

Testing of balanced communication cabling in accordance with standards series EN 50173 —

Part 1: Installed cabling

The European Standard EN 61935-1:2005 has the status of a
British Standard

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National foreword

This British Standard is the official English language version of EN 61935-1:2005. It was derived by CENELEC from IEC 61935-1:2005. It supersedes BS EN 61935-1:2001 which is withdrawn.

The CENELEC common modifications have been implemented at the appropriate places in the text and are indicated by tags (e.g. [C] [C]).

The UK participation in its preparation was entrusted to Technical Committee EPL/46, Cables, wires and waveguides, R.F. connectors and accessories for communication and signalling, which has the responsibility to:

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**Testing of balanced communication cabling
in accordance with standards series EN 50173
Part 1: Installed cabling
(IEC 61935-1:2005, modified)**

Essais de câblages de
télécommunications symétriques
selon la série de normes EN 50173
Partie 1: Câblages installés
(CEI 61935-1:2005, modifiée)

Prüfung der symmetrischen
Kommunikationsverkabelung
nach der Normenreihe EN 50173
Teil 1: Installierte Verkabelung
(IEC 61935-1:2005, modifiziert)

This European Standard was approved by CENELEC on 2005-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 46A/717/FDIS, future edition 2 of IEC 61935-1, prepared by SC 46A, Coaxial cables, of IEC TC 46, Cables, wires, waveguides, R.F. connectors, R.F. and microwave passive components and accessories, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61935-1 on 2005-10-01.

This European Standard supersedes EN 61935-1:2000 + corrigendum February 2001 + A1:2002.

This new edition was written to describe Level IV testers in support of ISO/IEC 11801:2002 and the series EN 50173.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
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with the EN have to be withdrawn (dow) 2008-10-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61935-1:2005 was approved by CENELEC as a European Standard with agreed common modifications.

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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  EN 50173  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 cords.

TESTING OF BALANCED COMMUNICATION CABLING IN ACCORDANCE WITH ISO/IEC 11801 –

Part 1: Installed cabling

1 Scope

☐ This part of EN 61935 specifies reference measurement procedures for cabling parameters and the requirements for field tester accuracy to measure cabling parameters identified in EN 50173. ☐

This standard applies when the cable assemblies are constructed of cables complying with IEC 61156 -1, IEC 61156-2, IEC 61156-3 IEC 61156-4, IEC 61156-5 or IEC 61156-6, and connecting hardware as specified in IEC 60603-7 or IEC 61076-3-104. 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 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 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 shall be 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.

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.

☐ EN 50173, series, *Information technology – Generic cabling systems* ☐

IEC 60169-16, *Radio-frequency connectors – Part 16: R.F. coaxial connectors with inner diameter of outer conductor 7 mm (0.276 in) with screw coupling – Characteristic impedance 50 ohms (75 ohms) (Type N)*

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 60603-7:1996 *Connectors for frequencies below 3 MHz for use with printed boards – Part 7: Detail specification for connectors, 8-way, including fixed and free connectors with common mating features, with assessed quality*

IEC 61076-3-104, *Connectors for electronic equipment – Part 3-104: Rectangular connectors – Detail specification for 8-way, shielded free and fixed connectors for data transmissions with frequencies up to 600 MHz minimum*

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

ISO/IEC 14763-1, *Information technology – Implementation and operation of customer premises cabling – Part 1: Administration*

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 terms and definitions in [C] EN 50173 [C] and the following apply.

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 [C] EN 50173 [C] (or equivalent). Examples: patch cord, work area cord, link

[C] 3.2

reflection coefficient

ratio of the voltage of the reflected wave to the voltage of the incident wave at the port or transverse cross-section to a cable assembly when the cable assembly is terminated with its application or nominal impedances, Z_{cnom} .

$$C_r = \frac{Z_{\text{cnom}} - Z_{\text{in}}}{Z_{\text{cnom}} + Z_{\text{in}}} \quad (1)$$

[C]

3.3**return loss**

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

$$R_l = 20 \log \left| \frac{u_i}{u_r} \right|$$

or

$$R_l = 20 \log \left| \frac{Z_{\text{cnom}} + Z_{\text{in}}}{Z_{\text{cnom}} - Z_{\text{in}}} \right| \quad (2)$$

where

u_i is the incident voltage;

u_r is the reflected voltage. 

3.4**electrical length**

equivalent free-space length of the cable assembly

3.5**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)

3.6**minimum static bending radius**

radius used in climatic tests which is the minimum permissible for fixed installations of the cable

3.7**dynamic bending radius**

bending radius used for the insertion loss stability, stability of electrical length and flexing endurance tests. It is the minimum bending radius for applications where the cable assembly is flexed. Larger bending radii will allow an increase in the maximum number of flexures

3.8**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

3.9**unbalanced 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

3.10**near-end crosstalk****NEXT**

near end measurement of the 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

3.11

far-end crosstalk

FEXT

measurement of square root of signal power coupling from the transmitting pair to a neighbouring pair at the far end. It is expressed in dB relative to the incident signal level

3.12

equal level far-end crosstalk

ELFEXT

FEXT minus the insertion loss of the disturbed pair when both numbers are expressed in dB

3.13

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)

3.14

nominal impedance

impedance for which the system is designed. The nominal impedance is resistive

3.15

reference plane

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

3.16

power sum

NEXT and FEXT and ELFEXT

power sum crosstalk takes in the combined crosstalk on a receiving pair from all disturbers operating simultaneously

3.17

delay skew

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

3.18

output signal balance

OSB

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

3.19

d.c. resistance

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

3.20

pair-to-pair ACR

difference between the pair-to-pair NEXT and the insertion loss (IL) of the cabling in dB

3.21

power sum ACR

difference between the power sum NEXT and the insertion loss (IL) of the cabling in dB

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

The reference measurement procedures that are described in this standard require the use of a network analyser, 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.

4.2.1 Network analyser test requirements

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

The test set-up shall be calibrated at the specified reference plane for the element 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.

4.2.2 Termination of conductor pairs

During measurement, all conductor pairs of the element 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 elements, and 150 Ω for 150 Ω elements. 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 ± 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 quarter 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.

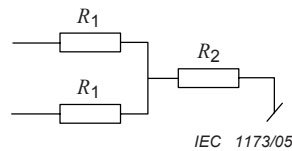


Figure 1 – Resistor load

where

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

and

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

where

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

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

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

4.2.3 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 an international 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 60169-16, 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 analyser 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 the frequencies for which the measurements are to be carried out.

4.2.4 Test configurations

The cabling configurations that are tested in the field are as follows:

– 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 [C] EN 50173 [C] (or equivalent), includes the horizontal cable, a work area equipment cord, a telecommunications outlet/connector, an optional transition connection

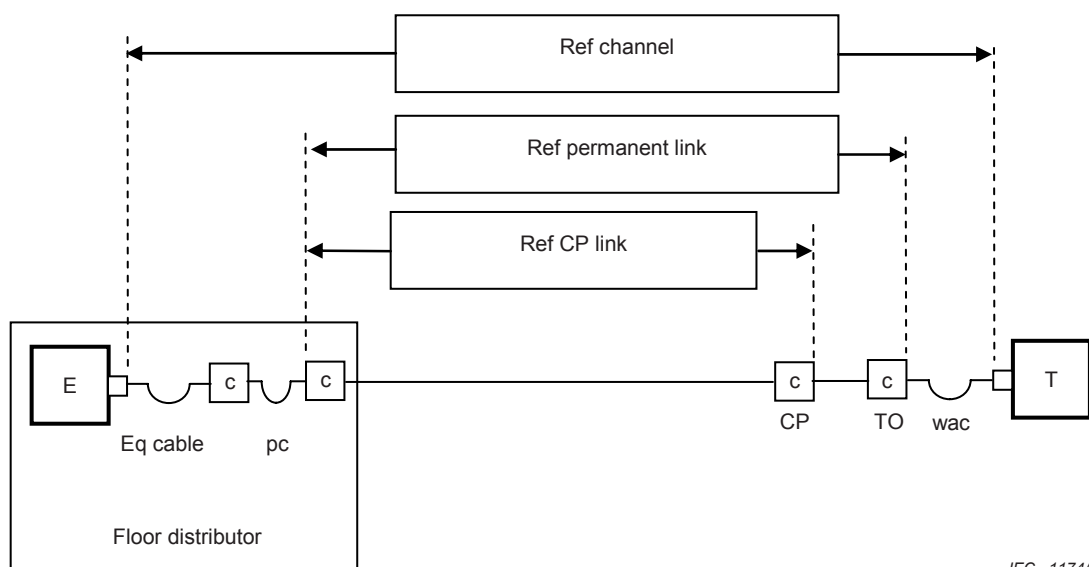
close to the work area and two cross-connect connections in the floor distributor. The total length of work area, patch cords and jumpers shall not exceed 10 m. The connections to the equipment at each end of the channel are not included in the channel definition. The end-user patch cord shall be used 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 [C] EN 50173 [C] (or equivalent) consists of the 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 transition 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 1174/05

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
E	equipment in floor distributor
c	connection
T	terminal equipment in work area
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 50 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 50 mm of the reference plane definition when making measurements on a channel.

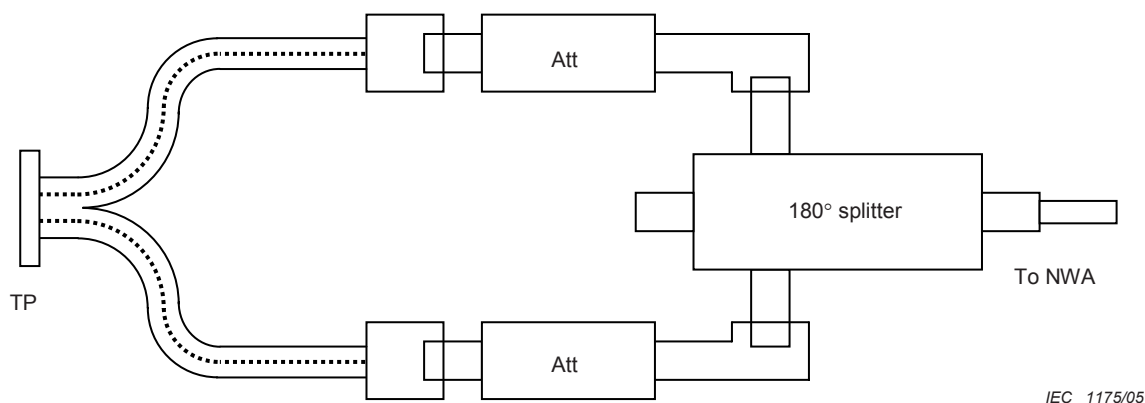
4.2.5 Coaxial cables and test leads for network analysers

Coaxial cable assemblies between the network analyser and baluns should be as short as possible. (It is *recommended* that they do not exceed 600 mm each). 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 element 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.

4.2.6 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).



Key

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

Figure 3 – 180° hybrid used as a balun

There are two class A balun requirements specified. class A-250 baluns are specified for frequency response measurements up to 250 MHz; class A-600 baluns are specified for frequency response measurements up to 600 MHz.

Class A baluns are preferred for the verifying 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.

The specifications for classes A and B baluns apply for the whole frequency range for which the balun is used. Baluns shall be RFI shielded and shall comply with the requirements given in Table 1.

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 ^d	Matched balanced	Matched balanced
Insertion loss	3 dB maximum	3 dB maximum	10 dB maximum
Return loss secondary	20 dB minimum	12 dB minimum, 1 MHz - 15 MHz 20 dB minimum, 15 MHz - 550 MHz 17,5 dB minimum 550 MHz -600 MHz	6 dB minimum
Return loss, Common mode ^b	10 dB minimum	15 dB minimum, 1 MHz - 15 MHz 20 dB minimum, 15 MHz - 400 MHz 15 dB minimum, 400 MHz - 600 MHz	10 dB minimum
Power rating	0,1 W minimum	0,1 W minimum	0,1 W minimum
Longitudinal balance ^c	60 dB minimum	60 dB minimum, 15 MHz - 350 MHz 50 dB minimum, 350 MHz – 600 MHz	35 dB minimum
Output signal balance ^c	50 dB minimum	60 dB minimum, 15 MHz - 350 MHz 50 dB minimum, 350 MHz - 600 MHz	35 dB minimum
Common mode rejection ^c	50 dB minimum	60 dB minimum, 15 MHz - 350 MHz 50 dB minimum, 350 MHz - 600 MHz	35 dB minimum
^a Primary impedance may differ, if necessary to accommodate analyser 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. ^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. Special guidelines for use of baluns: NOTE 1 For best accuracy, the baluns should be supplied with connectors (e.g. with IEC 60169-22 connectors). NOTE 2 For tests up to 250 MHz, class A-250 baluns should be used. NOTE 3 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. NOTE 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 must be less than 5 dB. If insertion loss is higher than 5 dB, return loss must be higher than 10 dB.			

4.2.7 Network analyser measurement precautions

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

- a) the reference plane of the calibration shall coincide with the measurement reference plane; in case of differences the magnitude of errors shall be determined;
- b) consistent and stable baluns and resistor loads shall be used for each pair throughout the test sequence (see 4.2.2);
- 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 analyser/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 analyser 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.

4.2.8 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.

The uncertainties specified in Clause 4 of this document are specified at the pass/fail limits for class F permanent link.

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 element under test shall be defined in the relevant detail specification, or agreed on as a part of a contractual specification.

An example of how this may be done is given in Figure 12.

4.3 DC loop resistance

This test is applicable to laboratory and installed cabling testing.

4.3.1 Object

The object 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 wire pair at the near end after applying a short circuit between each wire of that wire 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 element under test shall be short-circuited at the reference plane. The test set-up is shown in Figure 4.

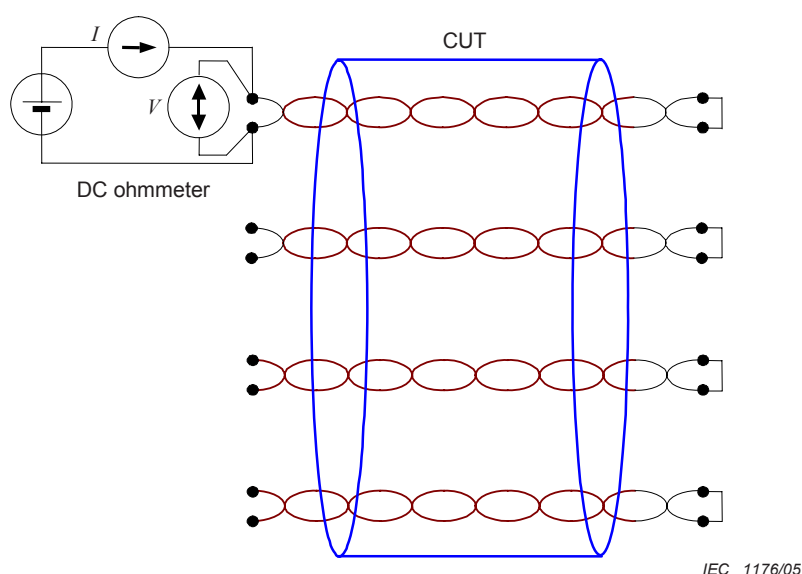
4.3.4 Procedure

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 element 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 wire pair with the highest resistance and this pair shall be identified. The highest resistance shall be compared to 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 Object

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

Test method

Measurement of resistance unbalance shall be carried out on each wire 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

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

4.4.2 Test equipment and set-up

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

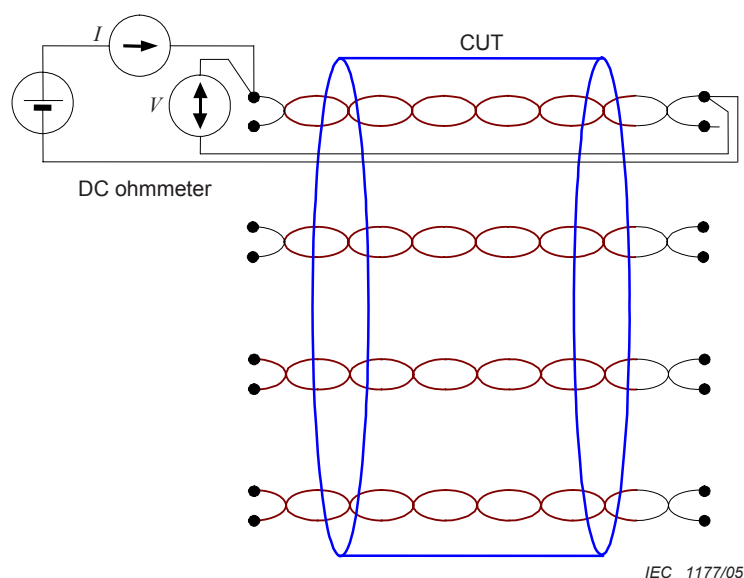
4.4.3 Procedure

4.4.3.1 Calibration

The ohmmeter shall be calibrated for $0\ \Omega$ at the ends of the test leads. After calibration, the test leads shall be connected to the element at the measurement reference plane.

4.4.3.2 Measurement

Measure the d.c. resistance of each wire of a wire pair combination. 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
(test configuration for one wire)**

4.4.4 Test report

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

4.4.5 Uncertainty

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

4.5 Insertion loss

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

4.5.1 Object

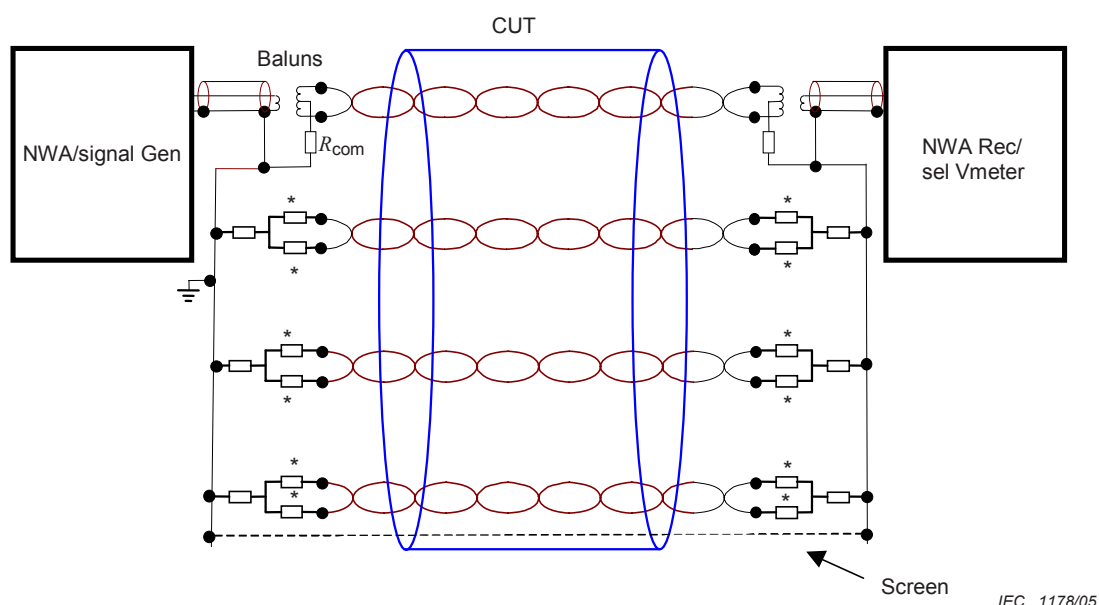
The object of this test is to measure the insertion loss of the element being tested.

4.5.2 Test method

Insertion loss is measured by determining the signal loss of the cabling element 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 element under test shall be measured at the reference planes defined in Figure 2.



Key

CUT	cabling under test
NWA/Signal Gen	signal generator of network analyser or signal generator
NWA Rec/Sel Vmeter	receiver of network analyser 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 element shall be performed. Each pair shall be measured. Pairs shall be terminated with loads according to 4.2.2 when not under test. The loads according to 4.2.2 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

The measurements shall be conducted at the same temperature throughout the test so that the effect of the change of temperature is negligible. Insertion loss increases with temperature so the insertion loss of cable segments shall be corrected to a value that would be reached at the predicted maximum operating temperature. The temperature coefficient and the maximum temperatures shall be specified in the relevant specification for the components.

The increase in insertion loss due to elevated temperature shall not be greater than 0,4 %/°C, in the frequency range from 1 MHz to 250 MHz and 0,6 %/°C for frequencies above 250 MHz for unscreened cables and 0,2 %/°C for screened cables.

4.5.7 Uncertainty

The uncertainty of reference insertion loss measurements for element shall be less than 0,5 dB up to 100 MHz, 0,35 dB up to 250 MHz and 0,5 dB up to 600 MHz.

4.6 Propagation delay and delay skew

This test is applicable for elements 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 Object

The object of this test is to measure propagation delay and delay skew of the element being tested.

4.6.2 Test method

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

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

where

δ is the phase delay;

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 element.

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 analyser 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 elements, 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 analysers 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 analyser 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;

φ_m is the measured phase;

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 (8).

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 of propagation delay and delay skew measurements

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 crosstalk (NEXT), pair to pair and power sum

This test is applicable to laboratory and installed cabling testing.

4.7.1 Object

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

4.7.2 Test method

NEXT is measured by applying the signal at the near end of one wire pair and measuring the coupled signal at the near end of a different wire 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 element under test shall be measured at the reference planes shown in Figure 2.