedure may also be applicable for field testing. If this is the case, the procedure shall be specifically identified as being suitable for field testing and appropriate precautions shall be described.

4.2 Test equipment considerations

4.2.1 General

The reference measurement procedures that are described in this standard require the use of a network analyzer, r.f. transformers (baluns), twisted pair (TP) test leads and impedance matching terminations. Separate generator/receiver test instrumentation may also be used for some of the measurements. Other measurement procedures, which can be shown to yield equivalent results, may be used.

4.2.2 Network analyzer test requirements

Usually, the input and output terminals of a network analyzer are unbalanced. R.F. transformers with balanced outputs (baluns) are required with unbalanced signal connections to the network analyzer.

The test set-up shall be calibrated at the specified reference plane for the cabling under test before testing. Full one-port calibrations shall be used when making one-port (e.g. return loss) measurements, Full two-port calibration shall be used when making two-port measurements (e.g. insertion loss) measurements.

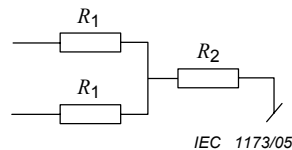
4.2.3 Termination of conductor pairs

During measurement, all conductor pairs of the cabling under test shall be terminated at both ends with impedance matching loads. For pairs under test, this is provided by the test instrumentation at one or both ends. For pairs not under test or not connected to test instrumentation, resistor loads or terminated baluns shall be applied.

Unless otherwise specified, the nominal differential mode impedance of the termination shall be 100 Ω for 100 Ω and 120 Ω cabling, and 150 Ω for 150 Ω cabling. The nominal common mode impedance shall be 50 $\Omega \pm 25 \Omega$ unless otherwise specified in the measurement procedure.

NOTE The exact value of the common mode impedance is not critical for most measurements. Normally, a value of 75 Ω is used for unscreened cabling while a value of 25 Ω is used for screened cabling.

Resistor loads shall use resistors specified for $\pm 0,1 \%$ accuracy at d.c. and have a return loss greater than $40 - 10\log(f/100)$ where f is the frequency in megahertz (MHz). For pairs connected to a balun, common mode load is implemented by applying a load at the centre tap of the balun. The impedance of the load is equal to the common mode impedance. For pairs connected to other kinds of balancing devices (180° power splitters), common mode load is implemented by use of an attenuator at each of the balanced terminals of the balancing device. This method is also used if the centre tap is not available at the balun used. The attenuation provided by the attenuators shall be ≥ 6 dB (see Figure 3). The common mode impedance is approximately one fourth of the differential mode impedance for this implementation. For pairs connected to resistor loads, common mode load is implemented by the Y configuration shown in Figure 1.



where

$$R_1 = \frac{R_{\text{dif}}}{2} \quad (3)$$

$$R_1 = 50 \Omega \pm 0,1 \%$$

and

$$R_2 = R_{\text{com}} - \frac{R_{\text{dif}}}{4} \quad (4)$$

$$R_2 = 25 \Omega \pm 1 \%$$

where

R_{dif} is the differential mode resistance (Ω);

R_{com} is the common mode resistance (Ω).

Figure 1 – Resistor load

For unscreened cabling, the common mode termination points for all pairs are connected together at either end of the cabling. For screened cabling, the common mode termination points are connected to the cable screen or screens at each end of the cabling.

4.2.4 Reference loads for calibration

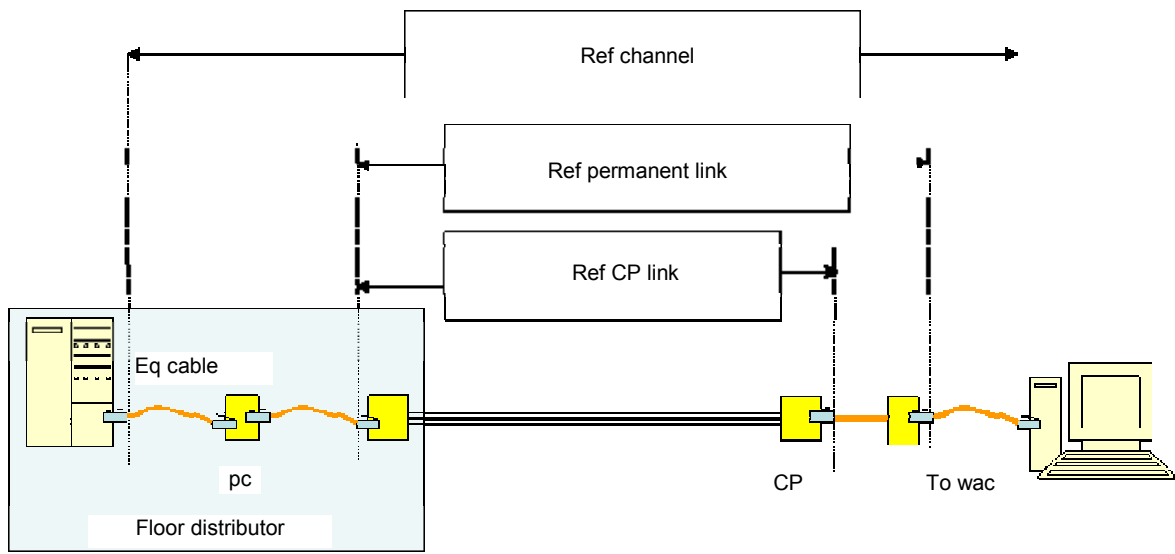
To perform a one or two-port calibration of the test equipment, a short circuit, an open circuit and an impedance termination are required. These devices shall be used to obtain a calibration at the reference plane.

The impedance termination shall be calibrated against a calibration reference, which shall be a 50 Ω load, traceable to a national reference standard. If the value of the reference load for calibration is 100 Ω , two loads in parallel shall be calibrated against the calibration reference. If the value of the reference load for calibration is 150 Ω , three loads in parallel shall be calibrated against the calibration reference. The reference loads for calibration shall be placed in an N type connector according to IEC 61169-16, meant for panel mounting, which is machined flat on the back side. The loads shall be fixed to the flat side of the connector, distributed evenly around the centre conductor. A network analyzer shall be calibrated, one port full calibration, with the calibration reference. Thereafter, the return loss of the reference loads for calibration shall be measured. The verified return loss shall be >40 dB at frequencies less than 100 MHz and $>40 - 10\log(f/100)$ at the higher frequencies for which the measurements are to be carried out.

4.2.5 Test configurations

The cabling configurations that are tested in the field are as follows (see Figure 2).

- Channel. The channel test configuration is intended to be used by system designers and users of data communication systems to verify the performance of the overall channel. The channel as defined in ISO/IEC 11801 (or equivalent) includes up to 90 m of horizontal cable, a work area equipment cord, a telecommunications outlet/connector, an optional transition connection close to the work area and two cross-connect connections in the floor distributor. The total length of work area, patch cords and jumpers shall not exceed 10 m. The connections to the equipment at each end of the channel are not included in the channel definition. The end-user patch cord shall be used to test channel performance.
- Permanent link. The permanent link test configuration is intended to be used by installers and users of data communication systems to verify the performance of permanently installed cabling. The permanent link distributor as defined in ISO/IEC 11801 (or equivalent) consists of up to 90 m of horizontal cabling and one connection at each end. The permanent link excludes both the cable portion of the test cord of the test equipment and the connection to the test equipment, but may include the optional consolidation point.
- CP Link. The CP link test configuration is intended to be used by installers and users of data communication systems to verify the portion of a permanent link between the floor distributor and consolidation point.



IEC 1221/09

Key

Ref channel	reference planes for channel
Ref permanent link	reference planes for the permanent link
Ref CP link	reference planes for the CP link
TO	telecommunications outlet
CP	consolidation point
Eq cable	equipment cable
pc	patch cord
wac	work area cable

Figure 2 – Reference planes for permanent link and channel

The test configuration reference planes of a permanent link are at the end of the permanent link test cords, where the cable enters the body of the plug attached to the test cords at the local end, and where the cable exits the body of the plug attached to the test cord at the remote end, which each mate with the permanent link under test. Practically, the reference plane of measurement should be within 5 mm from the reference plane definition when making measurements on a permanent link. The test configuration reference plane of a channel are at the end of the user patch cords where the cable enters the body of the plug attached to the user patch cord at the local end, and where the cable exits the body of the plug attached to the user patch cord at the remote end, which each mate with the channel adapter. Practically, the reference plane of measurement should be within 5 mm of the reference plane definition when making measurements on a channel.

4.2.6 Coaxial cables and test leads for network analyzers

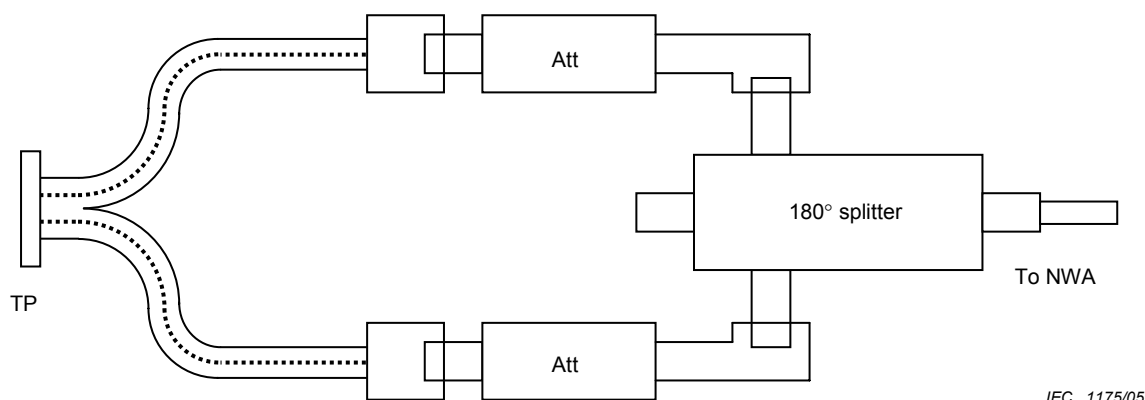
Coaxial cable assemblies between the network analyzer and baluns should be as short as possible. (It is recommended that they do not exceed 600 mm each). The coaxial cables shall be double screened. The baluns shall be attached to a common ground plane.

Balanced test leads and associated connecting hardware to connect between the test equipment and the cable assembly under test shall be taken from components that meet or exceed the requirements for the category of the cable assembly under test. Balanced test leads shall be limited to a length of 50 mm between each balun and the reference plane of the

cabling under test. Pairs shall remain twisted from the baluns to where connections are made, and unscreened balanced test leads shall be separated by 5 mm from any ground plane.

4.2.7 Balun requirements

Two classes of baluns with different performance levels are defined. This is in order to facilitate measurements up to 1 GHz with commercially available baluns. The baluns may be balun transformers or 180° hybrids with attenuators to improve matching if needed (see Figure 3).



IEC 1175/05

Key

Att	attenuator
180° splitter	180° phase splitter
to NWA	connection to network analyzer
TP	connections at test port

Figure 3 – 180° hybrid used as a balun

A balun is designated class A in the frequency range for which the class A requirements are met. A balun is designated class B in the frequency range for which the class B requirements are met. A balun may be class A in one frequency range and class B in another extended frequency range.

Class A baluns are preferred for verification of performance characteristics of all classes of cabling.

Class B baluns may be used to verify performance of all classes of cabling provided that the lower performance of the balun is taken into account in the measurement error calculation.

Baluns shall be RFI shielded and shall comply with the requirements given in Table 1.

Table 1 – Test balun performance characteristics

Parameter	Class A value	Class B value
Impedance, primary ^a	50 Ω unbalanced	50 Ω unbalanced
Impedance, secondary	Matched balanced	Matched balanced
Insertion loss	3 dB maximum	10 dB maximum
Return loss secondary	12 dB minimum, 1 MHz – 15 MHz 20 dB minimum, 15 MHz – 550 MHz 17,5 dB minimum 550 MHz – 600 MHz 10 dB minimum 600 MHz – 1 000 MHz	6 dB minimum
Return loss, Common mode ^b	15 dB minimum, 1 MHz – 15 MHz 20 dB minimum, 15 MHz – 400 MHz 15 dB minimum, 400 MHz – 600 MHz 10 dB minimum 600 MHz – 1 000 MHz	10 dB minimum
Power rating	0,1 W minimum	0,1 W minimum
Longitudinal balance ^c	60 dB minimum, 15 MHz – 350 MHz 50 dB minimum, 350 MHz – 600 MHz 40 dB minimum, 600 MHz – 1 000 MHz	35 dB minimum
Output signal balance ^c	60 dB minimum, 15 MHz – 350 MHz 50 dB minimum, 350 MHz – 600 MHz 40 dB minimum, 600 MHz – 1000 MHz	35 dB minimum
Common mode rejection ^c	60 dB minimum, 15 MHz – 350 MHz 50 dB minimum, 350 MHz – 600 MHz 10 dB minimum 600 MHz – 1 000 MHz	35 dB minimum
Special guidelines for use of baluns: – For best accuracy, the baluns should be supplied with connectors (for example with IEC 60169-22 connectors). – Class A baluns are preferred for accuracy. – Class B baluns can be used in the whole frequency range for which their specifications apply, provided their output signal balance is better than 50 dB below 100 MHz. – 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. – 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.		
^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 per ITU-T Recommendations G.117 and O.9		

4.2.8 Network analyzer measurement precautions

To assure a high degree of reliability for transmission measurements, the following precautions are required:

- the reference plane of the calibration shall coincide with the measurement reference plane; in case of differences, the magnitude of errors shall be determined;
- consistent and stable baluns and resistor loads shall be used for each pair throughout the test sequence (see 4.2.3);

- c) cable and adapter discontinuities, as introduced by physical flexing, sharp bends and restraints shall be avoided before, during and after the tests;
- d) the relative spacing of conductor pairs shall be preserved throughout the tests to the greatest extent possible;
- e) unscreened balanced cable test leads and interconnects shall remain separated from metallic surfaces, such as ground planes, and isolated from sources of electromagnetic interference (EMI);
- f) the balance of the cables is maintained to the greatest extent possible by consistent conductor lengths and pair twisting to the point of load;
- g) coaxial, balanced lead and printed line lengths shall be kept as short as possible so that resonance and parasitic effects are minimised;
- h) connections to the baluns and IC socket interfaces shall be made in such a way that conductor movement resulting from connection of different pairs to the network analyzer/baluns shall produce minimal variability for repeated measurements on the same reference cable ($\pm 0,25$ dB or less is acceptable). Where practical, a rigid test fixture is recommended;
- i) overload conditions of the network analyzer shall be avoided;
- j) the sensitivity to set-up variations for these measurements at high frequencies demands attention to detail for both the measurement equipment and the procedures. Data interpretation and application of the requirements is appropriate only if a satisfactory measurement repeatability of ± 1 dB or better is achieved.

4.2.9 Data reporting and accuracy

The measurement uncertainty shall be determined for each test. This shall be calculated by determining the uncertainty from each error source expressed as the resulting spread in the result. The values of the different error sources are based on instrumentation specifications, calculated errors from imperfect calibration loads and measurement experience. The overall estimated measurement uncertainty is calculated as two times the resulting spread coming from the different error sources. The resulting spread is calculated as:

$$\sigma_{\text{res}} = \sqrt{\sigma_1^2 + \sigma_2^2 + \dots + \sigma_n^2} \quad (5)$$

where σ_1 to σ_n is the spread of the different error sources.

The overall measurement uncertainty is defined as $2\sigma_{\text{res}}$, which is approximately equivalent to a 95 % confidence level. A measurement uncertainty band is determined on both sides of the specified limit.

Test results that are outside the uncertainty band are reported as either 'pass' or 'fail'. Test results that are inside the uncertainty band are reported as either '*pass' or '*fail', as appropriate. To which extent '*' results shall determine approval or disapproval of the cabling under test shall be defined in the relevant detail specification, or agreed on as a part of a contractual specification.

4.3 DC loop resistance

This test is applicable to laboratory and installed cabling testing.

4.3.1 Objective

The objective of this test is to ensure the d.c. and low frequency continuity of the conductors.

4.3.2 Test method

Measurement of loop resistance shall be carried out on each pair at the near end after applying a short circuit between each wire of that pair at the far end.

4.3.3 Test equipment and set-up

A four terminal ohmmeter suitable for low resistance measurements shall be used. The pairs at the far end of the cabling under test shall be short circuited at the reference plane. The test set-up is shown in Figure 4.

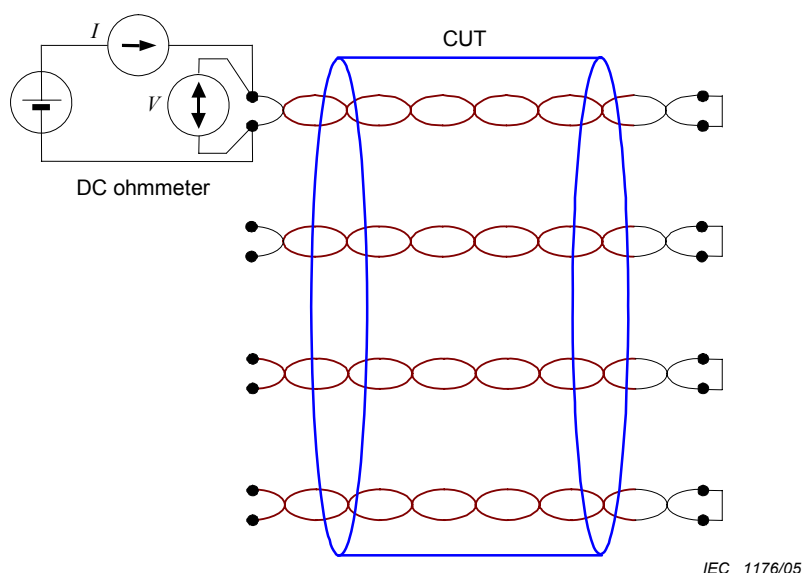
4.3.4 Procedure

4.3.4.1 Calibration

The ohmmeter shall be calibrated for 0 Ω at the ends of the test leads. After calibration, the test leads shall be connected to the cabling at the measurement reference plane.

4.3.4.2 Measurement

The loop resistance for all four pairs shall be measured.



Key

CUT	cabling under test
V	voltage applied to cabling under test
I	current applied to cabling under test
DC ohmmeter	d.c. ohmmeter

Figure 4 – Loop resistance measurement

4.3.5 Test report

The measured value shall be reported for the pair with the highest resistance and this pair shall be identified. The highest resistance shall be compared to the requirement specification limits.

4.3.6 Uncertainty

The uncertainty of reference d.c. resistance measurements shall be less than 0,1 Ω in the range from 0 Ω to 50 Ω .

4.4 Direct current (d.c.) resistance unbalance

This test is applicable to laboratory cabling testing.

4.4.1 Objective

The objective of this test is to ensure the d.c. resistance unbalance meets the requirements.

4.4.2 Test method

The test method is shown in Figure 5. The test configuration for one wire is shown. Measurement of resistance unbalance shall be carried out on each pair.

Each wire is measured and the d.c. resistance unbalance is the ratio of the difference of the d.c. resistance of each wire within a pair related to the sum of the d.c. resistance of each wire

$$\Delta R = \frac{R_{\max} - R_{\min}}{R_{\max} + R_{\min}} \times 100 \quad (6)$$

where

ΔR is the resistance unbalance expressed in %.

4.4.3 Test equipment and set-up

A four terminal ohmmeter suitable for low resistance measurements shall be used.

4.4.4 Procedure

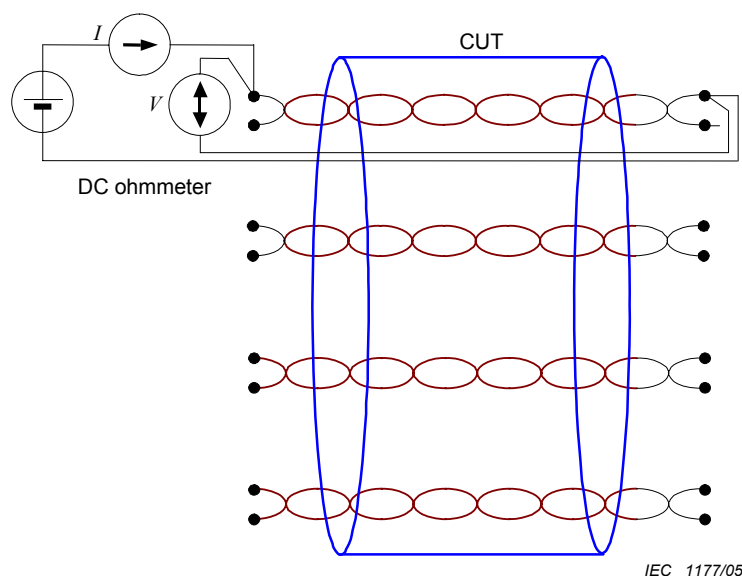
4.4.4.1 Calibration

The ohmmeter shall be calibrated for 0 Ω at the ends of the test leads. After calibration, the test leads shall be connected to the cabling at the measurement reference plane.

4.4.4.2 Measurement

Measure the d.c. resistance of each wire of a pair. Then calculate the d.c. resistance unbalance per Equation (6).

The d.c. resistance unbalance for all four pairs shall be measured.

**Key**

CUT	cabling under test
V	voltage applied to wire under test
I	current applied to wire under test
DC ohmmeter	d.c. ohmmeter

Figure 5 – DC resistance unbalance measurement**4.4.5 Test report**

The measured value shall be reported for the pair with the highest resistance unbalance and this pair shall be identified. The highest resistance unbalance shall be compared to requirement specification limits.

4.4.6 Uncertainty

The uncertainty of d.c. resistance unbalance measurements shall be less than 0,5 % + 0,05 Ω in the range from 0 Ω to 50 Ω .

4.5 Insertion loss

The test method is applicable to cabling in a laboratory environment. If insertion loss has to be measured for installed cabling using laboratory equipment, then a separate generator and receiver is required.

4.5.1 Objective

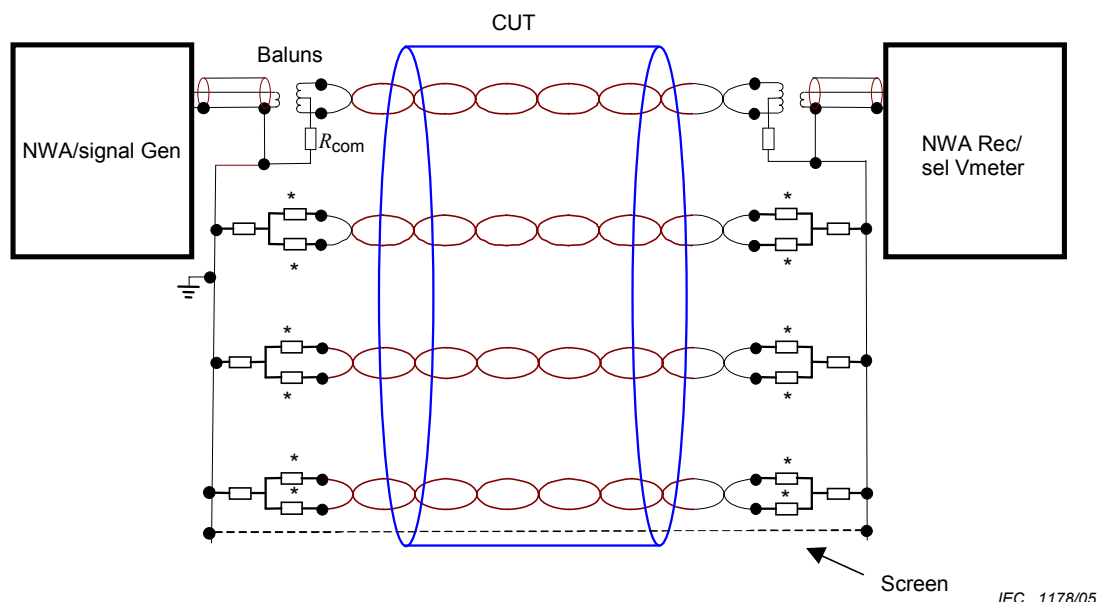
The objective of this test is to measure the insertion loss of the cabling being tested.

4.5.2 Test method

Insertion loss is measured by determining the signal loss of the cabling under test, referenced to the signal loss of a short connection between the test ports of the measuring instrument.

4.5.3 Test equipment and set-up

The general instrumentation requirements apply (see 4.2). The test configuration is shown in Figure 6 and the cabling under test shall be measured at the reference planes defined in Figure 2.



Key

CUT	cabling under test
NWA / Sig gen	signal generator of network analyzer or signal generator
NWA receiver / Sel Vmeter	receiver of network analyzer or selective voltmeter
*	matched resistors (in pairs)
Screen	screen (if present)
R_{com}	common mode impedance (optional in insertion loss test)
Baluns	baluns to interface laboratory equipment and balanced cabling

Figure 6 – Insertion loss test configuration

4.5.4 Procedure

4.5.4.1 Calibration

A transmission (S_{21}) 2-port calibration shall be performed at the reference plane. This is carried out by applying a calibration cable between the terminals of the baluns and carrying out the appropriate calibration procedure.

4.5.4.2 Measurement

Calibrated insertion loss measurements of the cabling shall be performed. Each pair shall be measured. Pairs shall be terminated with loads according to 4.2.3 when not under test. The loads according to 4.2.3 shall be applied at the test cable pairs. Common mode loads are not needed for pairs not under test. Measurements shall be performed in the specified frequency range. The frequency step size shall be no greater than 0,5 MHz up to 100 MHz and 5 MHz up to 1 000 MHz.

4.5.5 Test report

The measured results shall be reported in graphical or table format with the specification limits shown on the graphs or in the table at the same frequencies as specified in the relevant detail specification. Results for all pairs shall be reported. It shall be explicitly noted if the measured results exceed the test limits.

4.5.6 Temperature correction

Insertion loss measurements should be conducted at the expected highest operating temperature of the cabling, which may be affected by d.c. power that is supplied over the cabling system.

If it is not possible to conduct the measured at the expected highest operating temperature of the cabling, adjustments for insertion loss should be made based on the estimated difference of the expected highest operating temperature of the installation and the actual temperature at the time of measurement. This may be a critical issue when link lengths are near the maximum value.

The temperature coefficient for screened cabling is 0,2 %/°C. For unscreened cabling the temperature coefficient is 0,4 %/°C below 250 MHz and 0,6 %/°C above 250 MHz, see IEC 61156-5, IEC 61156-6, IEC 61156-7 and IEC 61156-8.

4.5.7 Uncertainty

The uncertainty of reference insertion loss measurements for cabling shall be less than 0,5 dB.

4.6 Propagation delay and delay skew

The test method is applicable to cabling in a laboratory environment only. The reference test method cannot be used for installed cabling. Field testers use time domain reflectometry (TDR) methods. The performance of field propagation delay measurement accuracy is determined using comparisons with the reference test method described in this subclause.

4.6.1 Objective

The objective of this test is to measure propagation delay and delay skew of the cabling being tested.

4.6.2 Test method

Propagation delay is measured by determining the phase delay of a signal transmitted through the cabling using Equation (7).

$$\delta = \frac{\phi}{2\pi f} \quad (7)$$

where

δ is the phase delay in seconds;

ϕ is the phase in radians;

f is the frequency in Hertz.

Delay skew is calculated as the worst case difference of propagation delay for the pairs in the cabling.

4.6.3 Test equipment and set-up

The set-up is the same as for insertion loss measurements (see 4.5.3). Insertion loss and delay can be measured in the same test with one sweep if the network analyzer can measure the complex scattering parameter, S_{21} .

4.6.4 Procedure

4.6.4.1 Calibration

See 4.5.4.1.

4.6.4.2 Measurement

See 4.5.4.2, but note that for this measurement, a linear frequency sweep shall be applied. The frequency steps shall be made small enough to ensure that the phase shift from one measurement frequency to the next measurement frequency is less than 2π . For compliant cabling, this is ensured by limiting frequency steps to 1,7 MHz or less. In order to assure an adequate margin, the frequency steps shall be no greater than 1 MHz.

4.6.4.3 Calculation

Some network analyzers give a readout of the continuous phase trace of the tested item. This readout can be directly inserted in Equation (8). It is usual for the network analyzer to measure the phase in an interval of $\pm \pi$. As the ratio of phase versus frequency is a continuously decreasing function, 2π shall be subtracted from the measured phase every time there is a positive step in the measured phase versus frequency trace, therefore:

$$\varphi_f = \varphi_m - 2n\pi \quad (8)$$

where

φ_f is the accumulated phase in degrees;

φ_m is the measured phase in degrees;

n is the number of times the measured phase has passed $-\pi$ during the measurement from the lowest frequency to the actual frequency f .

The propagation delay is calculated by applying Equation (7).

Skew is calculated as the difference between the measured propagation delays of the individual pairs.

4.6.5 Test report

Propagation delay and skew is reported at 10 MHz. Results at other frequencies shall be reported, if required in the relevant sectional specification.

4.6.6 Uncertainty

Uncertainty of reference propagation delay measurements shall be less than 2,5 ns in the range of 0 ns to 60 ns.

Uncertainty of reference delay skew measurements shall be less than 5 ns in the range of 0 ns to 600 ns.

4.7 Near-end cross-talk (NEXT) and power sum NEXT

The test method is applicable to laboratory and installed cabling testing.

4.7.1 Objective

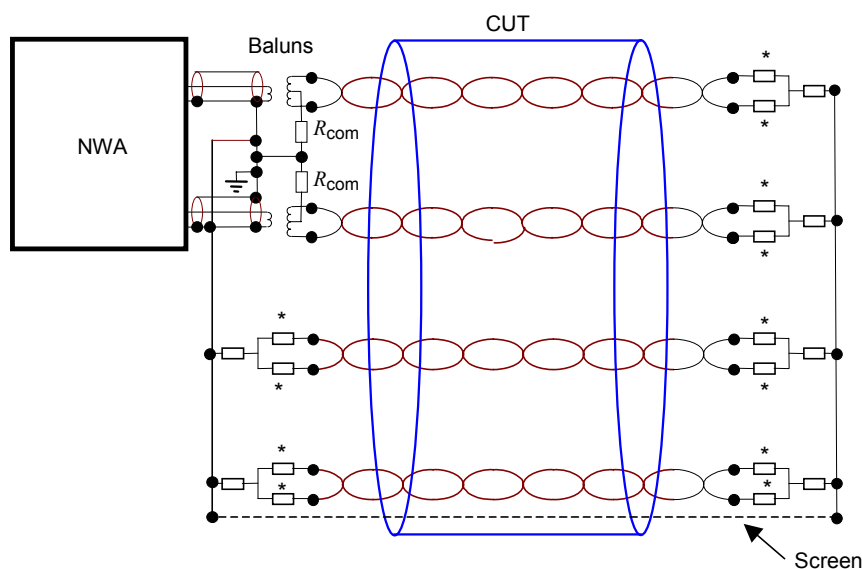
The objective of this test is to determine the coupling between a signal applied at the near end of one pair to the signal received at the near end of a different pair.

4.7.2 Test method

NEXT is measured by applying the signal at the near end of one pair and measuring the coupled signal at the near end of a different pair.

4.7.3 Test equipment and set-up

The general instrumentation requirements apply (see 4.2). The test configuration is shown in Figure 7 and the cabling under test shall be measured at the reference planes shown in Figure 2.



IEC 1179/05

Key

CUT	cabling under test
NWA	network analyzer
*	matched resistors (in pairs)
Screen	screen (if present)
R_{com}	common mode impedance
Baluns	baluns to interface laboratory equipment and balanced cabling

Figure 7 – NEXT test configuration

4.7.4 Procedure

4.7.4.1 Calibration

A transmission (S_{21}) calibration shall be performed at the reference plane.

Residual NEXT shall be determined by measuring the insertion loss between the test ports when the baluns are terminated with resistor loads according to 4.2.3. If the residual NEXT is closer than 30 dB to the measured NEXT, then isolation calibration shall be applied. The noise floor shall be measured in the same way. If the noise floor is closer than 30 dB from the measured NEXT, then the dynamic range shall be increased by increasing the test power and decreasing the measurement bandwidth, as appropriate. For cabling with high NEXT, this is not always possible, in which case the actual value of residual NEXT and noise floor shall be estimated in the calculation for uncertainty.

4.7.4.2 Measurement

Calibrated NEXT measurements of the cabling shall be performed. Each pair combination shall be measured from the near end and far end of the cabling under test. For four pair cabling this is six measurements from each end, providing a total of twelve measurements. Pairs shall be terminated with loads in accordance with 4.2.3 when not under test. The loads shall comply with the requirements given in 4.2.3. The cabling under test shall be terminated with a connector at the far end with loads at each pair. Pairs that are not used in the measurement shall have terminations at the near end. Loads at both ends shall provide differential and common mode terminations (see Figure 7). At each end, the screens shall be connected to the common mode ground port. Measurements shall be performed in the specified frequency range. If the test instrument measures at discrete frequencies, the frequency steps shall be no greater than 150 kHz up to 31,25 MHz; 250 kHz up to 100 MHz; 500 kHz up to 250 MHz and 2,5 MHz up to 1 000 MHz.

4.7.4.3 Calculation

NEXT is calculated from:

$$NEXT_{i,k} = -20 \log |S_{21,i,k}| \quad (9)$$

where

$NEXT_{i,k}$ is the NEXT between the disturbing pair i and the disturbed pair k in dB;

Power sum NEXT shall be calculated based on the measured NEXT values.

The power sum NEXT to disturbed pair k $PSNEXT_k$ shall be calculated over the specified frequency range from:

$$PSNEXT_k = -10 \log \left(\sum_{i=1, i \neq k}^n 10^{-0,1 \cdot NEXT_{i,k}} \right) \quad (10)$$

where

$PSNEXT_k$ is the power sum of near-end cross-talk at the disturbed pair k in dB;

n is the number of pairs;

4.7.5 Test report

The measured results shall be reported in table or graphical format with the specification limits shown on the graphs. Results from all pair combinations shall be reported for reference measurements. It shall be explicitly noted if the measured results exceed the requirements.

4.7.6 Uncertainty

The uncertainty of reference NEXT measurements is defined to be valid at the pass/fail limit for the class F permanent link. The measurement accuracy shall be better than 1 dB at 100 MHz, 1,2 dB at 250 MHz and 2 dB at 1 000 MHz. These accuracies are valid for both NEXT and power sum NEXT measurements.

NOTE If requirements for residual NEXT and noise floor cannot be achieved, the actual uncertainty may be calculated and reported (see 5.5).

4.8 Attenuation to crosstalk ratio, near end (ACR-N) and power sum ACR-N

This test is applicable to laboratory and installed cabling testing.

4.8.1 Objective

The objective of this test is to determine the contribution to the signal-to-noise ratio from NEXT and insertion loss.

4.8.2 Test method

NEXT and insertion loss are measured and the ACR-N is computed from the NEXT and insertion loss measurements.

4.8.3 Test equipment and set-up

Refer to 4.5 and 4.7.

4.8.4 Procedure

Refer to 4.5 and 4.7.

4.8.4.1 Calculation

The ACR-N of disturbed pair k to disturbing pair i is calculated from Equation (11).

$$ACRN_{i,k} = NEXT_{i,k} - IL_k \quad (11)$$

where

$ACRN_{i,k}$ is the ACR-N for disturbing pair i and disturbed pair k ;

$NEXT_{i,k}$ is the ACR-N for disturbing pair i and disturbed pair k ;

IL_k is the insertion loss of disturbed pair k .

Power sum ACR-N shall be calculated based on the measured power sum NEXT values.

4.8.5 Test report

The measured results shall be reported in table or graphical format with the specification limits shown on the graphs. Results from all pair combinations shall be reported for reference measurements. It shall be explicitly noted if the measured results exceed the requirements.

4.8.6 Uncertainty

The uncertainty of ACR-N measurements are the calculated summed uncertainties of insertion loss and NEXT measurements and shall be calculated as shown in 4.2.9.

4.9 Far-end cross-talk (FEXT) and power sum FEXT

This test is applicable for cabling in a laboratory environment. If far end crosstalk has to be measured for installed cabling using laboratory equipment, then a separate generator and receiver shall be required.

4.9.1 Objective

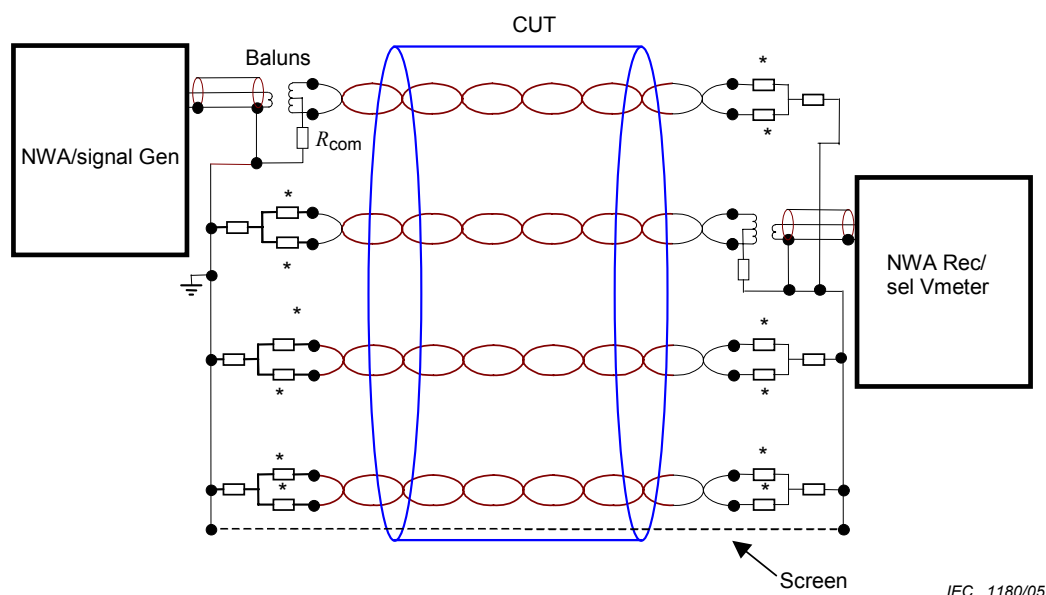
The objective of this test is to determine the coupling between a signal applied at the near end of one pair to the signal received at the far end on a different pair.

4.9.2 Test method

FEXT is measured by applying the signal to the near end of one pair and measuring the coupled signal at the far end of a different pair.

4.9.3 Test equipment and set-up

The general instrumentation requirements apply (see 4.2). The test configuration is shown in Figure 8 and the cabling under test shall be measured at the reference planes shown in Figure 2.



IEC 1180/05

Key

CUT	cabling under test
NWA / Signal gen	signal generator of network analyzer or signal generator
NWA receiver / Sel Vmeter	receiver of network analyzer or selective voltmeter
*	matched resistors (in pairs)
Screen	screen (if present)
R_{com}	common mode impedance
Baluns	baluns to interface laboratory equipment and balanced cabling

NOTE A network analyzer may be used after determining that a ground connection that exists inside the network analyzer between source and load does not affect the result.

Figure 8 – FEXT test configuration

4.9.4 Procedure

4.9.4.1 Calibration

The method of calibration is the same as for NEXT (see 4.7.4.1).

4.9.4.2 Measurement

FEXT measurements of the cabling shall be performed and each pair combination shall be measured. The generator shall be connected to one end of the cabling while the receiver shall be connected to the other end. It is not necessary to interchange generator and receiver as $S_{21} = S_{12}$. For four pair cabling, a total of 12 measurements are needed. Pairs shall be terminated as defined for NEXT measurements. Requirements for maximum frequency step size are also as for NEXT (see 4.7.4.2).

4.9.4.3 Calculation

The FEXT from disturbing pair i to disturbed pair k is calculated from:

$$FEXT_{i,k} = -20 \log |S_{21_{i,k}}| \quad (12)$$

where

$FEXT_{i,k}$ is the far-end cross-talk loss between the disturbing pair i and the disturbed pair k in dB;

Power sum FEXT shall be calculated based on the measured FEXT values.

The power sum to disturbed pair k shall be calculated over the specified frequency range.

$$PSFEXT_k = -10 \log \left(\sum_{i=1, i \neq k}^n 10^{-0,1 \times FEXT_{i,k}} \right) \quad (13)$$

where

$PSFEXT_k$ is the power sum of far end crosstalk at the disturbed pair k in dB;

n is the number of pairs;

4.9.5 Test report

The measured results shall be reported in table or graphical format with the specification limits shown on the graphs. Results from all pair combinations shall be reported. It shall be explicitly noted if the measured results exceed the requirements.

4.9.6 Uncertainty of FEXT measurements

The uncertainty of FEXT measurements is assumed to be approximately the same as for NEXT measurements.

4.10 Equal level far end crosstalk (ELFEXT) and attenuation to crosstalk ratio, far end (ACR-F)

4.10.1 Objective

The objective of this test is to determine ELFEXT or ACR-F by calculation from the measured insertion loss and far-end cross-talk

4.10.2 Calculation

ACR-F between disturbing pair i and disturbed pair k is calculated from the expressions:

$$ACRF_{i,k} = FEXT_{i,k} - IL_k \quad (14)$$

where

$ACRF_{i,k}$ is the computed ACR-F between disturbing pair i and disturbed pair k in dB;

$FEXT_{i,k}$ is the measured far-end cross-talk loss between disturbing pair i and disturbed pair k in dB;

IL_k is the measured insertion loss of disturbed pair k in dB.

For four pair cabling, there are 12 ELFEXT and 12 ACR-F results.

Power sum ACR-F to disturbed pair k is calculated from the expression:

$$PSACRF_k = PSFEXT_k - IL_k \quad (15)$$

where

$PSACRF_k$ is the calculated power sum ACR-F to pair k in dB;

$PSFEXT_k$ is power sum FEXT in dB from disturbed pair k (measured and calculated) in dB;

IL_k is the measured insertion loss in dB of the disturbed pair k .

4.10.3 Test report

See 4.8.5.

4.10.4 Uncertainty

The uncertainty of ELFEXT and ACR-F measurements are the calculated summed uncertainties of insertion loss and FEXT measurements and shall be calculated as shown in 4.2.9.

4.11 Return loss

This test is applicable to cabling in a laboratory environment and for installed cabling.

4.11.1 Objective

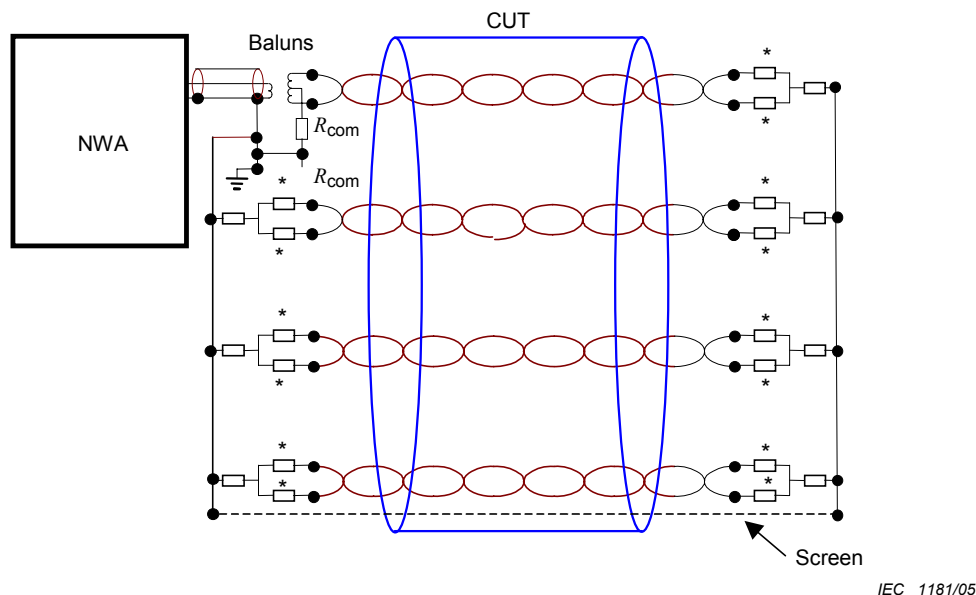
The objective of this test is to measure the return loss of the cable assembly.

4.11.2 Test method

Return loss is calculated by measuring the input impedance of the cabling, which is terminated in the far end by a load of the specified nominal impedance according to 4.2.3.

4.11.3 Test equipment and set-up

The general instrumentation requirements apply (see 4.2). The test configuration is shown in Figure 9. The cabling under test shall be measured at the reference planes shown in Figure 2.



Key

CUT	cabling under test
NWA	network analyzer with S-parameter test set
*	matched resistors (in pairs)
Screen	screen (if present)
R_{com}	common mode impedance (optional in return loss tests)
Balun	balun to interface laboratory equipment and balanced cabling

Figure 9 – Return loss test configuration

4.11.4 Procedure

4.11.4.1 Calibration

A full one port (S11) calibration shall be performed at the reference plane.

4.11.4.2 Measurement

Each pair shall be measured. The far end of the cabling shall be terminated with loads according to 4.2.3, which are integrated into a connector, which mates with the far end connector of the cabling. The loads shall comply with the requirements given in 4.2.3. The near end pairs may be left open when not under test.

Common mode loads are not needed. If the test instrument measures at discrete frequencies, the frequency steps shall be no greater than 250 kHz up to 100 MHz and 2,5 MHz up to 1 000 MHz.

Return loss for both ends of the cabling shall be measured, if required by the relevant detail specification.

4.11.5 Test report

The measured results shall be reported in tabular or graphical format with the specification limits shown on the graphs. Results from all pairs shall be reported.

4.11.6 Uncertainty

The uncertainty is specified at the performance limit for a class F permanent link.

The uncertainty of return loss measurements shall be better than 1 dB up to 250 MHz and 2 dB up to 1 000 MHz.

NOTE This is based on an accuracy of the reference load for calibration as specified in 4.2.4.

4.12 PS alien near end crosstalk (PS ANEXT – Exogenous crosstalk)

4.12.1 Objective

The objective of this test is to determine the PS ANEXT of the cabling. This test is applicable to cabling in a laboratory environment and for installed cabling. A sample laboratory reference measurement assembly is described in Annex B.

4.12.2 Test method

ANEXT contributions to an overall PS ANEXT are measured by applying the signal at the near end to one pair to a disturbing link and measuring the coupled signal at the near end of a pair in a disturbed link. This process is repeated for every pair in a disturbing link and for all other links in close proximity. The PS ANEXT for each pair in a disturbed link is obtained by power summing the ANEXT results to that pair from all pairs in disturbing links in close proximity.

4.12.3 Test equipment and set-up

The test configuration for an alien near end crosstalk measurement is shown in Figure 10. The cabling under test shall be measured at the reference planes shown in Figure 2.