

Generic cabling systems — Specification for the testing of balanced communication cabling in accordance with EN 50173 —

Part 1: Installed cabling

The European Standard EN 61935-1:2000, with the incorporation of amendment A1:2002, has the status of a British Standard

ICS 33.120.10

National foreword

This British Standard is the official English language version of EN 61935-1:2000, including corrigendum February 2001 and amendment A1:2002. It is identical with IEC 61935-1:2000, including amendment 1:2002.

The start and finish of text introduced or altered by amendment is indicated in the text by tags **A1** **A1**. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by **A1** **A1**.

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**Generic cabling systems -
Specification for the testing of balanced communication cabling
in accordance with ISO/IEC 11801
Part 1: Installed cabling
(includes amendment A1:2002)
(IEC 61935-1:2000 + A1:2002)**

Systèmes de câblage générique -
Spécification pour les essais de câblage
de télécommunications équilibrées selon
l'ISO/CEI 11801
Partie 1: Câblages installés
(inclut l'amendement A1:2002)
(CEI 61935-1:2000 + A1:2002)

Anwendungsneutrale
Kommunikationskabelanlagen -
Spezifikation für die Prüfung der
symmetrischen Kommunikations-
verkabelung nach ISO/IEC 11801
Teil 1: Installierte Verkabelung
(enthält Änderung A1:2002)
(IEC 61935-1:2000 + A1:2002)

This European Standard was approved by CENELEC on 2000-11-01. Amendment A1 was approved by CENELEC on 2002-10-01. 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.

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CENELEC

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

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of document 46A/370/FDIS, future edition 1 of IEC 61935-1, prepared by SC 46A, Coaxial cables, of IEC TC 46, Cables, wires, waveguides, r.f. connectors, and accessories for communication and signalling, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61935-1 on 2000-11-01.

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Annexes designated "normative" are part of the body of the standard.
In this standard, annex ZA is normative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61935-1:2000 was approved by CENELEC as a European Standard without any modification.

Foreword to amendment A1

The text of document 46A/483/FDIS, future amendment 1 to IEC 61935-1:2000, 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 amendment A1 to EN 61935-1:2000 on 2002-10-01.

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Annexes designated "normative" are part of the body of the standard.
In this standard, annex ZA is normative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of amendment 1:2002 to the International Standard IEC 61935-1:2000 was approved by CENELEC as an amendment to the European Standard without any modification.

In the official version, all occurrences of "ISO/IEC 11801 and "ISO/IEC 11801 (or equivalent)" are to be replaced by "EN 50173".

This replacement is to be made in subclauses 5.1 (four times), 5.3.5 and 6.1.

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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, on 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.

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 respectively.

NOTE 2 Wherever possible, cables and connectors used in cable assemblies, even if they are not described in the series IEC 61156 or in IEC 60603-7 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.

GENERIC CABLING SYSTEMS – SPECIFICATION FOR THE 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 or IEC 61156-4, $\square_{A1}$ IEC 61156-5 and IEC 61156-6 $\square_{A1}$, and of connecting hardware as specified in IEC 60603-7 or IEC 60807-8. In the case where cables and/or connectors do not comply with these standards, then additional $\square_{A1}$ testing $\square_{A1}$ may be required.

This standard relates to performance with respect to 100 Ω , 120 Ω or 150 Ω cabling.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61935. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 61935 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

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

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

IEC 61156-2:1995, *Multicore and symmetrical pair/quad cables for digital communications – Part 2: Horizontal floor wiring – Sectional specification*

IEC 61156-3:1995, *Multicore and symmetrical pair/quad cables for digital communications – Part 3: Work area wiring – Sectional specification*

IEC 61156-4:1995, *Multicore and symmetrical pair/quad cables for digital communications – Part 4: Riser cables – Sectional specification*

A1 IEC 61156-5:2002, *Multicore and symmetrical pair/quad cables for digital communications – Part 5: Symmetrical pair/quad cables with transmission characteristics up to 600 MHz – Horizontal floor wiring – Sectional specification*

IEC 61156-6:2002, *Multicore and symmetrical pair/quad cables for digital communications – Part 6: Symmetrical pair/quad cables with transmission characteristics up to 600 MHz – Work area wiring – Sectional specification* **A1**

EN 50173:1995, *Information technology – Generic cabling systems* + amendment A1:2000

ITU-T Recommendation G.117:1996, *Series G – Transmission systems and media, digital systems and networks – International telephone connections and circuits – General Recommendations on the transmission quality for an entire international telephone connection – G.117: Transmission aspects of unbalance about earth*

ITU-T Recommendation O.9:1988, *Series O – Specifications of measuring equipment – General – O.9: Measuring arrangements to assess the degree of unbalance about earth*

3 Definitions

For the purpose of this part of IEC 61935, the following definitions, in addition to the definitions included in EN 50173, 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 EN 50173 (or equivalent). Examples of cable assembly: patch cord, work area cable, link.

3.2

attenuation (insertion loss, composite loss, operational attenuation and S_{21})

ratio of the unreflected square root of power $\sqrt{P_0}$ into a cable assembly to the square root of power $\sqrt{P_2}$ into the load.

This ratio is identical to $-20 \log_{10}(S_{21})$, where S_{21} is the forward transfer scattering parameter of the cable assembly. If the generator and load impedances are the same, it equals the insertion loss of the cable assembly.

$$A_B = 20 \log \frac{\sqrt{P_0}}{\sqrt{P_2}} = 20 \log \frac{1}{S_{21}} \quad (1)$$

A1 NOTE The term “attenuation” is often used where insertion loss is intended. **A1**

3.3

reflection coefficient

ratio of the complex square root of the reflected wave to the complex square root 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_{cnom} .

$$C_r = \frac{Z_{\text{in}} - Z_{\text{cnom}}}{Z_{\text{in}} + Z_{\text{cnom}}} \quad (2)$$

3.4

return loss

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

$$R_l = 20 \log \left(\frac{u_i}{u_r} \right) \quad \text{or}$$

$$R_l = 20 \log \left(\frac{|Z_{\text{in}} - Z_{\text{cnom}}|}{|Z_{\text{in}} + Z_{\text{cnom}}|} \right) \quad (3)$$

where

u_i is the incident voltage;

u_r is the reflection voltage.

3.5

electrical length

equivalent free-space length of the cable assembly

3.6

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)

3.7

minimum static bending radius

radius used in climatic tests

This radius is the minimum permissible radius for fixed installations of the cable.

3.8

dynamic bending radius

bending radius used for the insertion loss stability, stability of electrical length and flexing endurance tests

This radius 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.

3.9

screening attenuation (of the cable assembly)

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

3.10

coupling attenuation

ratio of the square root of signal power inside the cable assembly to the total square root of signal power that radiates outside the cable assembly when the cable is fed in differential mode

Coupling attenuation applies to both screened and unscreened cable assemblies.

3.11

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

3.12

near-end cross-talk (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

NEXT is expressed in decibels relative to the incident square root of signal power.

3.13

far-end cross-talk (FEXT)

measurement of the square root of signal power coupling from the transmitting pair to a neighbouring pair at the far end

FEXT is expressed in decibels relative to the incident signal level.

3.14

equal level far-end cross-talk (ELFEXT)

FEXT minus the attenuation of the disturbed pair when both numbers are expressed in decibels

3.15

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)

3.16

nominal impedance

impedance for which the system is designed

The nominal impedance is resistive.

3.17

reference plane

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

3.18

power sum (NEXT & FEXT & ELFEXT)

the power sum cross-talk is the combined cross-talk on a receiving pair from all disturbers operating simultaneously

3.19

delay skew

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

3.20

output signal balance (OSB)

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

3.21

d.c. loop resistance

measure of the sum of the d.c. resistance of both wires of a wire pair

4 Reference measurement procedures for electrical properties

4.1 Introduction

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 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.

4.2.1 Network analyzer test requirements

Usually the input and output terminals of a network analyzer are unbalanced. RF 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 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. attenuation) measurements. If load and source match is known to be better than 20 dB, then a response calibration may be sufficient.

4.2.2 Termination of conductor pairs

During the 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.

[A1] NOTE 1 When testing 120 Ω cabling systems, it might be more appropriate to apply terminations other than 100 Ω .

The nominal common mode impedance shall be 50 $\Omega \pm 25 \Omega$, unless otherwise specified in the measurement procedure.

NOTE 2 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 whereas a value of 25 Ω is used for screened cabling. **[A1]**

Resistor loads shall use resistors specified for $\pm 1 \%$ accuracy at d.c. and have a return loss greater than $40 - 10 \log(f)$, where f is the frequency in megahertz.

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 greater than or equal to 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.

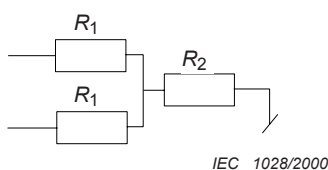


Figure 1 – Resistor load

where

$$R_1 = \frac{R_{\text{dif}}}{2} \quad (4)$$

and

$$R_2 = R_{\text{com}} - \frac{R_{\text{dif}}}{4} \quad (5)$$

where

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

R_{com} is the common mode impedance (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 and 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 greater than 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 EN 50173 (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 EN 50173 (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 transition point.

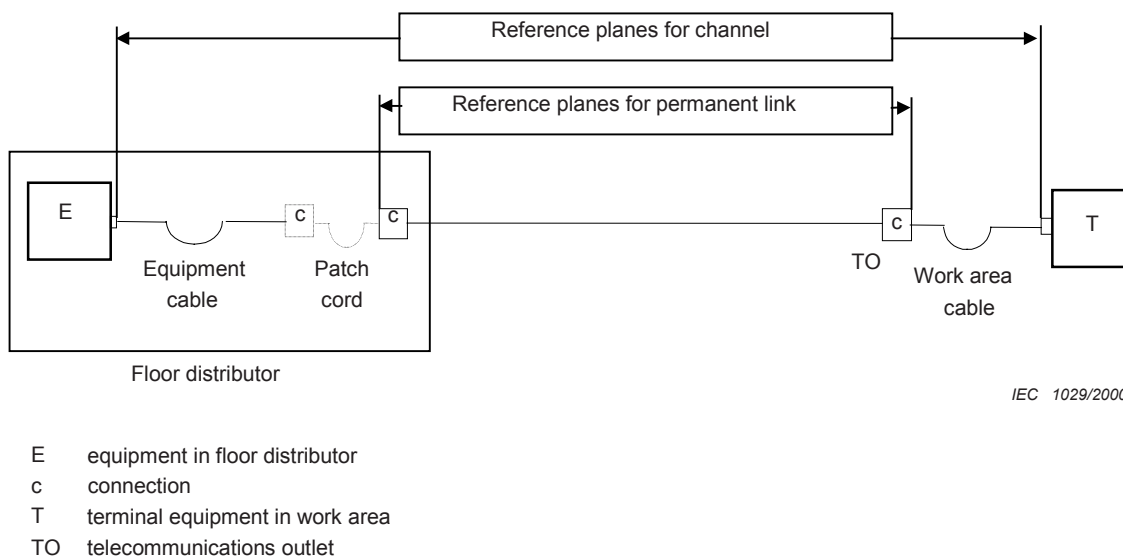


Figure 2 – Reference planes for permanent link and channel

The reference plane of a permanent link is at the end of the permanent link test cord. The reference plane of a channel is at the location where the cable exits the plug which mates with the jack of the equipment.

Test leads used to connect instruments for measurements at the reference planes shall be shorter than 50 mm.

4.2.5 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 baluns shall be attached to a common ground plane.

The 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. The 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).

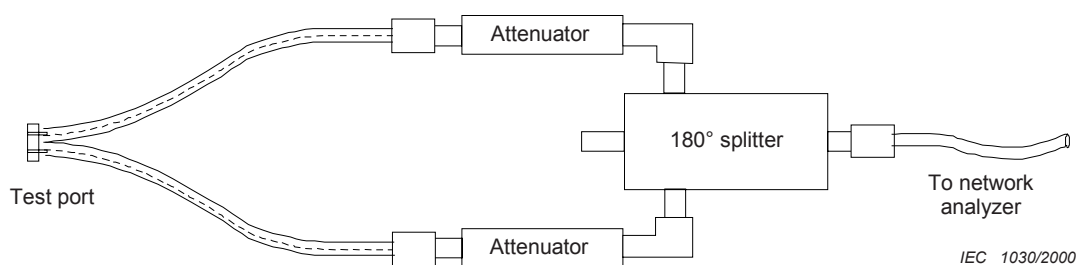


Figure 3 – 180° hybrid used as a balun

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

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

The specifications for class 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 value	Class B value
Impedance, primary ¹⁾	50 Ω unbalanced	50 Ω unbalanced
Impedance, secondary	Matched balanced ⁴⁾	Matched balanced ⁴⁾
Insertion loss	3 dB maximum	10 dB maximum
Return loss secondary	20 dB minimum	6 dB minimum
Return loss, common mode ²⁾	10 dB minimum	10 dB minimum
Power rating	0,1 W minimum	0,1 W minimum
Longitudinal balance ³⁾	60 dB minimum	
Output signal balance ³⁾	50 dB minimum	35 dB minimum
Common mode rejection ³⁾	50 dB minimum	
¹⁾ Primary impedance may differ, if necessary, to accommodate analyzer outputs other than 50 Ω . ²⁾ 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. ³⁾ Measured per ITU-T recommendations G.117 and O.9. ⁴⁾ 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: a) For best accuracy, the baluns should be supplied with connectors (for example with IEC 60169-22 connectors). b) For tests up to $\boxed{A_1}$ 600 $\boxed{A_1}$ MHz, class A baluns should be used. c) 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. d) 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 analyzer measurement precautions

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

- 1) Consistent and stable baluns and resistor loads shall be used for each pair throughout the test sequence (see 4.2.2).
- 2) Cable and adapter discontinuities, as introduced by physical flexing, sharp bends and restraints, shall be avoided before, during and after the tests.
- 3) The relative spacing of conductor pairs shall be preserved throughout the tests to the greatest extent possible.
- 4) 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).
- 5) The balance of the cables is maintained to the greatest extent possible by consistent conductor lengths and pair twisting to the point of load.
- 6) Coaxial, balanced lead and printed line lengths shall be kept as short as possible so that resonance and parasitic effects are minimized.

- 7) Connections to the baluns and IC socket interfaces shall be made in such a way that the conductor movement resulting from the 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.
- 8) Overload conditions of the network analyzer shall be avoided.
- 9) 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 are appropriate only if a satisfactory measurement repeatability of ± 1 dB 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:

$$\sigma_{\text{res}} = \sqrt{\sigma_1^2 + \sigma_2^2 + \dots + \sigma_n^2} \quad (6)$$

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

The overall measurement uncertainty is defined as $2 \times \sigma_{\text{res}}$, 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 element under test shall be defined in the relevant detail specification, or agreed on as part of a contractual specification.

An example of how this may be done is given in figure 11.

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

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

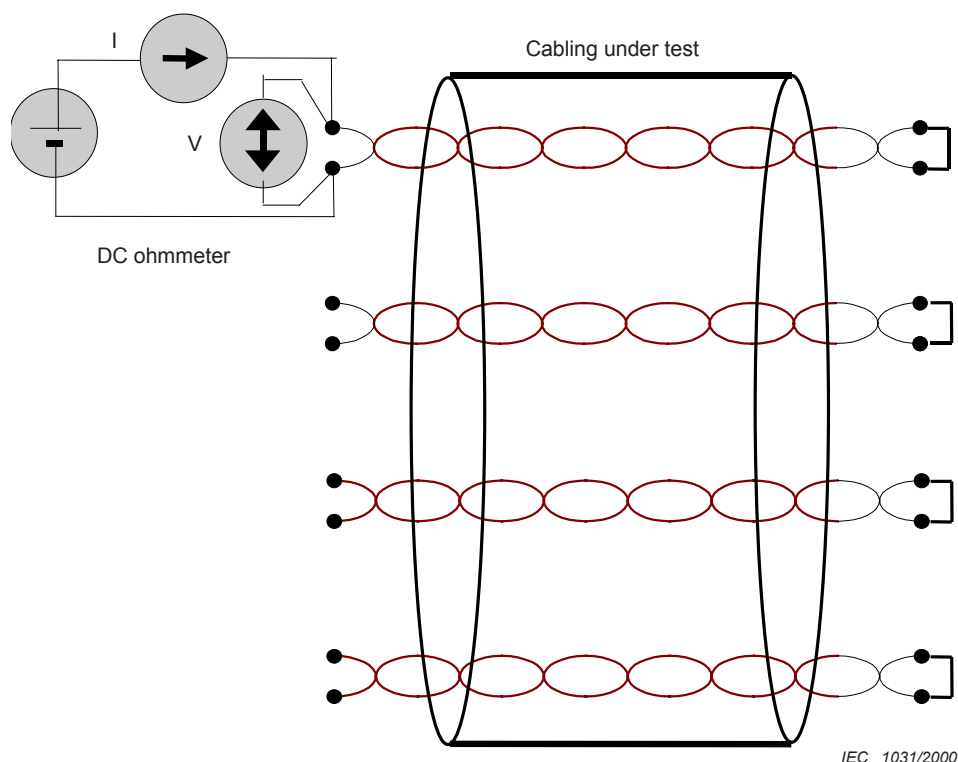


Figure 4 – Loop resistance measurement

4.3.4.2 Measurement

The loop resistance for all four pairs shall be measured.

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 $0,1\ \Omega$ in the range from $0\ \Omega$ to $50\ \Omega$.