BS IEC 60512-29-100:2015

BSI Standards Publication

# Connectors for electronic equipment — Tests and measurements

## Part 29-100: Signal integrity tests up to 500 MHz on M12 style connectors — Tests 29a to 29g

bsi.

...making excellence a habit.™

## National foreword

This British Standard is the UK implementation of IEC 60512-29-100:2015.

The UK participation in its preparation was entrusted to Technical Committee EPL/48, Electromechanical components and mechanical structures for electronic equipment.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.


Published by BSI Standards Limited 2015

ISBN 978 0 580 72296 7
ICS 31.220.10

**Compliance with a British Standard cannot confer immunity from legal obligations.**

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 March 2015.

### Amendments/corrigenda issued since publication

| Date | Text affected |
| --- | --- |

# IEC 60512-29-100

Edition 1.0 2015-03

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

colour inside

## Connectors for electronic equipment – Tests and measurements – Part 29-100: Signal integrity tests up to 500 MHz on M12 style connectors – Tests 29a to 29g

## Connecteurs pour équipements électroniques – Essais et mesures – Partie 29-100: Essais d'intégrité des signaux jusqu'à 500 MHz sur les connecteurs de type M12 – Essais 29a à 29g

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 31.220.10

ISBN 978-2-8322-2306-2

**Warning! Make sure that you obtained this publication from an authorized distributor.**
**Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

# CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

___________

**CONNECTORS FOR ELECTRONIC EQUIPMENT –
TESTS AND MEASUREMENTS –**

**Part 29-100: Signal integrity tests up
to 500 MHz on M12 style connectors –
Tests 29a to 29g**

## FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60512-29-100 has been prepared by subcommittee 48B: Electrical connectors, of IEC technical committee 48: Electrical connectors and mechanical structures for electrical and electronic equipment.

The text of this standard is based on the following documents:

| FDIS | Report on voting |
|---|---|
| 48B/2410/FDIS | 48B/2424/RVD |

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60512 series, published under the general title *Connectors for electronic equipment – Tests and measurements*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

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

# CONNECTORS FOR ELECTRONIC EQUIPMENT – TESTS AND MEASUREMENTS –

# Part 29-100: Signal integrity tests up to 500 MHz on M12 style connectors – Tests 29a to 29g

## 1 Scope and object

This part of IEC 60512 specifies the test methods for transmission performance for M12-style connectors up to 500 MHz. It is also suitable for testing lower frequency connectors if they meet the requirements of the detail specifications and of this standard.

NOTE 1 All figures show equipment for connectors according to IEC 61076-2-109 as an example.

The test methods provided herein are:

- insertion loss, test 29a;
- return loss, test 29b;
- near-end crosstalk (NEXT) test 29c;
- far-end crosstalk (FEXT), test 29d;
- transverse conversion loss (TCL), test 29f;
- transverse conversion transfer loss (TCTL), test 29g.

For the transfer impedance (ZT) test, see IEC 60512-26-100, test 26e.

For the coupling attenuation see ISO/IEC 11801.

All test methods apply for two and four pair connectors.

NOTE 2 All figures show schemes for four pair cabling and are also suitable for two pair cabling.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts): *International Electrotechnical Vocabulary* (available at http://www.electropedia.org)

IEC 60512-1, *Connectors for electronic equipment – Tests and measurements – Part 1: General*

IEC 60512-26-100, *Connectors for electronic equipment – Tests and measurements – Part 26-100: Measurement setup, test and reference arrangements and measurements for connectors according to IEC 60603-7 – Tests 26a to 26g*

IEC 61076-1, *Connectors for electronic equipment – Product requirements – Part 1: Generic specification*

IEC 61076-2-101, *Connectors for electronic equipment – Product requirements – Part 2-101: Circular connectors – Detail specification for M12 connectors with screw-locking*

IEC 61076-2-109, *Connectors for electronic equipment – Product requirements – Part 2-109: Circular connectors – Detail specification for connectors with M 12 x 1 screw-locking, for data transmission frequencies up to 500 MHz*

IEC 61169-16, *Radio-frequency connectors – Part 16: Sectional specification – RF coaxial connectors with inner diameter of outer conductor 7 mm (0,276 in) with screw coupling – Characteristics impedance 50 ohms (75 ohms) (type N)*

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

EN 50289-1-14, *Communication cables – Specification for test methods – Part 1-14: Electrical test methods − Coupling attenuation or screening attenuation of connecting hardware*

ITU-T Recommendation G.117, *Transmission aspects of unbalance about earth*

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

## 3 Terms, definitions and abbreviations

### 3.1 Terms and definitions

For the purposes of this document, the terms and definitions of IEC 60050-581, IEC 61076-1, IEC 60512-1, as well as the following, apply.

**3.1.1**
**Reference Test Jack**
**RTJ**
connector with female contacts which is constructed such that it is a test artefact

**3.1.2**
**Reference Test Plug**
**RTP**
connector with male contacts which is constructed such that it is a test artefact

**3.1.3**
**Direct Fixture Jack**
**DFJ**
interface with contacts to mate a plug with male contacts

**3.1.4**
**Direct Fixture Plug**
**DFP**
interface with contacts to mate a jack with female contacts

### 3.2 Abbreviations

| | |
|---|---|
| CM | Common mode |
| DM | Differential mode |
| DFJ | Direct Fixture Jack |
| DFP | Direct Fixture Plug |
| DMCM | Differential mode plus common mode |
| DUT | Device under test |

| | |
|---|---|
| FEXT | Far-end crosstalk |
| IDC | Insulation displacement connection |
| IEC | International Electrotechnical Commission |
| IL | Insertion Loss |
| NEXT | Near-end crosstalk |
| RL | Return Loss |
| RTJ | Reference Test jack |
| RTP | Reference Test plug |
| TCL | Transverse conversion loss |
| TCTL | Transverse conversion transfer loss |

## 4 Overall test arrangement

### 4.1 Test instrumentation

All test instrumentation shall be qualified over the frequency range of 1 MHz to the maximum specified frequency from the DUT.

These test procedures require the use of a vector network analyzer. The analyser should have the capability of full 2-port calibrations. The analyser shall cover the frequency range of 1 MHz to the maximum specified frequency from the DUT at least.

When used, at least two test baluns are required in order to perform measurements with balanced symmetrical signals. The requirements for the baluns are given in 4.3.

Optionally, multi-port network analysers for balun-less test set-up may be used.

Reference loads are needed for the calibration of the set-up. Requirements for the reference loads are given in 4.5.1.

Termination loads are needed for termination of pairs, used and unused, which are not terminated by the test baluns. Requirements for the termination loads are given in 4.6.

An absorbing clamp and ferrite absorbers are needed for the coupling attenuation measurements. The requirements for these items are given in EN 50289-1-14.

The test procedures allow an independent test of the male and female part of the connector. Both are described in Clause 5. Figure 1 shows the feasible measurement strategies for the qualification of a DUT.

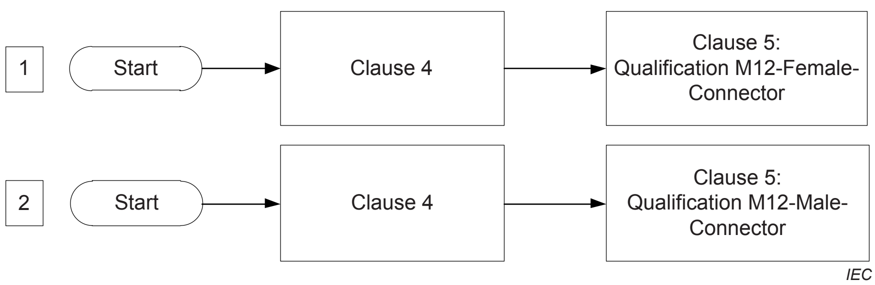



**Figure 1 – Measurement strategies**

### 4.2 Coaxial cables and interconnect for network analysers

Lengths of coaxial cables used to connect the network analyser to the baluns shall be as short as possible. (It is recommended that they do not exceed 600 mm each.) The baluns shall be electrically bonded to a common ground plane. For crosstalk measurements, a test fixture may be used, in order to reduce residual crosstalk (see Annex A). Balanced interconnect and associated connecting hardware used to connect the test equipment and the connector under test shall meet the requirements given in 4.8.

### 4.3 Measurement precautions

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

a) Consistent and stable balun and resistor loads shall be used for each pair throughout the test sequence.
b) Cable and adapter discontinuities, as introduced by physical flexing, sharp bends and restraints shall be avoided before, during and after the tests.
c) Consistent test methodology and terminations (baluns or resistors) shall be used at all stages of transmission performance qualifications. The relative spacing of conductors in the pairs shall be preserved throughout the tests to the greatest extent possible.
d) The balance of the cables is maintained to the greatest extent possible by consistent conductor lengths and pair twisting to the point of load.
e) The sensitivity to set-up variations for these measurements at high frequencies demands attention to details for both the measurement equipment and the procedures.

Balun requirements

The baluns may be balun transformers or 180° hybrids with attenuators to improve matching if needed (see Figure 2)

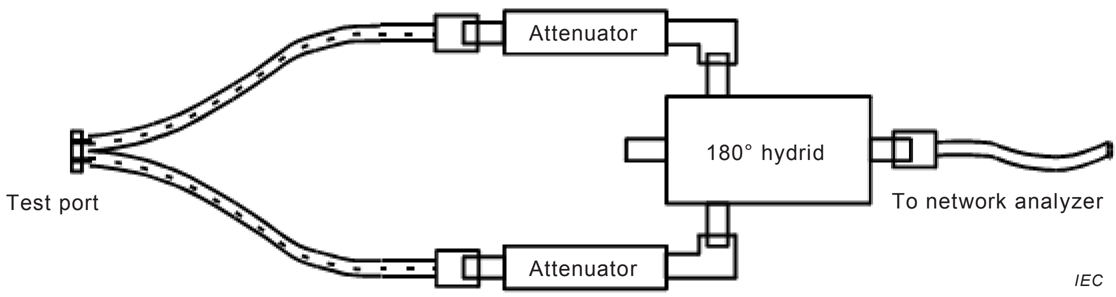



**Figure 2 – 180° hybrid used as a balun**

The specifications for the baluns apply for the whole frequency range for which they are used. Baluns shall be RFI shielded and shall comply with the specifications listed in Table 1 and Table 2.

**Table 1 – Test balun performance characteristics up to 500 MHz**

| Parameter | Frequency<br>MHz | Value |
|---|---|---|
| Impedance, primary [1)] | $1 \le f \le 500$ | 50 Ω unbalanced |
| Impedance, secondary | $1 \le f \le 500$ | 100 Ω balanced |
| Insertion loss | $1 \le f \le 500$ | 2,0 dB maximum |
| Return loss, bi-directional [2)] | $1 \le f < 15$<br>$15 \le f \le 500$ | 12 dB minimum<br>20 dB minimum |
| Return loss, common mode [2)] | $1 \le f < 15$<br>$15 \le f < 400$<br>$400 \le f \le 500$ | 15 dB minimum<br>20 dB minimum<br>15 dB minimum |
| Power rating | $1 \le f \le 500$ | 0,1 W minimum |
| Longitudinal balance [2)] | $1 \le f < 100$<br>$100 \le f \le 500$ | 60 dB minimum<br>50 dB minimum |
| Output signal balance [2)] | $1 \le f \le 500$ | 50 dB minimum |
| Common mode rejection [2)] | $1 \le f \le 500$ | 50 dB minimum |

1) Primary impedance may differ, if necessary, to accommodate analyzer outputs other than 50 Ω.

2) Measured per ITU-T Recommendation G.117 with the network analyzer calibrated using a 50 Ω load.

**Table 2 – Test balun performance characteristics up to 100 MHz**

| Parameter | Frequency<br>MHz | Value |
|---|---|---|
| Impedance, primary | $1 \le f \le 100$ | 50 Ω unbalanced |
| Impedance, secondary | $1 \le f \le 100$ | 100 Ω balanced |
| Insertion loss | $1 \le f \le 100$ | 10,0 dB maximum |
| Return loss, secondary | $1 \le f < 100$ | 14 dB minimum |
| Return loss, common mode with common mode termination [1)] | $1 \le f < 100$ | 10 dB maximum |
| Power rating | $1 \le f \le 100$ | 0,1 W minimum |
| Longitudinal balance [2)] | $1 \le f < 100$ | 50 dB minimum |
| Output signal balance [3)] | $1 \le f \le 100$ | 50 dB minimum |
| Common mode rejection [3)] | $1 \le f \le 100$ | 50 dB minimum |

1) Measured by connecting the balanced output terminals together and measuring the return loss. The nominal primary impedance shall terminate the primary input terminal. See also Figure 3, part Common Mode Return Loss.

2) Applicable for baluns, which are used for balance measurements. Measured from the primary input terminal to the common mode terminal when the secondary balanced terminal is terminated with 100 Ω.

3) Measured according to ITU-T Recommendations G.117 and O.9 .

For ease of interfacing to test fixtures, a pin and socket interface with dimensions as shown in Annex D is recommended. Figure 3 depicts the proper test configurations for qualifying test baluns to the requirements of Table 2.

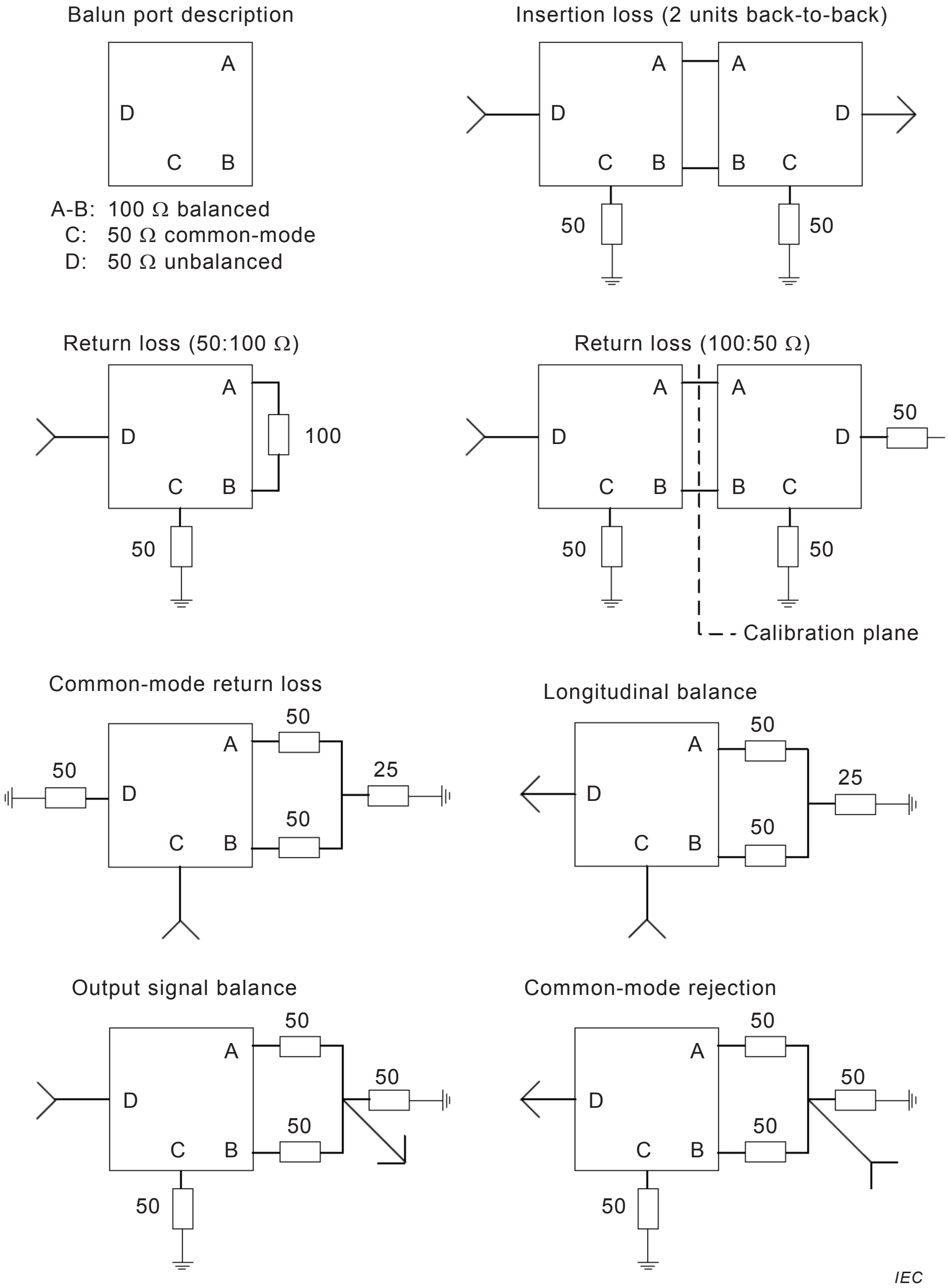



**Figure 3 – Measurement configurations for test balun qualification**

## 4.4 Reference components for calibration

### 4.4.1 Reference loads for calibration

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

The reference load shall be calibrated against a calibration reference, which shall be a 50 Ω load, traceable to an international reference standard. Two 100 Ω reference 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 (see Figure 4). The loads shall be fixed to the flat side of the connector, distributed evenly around the centre conductor. A network analyser shall be calibrated, 1-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 >46 dB at frequencies up to 100 MHz and >40 dB at frequencies above 100 MHz and up to the limit for which the measurements are to be carried out.

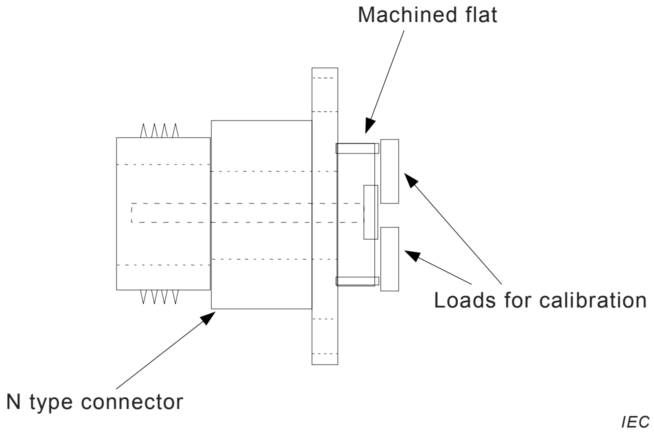



**Figure 4 – Calibration of reference loads**

## 4.5 Termination loads for termination of conductor pairs

### 4.5.1 Differential mode

Differential mode plus common mode (DMCM) terminations, as shown in Figure 5 on the left, shall be used on all active pairs under test, except when measuring return loss, where DM only resistor terminations are recommended. DMCM resistor terminations shall be used on all inactive pairs and on the opposite ends of active pairs for NEXT loss and FEXT loss testing. Inactive pairs for return loss testing may be terminated with DM or DMCM resistor terminations, or left un-terminated. Balun terminations may be used on the far-end of all inactive pairs provided that their DM and common mode return loss performance characteristics meet the minimum performance of the specified resistor networks.

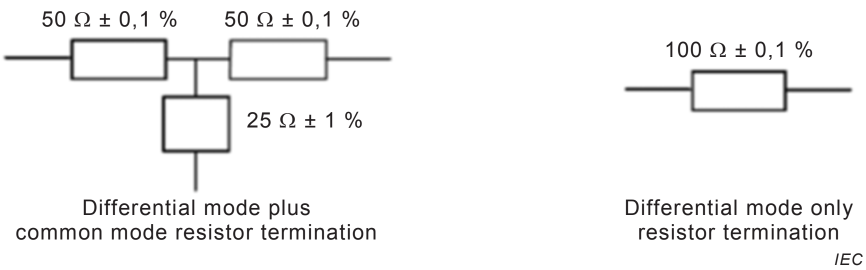



**Figure 5 – Resistor termination networks**

Small geometry chip resistors shall be used for the construction of resistor terminations. The two 50 Ω DM terminating resistors shall be matched to within 0,1 % at DC. The length of connections to impedance terminating resistors shall be minimized. Lead lengths of 2 mm or less are recommended.

### 4.5.2 Balun terminations

Baluns used for termination shall comply with the requirements of 4.3. The common mode termination resistor applied to the CM port of the balun shall be 50 Ω ± 1 %.

#### 4.5.3 Termination types

The performance of impedance matching resistor termination networks shall be verified by measuring the return loss of the termination at the calibration plane. For this measurement, a one port calibration is required using a traceable reference load as described in 4.4.1.

The DM return loss of the load termination shall exceed 20-20 log (f/500). Calculations that result in return loss limit values greater than 40 dB shall revert to a requirement of 40 dB minimum. The common mode return loss shall exceed 15 dB. The residual NEXT loss between any two impedance termination networks shall exceed the requirements of formula (1). Calculations that result in residual NEXT loss limit values greater than 84 dB shall revert to a requirement of 84 dB minimum.

$$\text{NEXT}_{\text{residual\_term}} \geq 114 - 20 \cdot \log(f)\ \text{dB} \qquad (1)$$

### 4.6 Termination of screens

If the connector under test is screened, screened measurement cables shall be applied.

The screen or screens of these cables shall be fixed to the ground plane as close as possible to the measurement baluns.

### 4.7 Test specimen and reference planes

#### 4.7.1 General

The test specimen is a mated pair of relevant connectors. The connector reference plane for the test specimen is the point at which the cable sheath enters the connector (the back end of the connector) or the point at which the internal geometry of the cable is no longer maintained, whichever is farther from the connector (see Figure 6). Also connectors with PCB-mounting are applicable. This definition applies to both ends of the test specimen. The connector shall be terminated in accordance with the manufacturer's instructions and shall be compatible with the measurement test set up and fixtures.

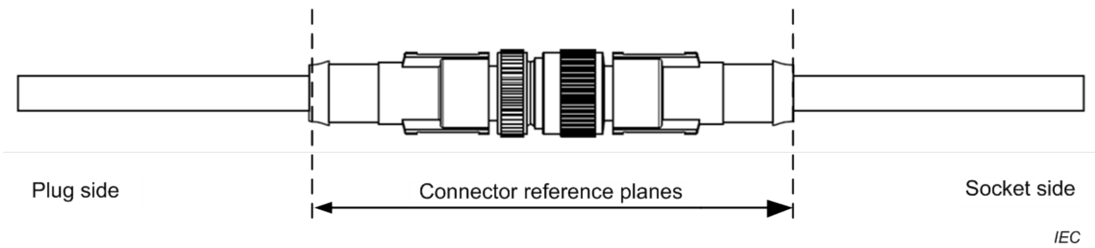



**Figure 6 – Definition of reference planes**

#### 4.7.2 Interconnections between device under test (DUT) and the calibration plane

##### 4.7.2.1 General

Twisted-pair interconnect, printed circuits or other interconnections are used between the connector reference plane of the DUT and the calibration plane. It is necessary to control the characteristics of these interconnections to the best extent possible as they are beyond the calibration plane. These interconnections should be as short as practical and their common mode and DM impedances shall be managed to minimize their effects on measurement. Refer to Annex A for additional information about test fixtures which may be used to facilitate impedance management. The return loss performance of the interconnections shall meet the requirements of Table 3. The insertion loss performance of the interconnections is assumed to be less than 0,1 dB over the frequency range from 1 MHz to 100 MHz (Category 5) and 1 MHz to 500 MHz (Category $6_A$).

It is recommended that all DUTs, including TFJs and TFPs, have sockets with 2,5 mm spacing applied to the ends of their interconnects to facilitate a consistent interfacing with the baluns.

#### 4.7.2.2 Impedance matching interconnect

##### 4.7.2.2.1 General

When used, twisted-pair interconnect shall have 100 Ω nominal differential characteristic impedance. The twisted-pairs should not exhibit gaps between the conductors insulation. Interconnect shall be qualified for differential mode return loss. There are two different methods to obtain interconnect: they may be obtained as individual twisted-pairs, or they may be part of a cable. If common mode terminations are required, the interconnect shall be placed in an impedance managing system, as described in Annex A. The maximum length of the twisted-pair leads at each end of the DUT shall be 51 mm.

##### 4.7.2.2.2 Individual twisted-pair interconnect

Twisted-pair interconnect may be obtained from discrete twisted-pair stock or removed from sheathed cable. Prior to attachment to the DUT, the return loss of each pair shall be tested. For this test, 100 mm lengths of twisted-pair shall be used. The interconnect shall be terminated across each pair with a precision 0,1 % (0603 size or similar) chip resistor or similar chip resistor as described in 4.5.1. The resistor shall be attached directly to the conductors of the pair in such a way as to minimize the disturbance of the pair. Potential disturbances include gaps between the conductor insulation in the pair, melting insulation, and excess solder. When tested, the test leads shall be attached to the balun or differential mode test port using the same fixtures as when testing the DUT. The twisted-pair leads are then trimmed for attachment to the device and the test fixtures. See Annex A for an appropriate test fixture. It is recommended to use the same load for both calibration and termination of the test lead during measurement.

##### 4.7.2.2.3 Interconnect as part of cables

Interconnect may also be obtained from a section of twisted-pair cable where the four twisted-pair interconnect are maintained in the cable sheath. This method will most often be used with TFPs, cut from the ends of assembled cords, but can also be used with connector with female contacts. Prior to attachment to the DUT, the return loss of the cable pairs (within the cable) shall be tested. For this test, a 100 mm length of cable shall be selected. Each twisted-pair of the cable end shall be DM terminated across each pair with precision 0,1 % (0603 size or similar) differential mode chip resistors as described in 4.6. The cable shall then be terminated to the DUT per manufacturer's instructions and trimmed for attachment to the measurement system. When this method is used with TFPs cut from assembled cords, it shall be sufficient if the cord cable was qualified for return loss to 100 MHz at Category 5 and 500 MHz at Category $6_A$, or if the assembled cord was qualified for return loss to 100 MHz or 500 MHz.

#### 4.7.2.3 Interconnection return loss requirements

The interconnection shall meet the requirements in Table 3 relative to the calibration resistor specified in 4.7.2.2.2.

**Table 3 – Interconnection return loss**

| **Frequency** MHz | **Return loss** dB | **Category** |
|---|---|---|
| $1 \le f < 80$ | 40 dB | All |
| $80 \le f \le 100$ | $78 - 20 \log(f)$ dB | 5 |
| $80 \le f \le 500$ | $78 - 20 \log(f)$ dB | $6_A$ |

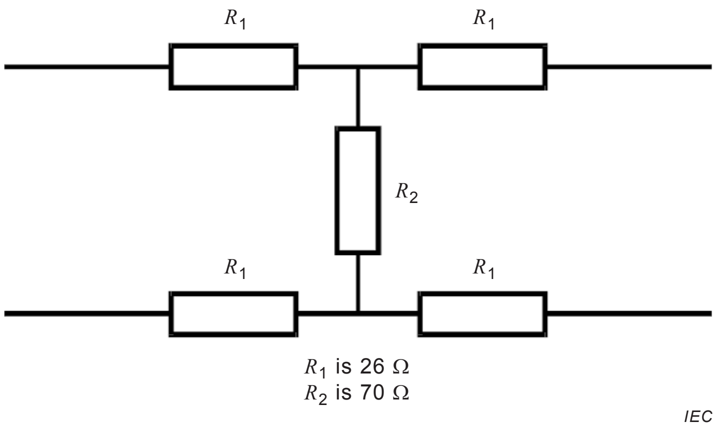
### 4.8 Termination of balun

#### 4.8.1 General requirements

If the available balun does not provide a common-mode termination (centre tap is either connected to ground or open), a balanced resistor attenuator shall be applied in order to provide the required return loss. The attenuator shall be implemented at a small printed circuit board mounted with SMD resistors. There are two cases: one for the centre tap connected to ground and one for the centre tap open.

#### 4.8.2 Centre tap connected to ground

A diagram of the attenuator is shown in Figure 7. The nominal attenuation is 10 dB and the calculated common-mode impedance is 26 Ω.

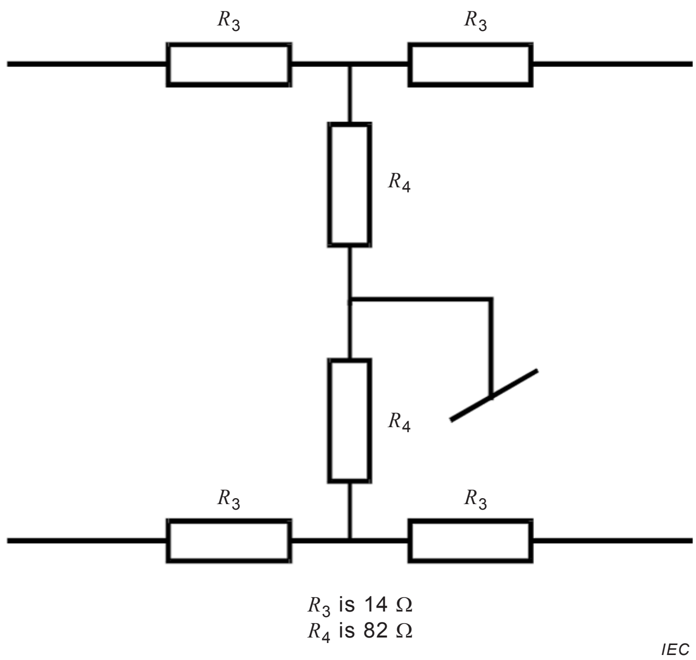



NOTE Resistor values are nominal. The nearest standard values may be chosen.

**Figure 7 – Balanced attenuator for balun centre tap grounded**

### 4.8.3 Centre tap open

A diagram of the attenuator is shown in Figure 8. The nominal attenuation is 5 dB and the calculated common-mode impedance is 48 Ω.




NOTE Resistor values are nominal. The nearest standard values may be chosen.

**Figure 8 – Balanced attenuator for balun centre tap open**

### 4.9 Sequence for calibration and measurement

The following sequence shall be used to perform a correct calibration of the test equipment and measurement of the DUT.

NOTE Figures 9 to 14 show grey schematics which is similar to the frame in Figure A.3.

a) Open calibration on the reference plane with a 2port network analyser as shown in Figure 9.

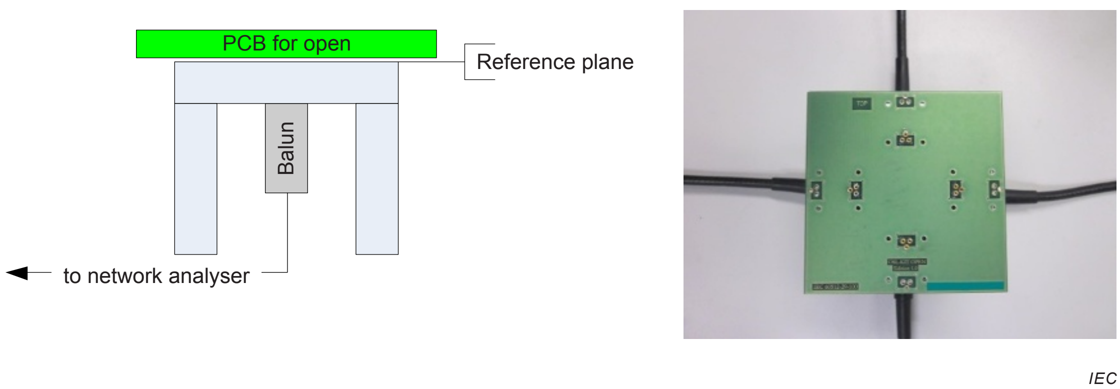



**Figure 9 – Open calibration**

b) Short calibration on the reference plane with a 2 port network analyser as shown in Figure 10.

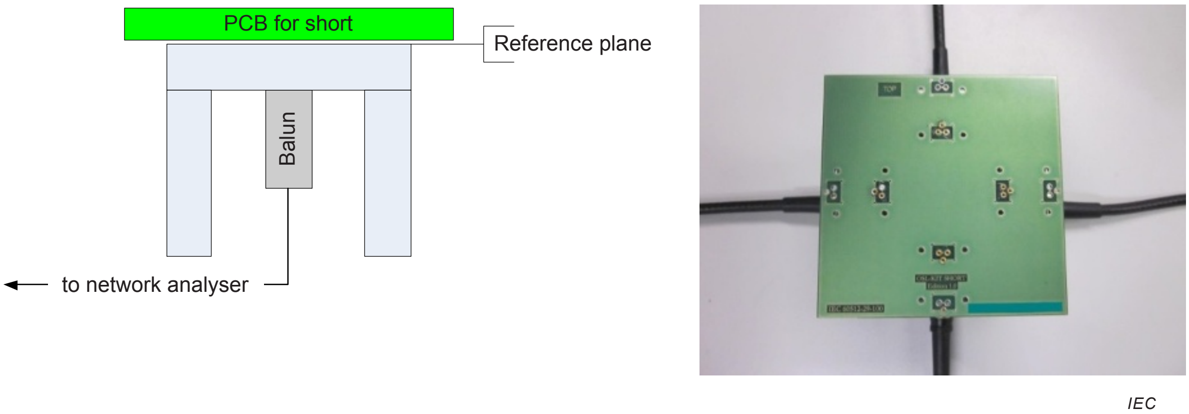



**Figure 10 – Short calibration**

c) Load calibration on the reference plane with a 2 port network analyser as shown in Figure 11.

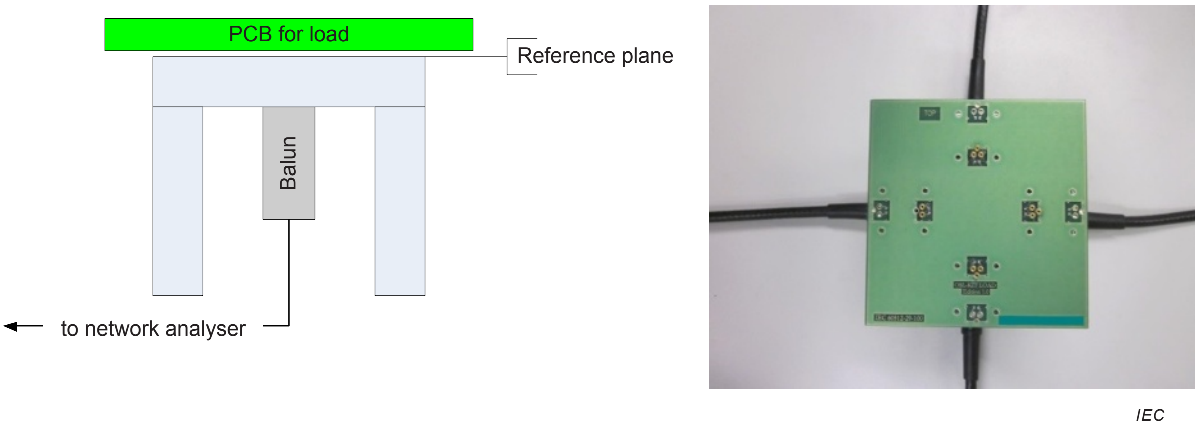
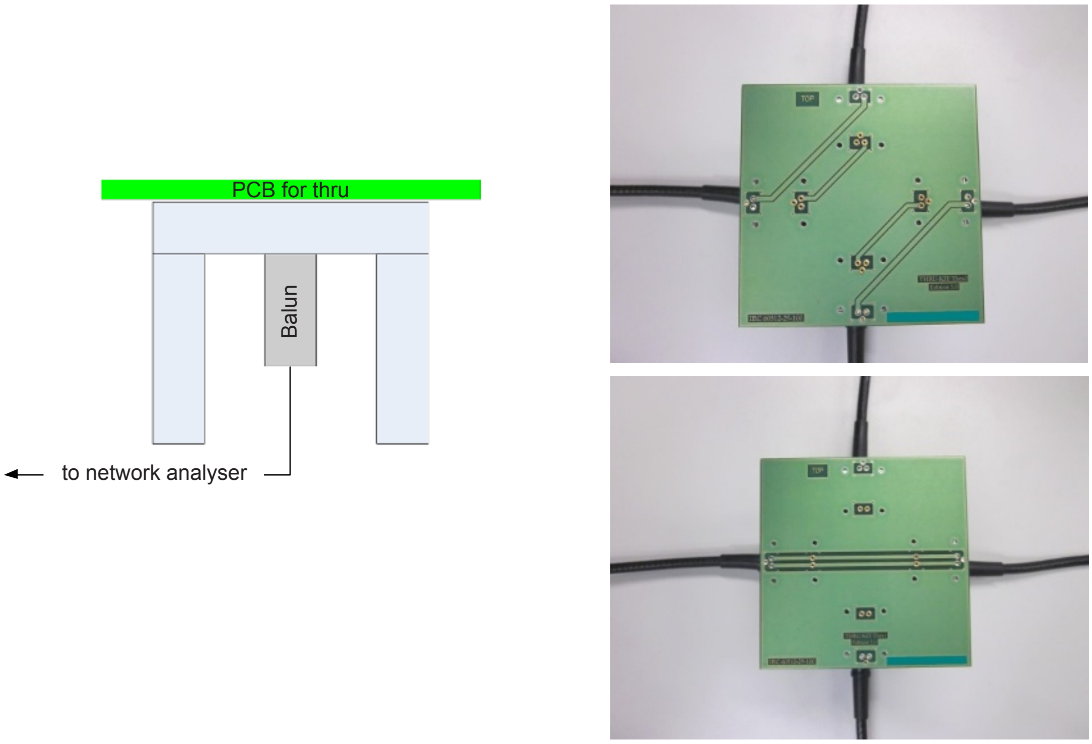



**Figure 11 – Load calibration**

d) Thru calibration on the reference plane with a 2 port network analyser as shown in Figure 12.




IEC

**Figure 12 – Thru calibration**

e) Measurement of RL and NEXT on the DUT as shown in Figure 13.

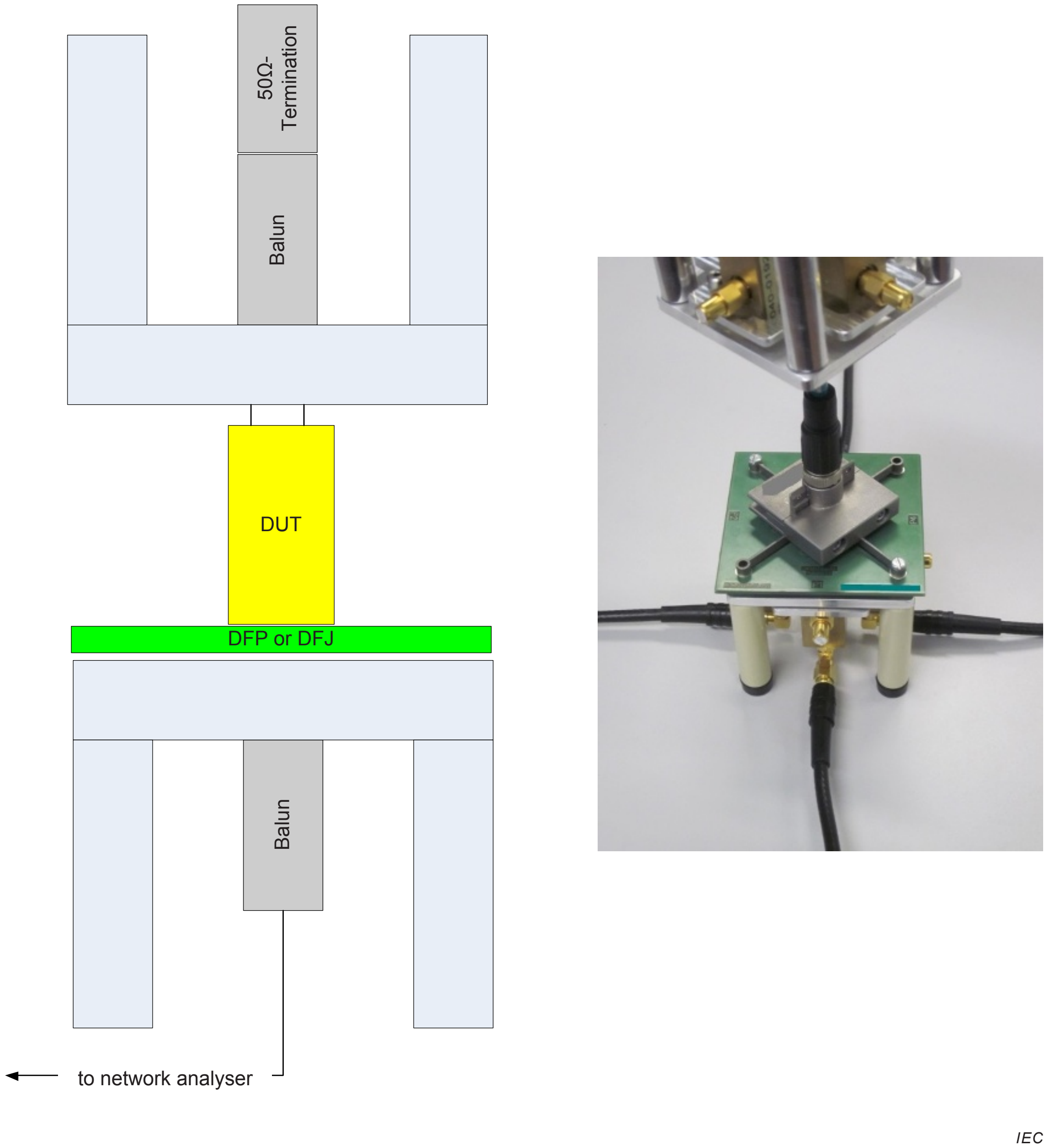



**Figure 13 – Measurement of RL and NEXT on the DUT**

f) Measurement of IL and FEXT on the DUT as shown in Figure 14.

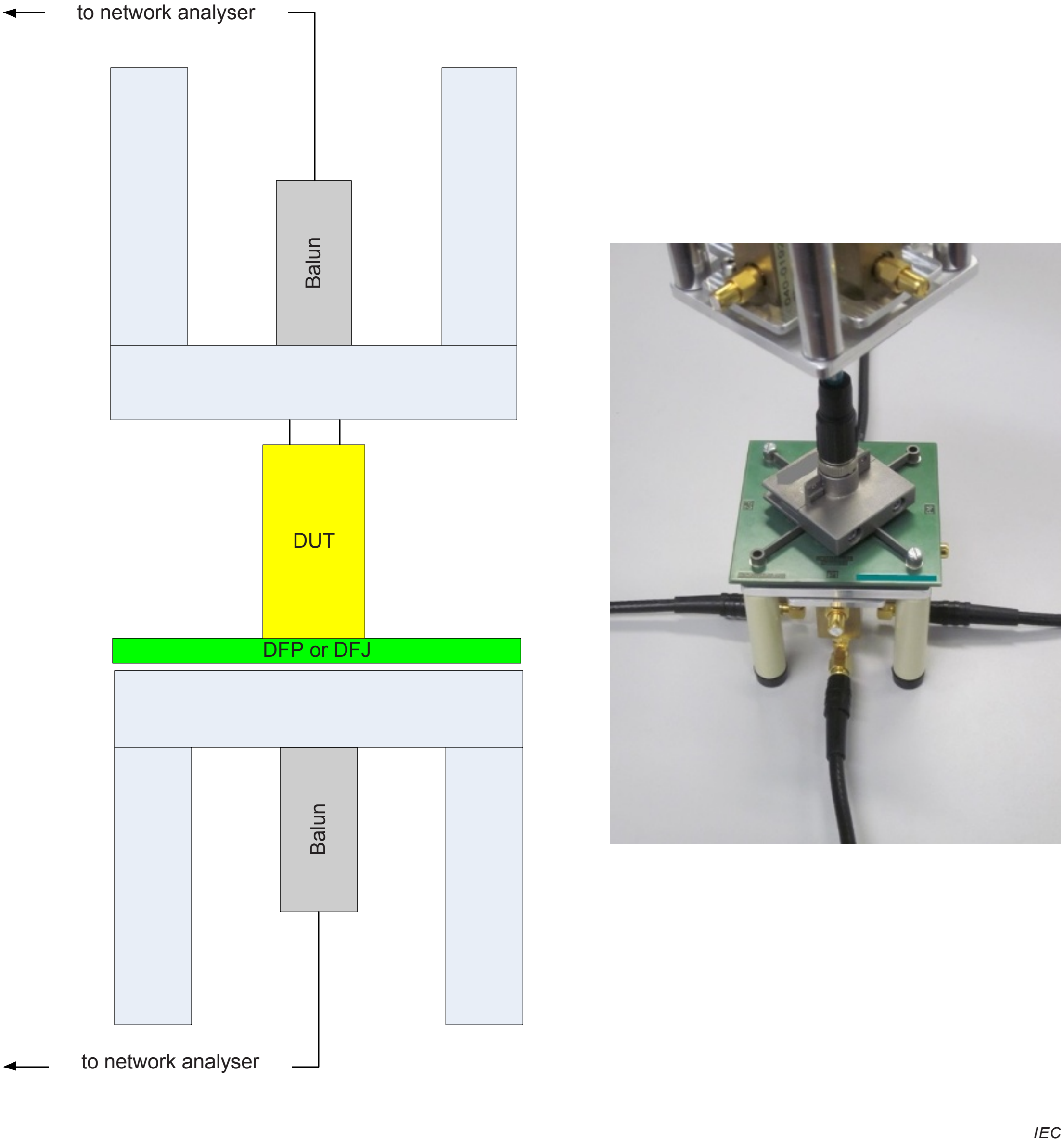



**Figure 14 – Measurement of IL and FEXT on the DUT**

# 5 Connector measurement up to 100 MHz and 500 MHz

## 5.1 General

The measurements made in this clause are of a mated connector with male contacts and a connector with female contacts. DFPs and DFJs for use in these tests, shall meet all the requirements of 6.2.

## 5.2 Insertion loss, Test 29a

### 5.2.1 Object

The object of this test is to measure the insertion loss, which is defined as the additional attenuation that is provided by a pair of mated connectors inserted in a communication cable.

### 5.2.2 Connector with male or female contacts for insertion loss

The insertion loss shall be measured in at least one direction.

### 5.2.3 Test method

Insertion loss (IL) is evaluated by measuring the scattering parameters, $S_{21}$, of all the conductor pairs.

### 5.2.4 Test set-up

The test set-up consists of a network analyser and two baluns as defined in 4.3. It is not necessary to terminate the unused pairs.

### 5.2.5 Procedure

#### 5.2.5.1 Calibration

A full 2-port calibration shall be performed at the calibration planes.

#### 5.2.5.2 Measurement

The test specimen shall be terminated with measurement cables at both ends as shown in Figure 15. The length of measurement cables shall be equal to the length of the reference cables used for reflection calibrations. The measurement cables shall be the cable types for which the connector is intended. An $S_{21}$ measurement shall be performed. Common mode termination is required on the pair under test at least one end.

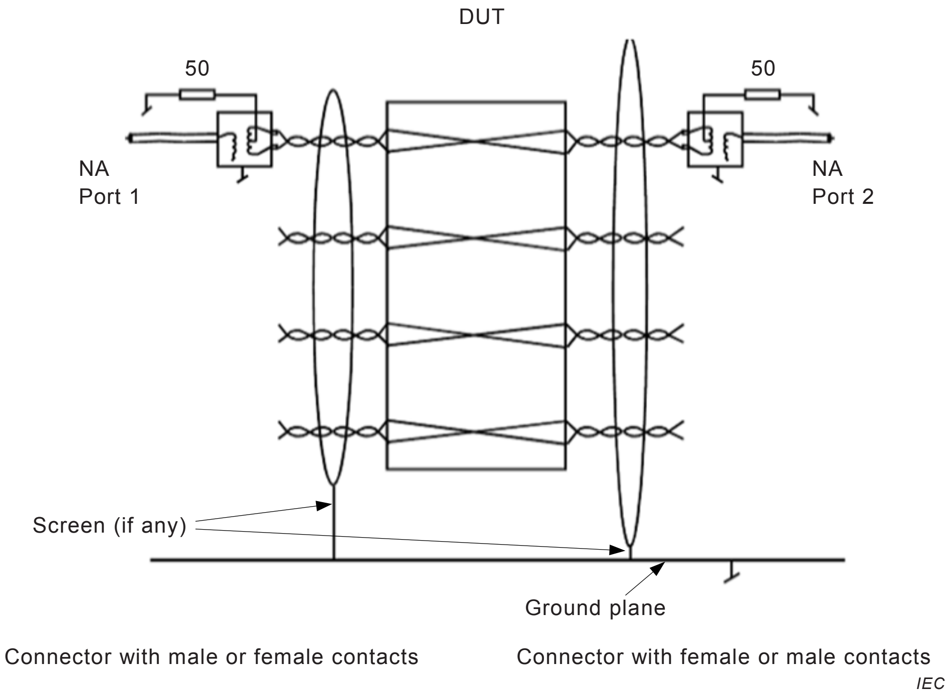



**Figure 15 – Measuring set-up**

Connectors with female or male contacts shall be measured with at least one connector with male or female contacts in at least one direction. For improved accuracy, the insertion loss of the interconnections at each end of the mated connection may be subtracted from the measurement of the DUT.

#### 5.2.6 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.

#### 5.2.7 Accuracy

The accuracy shall be within ±0,05 dB.

### 5.3 Return loss, Test 29b

#### 5.3.1 Object

The object of this test is to measure the return loss (RL) of the DUT with male or female contacts mated with the direct fixture of appropriate gender. See Figure 16.

#### 5.3.2 Connector with male or female contacts for return loss

Connecting hardware shall be tested in at least one direction for return loss using at least one connector with male or female contacts. This connector with male or female contacts shall satisfy the requirements of 6.2.

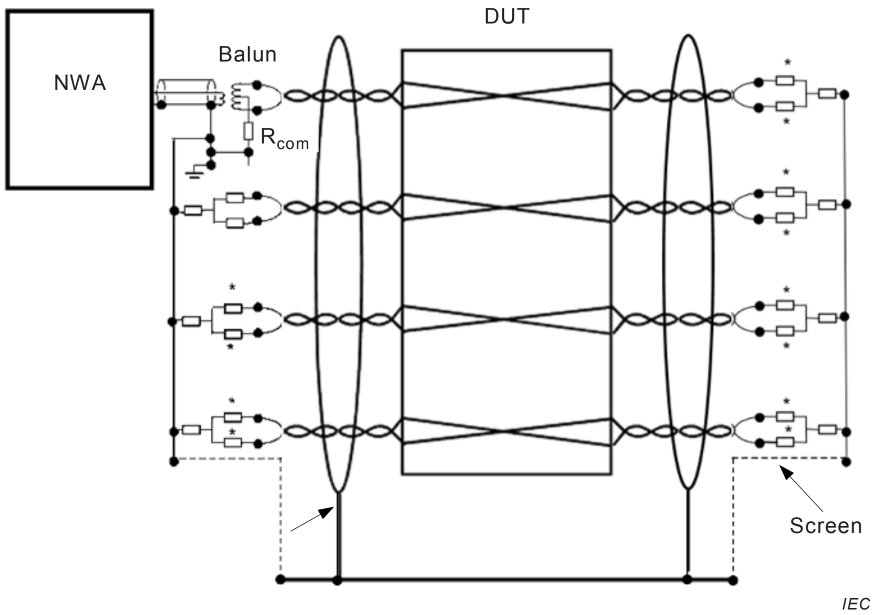
#### 5.3.3 Test method

Return loss is measured by measuring the scattering parameters, $S_{11}$ and $S_{22}$, of all the conductor pairs.

NOTE As a connector is a low-loss device, the return loss of the two sides is nearly equal.

#### 5.3.4 Test set-up

The test set-up is as described in Clause 4. Differential mode only termination resistors are recommended and shall satisfy the requirements of 4.5.3. When possible, it is recommended to use the same resistor terminations as were used for instrument calibration as the far-end terminations. Interconnect (if used) shall be prepared and controlled per 4.7.2 and shall satisfy the requirements of 4.5.3.




NOTE The line termination resistor networks marked with an asterisk (*) may also include only-differential-mode or balun-used termination.

**Figure 16 – Return loss measurement**

### 5.3.5 Procedure

#### 5.3.5.1 Calibration

A full one port, open, short, and load, calibration, shall be performed at the reference plane, as a minimum. A full two port calibration is also acceptable. The calibration load shall meet the requirements of 4.5.3.

#### 5.3.5.2 Measurement

$S_{11}$ and $S_{22}$ measurements shall be carried out for each of the pairs.

Pass-fail qualification is determined by comparing the results to the corresponding connecting hardware requirements plus 6 dB. These higher limits for the components are necessary to ensure the limits for the corresponding connecting hardware considering all worst-case scenarios.

### 5.3.6 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.

### 5.3.7 Accuracy

The return loss of the load for calibration is verified to be greater than 46 dB up to 100 MHz and greater than 40 dB at higher frequencies. The uncertainty of the connection between the connector under test and the baluns is expected to deteriorate the return loss of the set-up (effectively the directional bridge implemented by the test set-up) by 6 dB. The accuracy of the return loss measurements is then equivalent to measurements performed by a directional bridge with a directivity of 40 dB and 34 dB. The accuracy (uncertainty band) is given in Table 4 and Table 5.

**Table 4 – Uncertainty band of return loss measurement at frequencies below 100 MHz**

| Measured RL (dB) | 10 | 12 | 15 | 18 | 20 | 22 | 25 | 28 | 30 |
|---|---|---|---|---|---|---|---|---|---|
| Lower uncertainty limit (dB) | –0,3 | –0,3 | –0,5 | –0,7 | –0,8 | –1,0 | –1,4 | –1,9 | –2,4 |
| Higher uncertainty limit (dB) | +0,3 | +0,4 | +0,5 | +0,7 | +0,9 | +1,2 | +1,7 | +2,5 | +3,3 |

**Table 5 – Uncertainty band of return loss measurement at frequencies above 100 MHz**

| Measured RL (dB) | 10 | 12 | 15 | 18 | 20 | 22 | 25 | 28 | 30 |
|---|---|---|---|---|---|---|---|---|---|
| Lower uncertainty limit (dB) | –0,5 | –0,7 | –0,9 | –1,3 | –1,6 | –1,9 | –2,6 | –3,5 | –4,2 |
| Higher uncertainty limit (dB) | +0,6 | +0,7 | +1,0 | +1,3 | +1,9 | +2,5 | +3,8 | +6,0 | +8,7 |

EXAMPLE Let the measured RL be 20 dB. The true RL then lies in the band of 18,4 dB to 21,9 dB at frequencies above 100 MHz.

## 5.4 Near-end crosstalk (NEXT), Test 29c

### 5.4.1 Object

The object of this test procedure is to measure the magnitude of the electric and magnetic coupling between disturber and disturbed pairs of a mated connector pair.

### 5.4.2 Connector with male or female contacts for NEXT

Connecting hardware shall be tested in both directions for NEXT loss using at least one connector with male or female contacts. This connector with male or female contacts shall satisfy the requirements of Clause 6.

### 5.4.3 Test method

NEXT is evaluated by measuring the scattering parameters, $S_{21}$, of the possible conductor pair combinations at each end of the mated connector, while the other ends of the pairs are terminated.

### 5.4.4 Test set-up

The test set-up consists of two baluns and a network analyser. An illustration of the set-up, which also shows the termination principles, is shown in Figure 17.

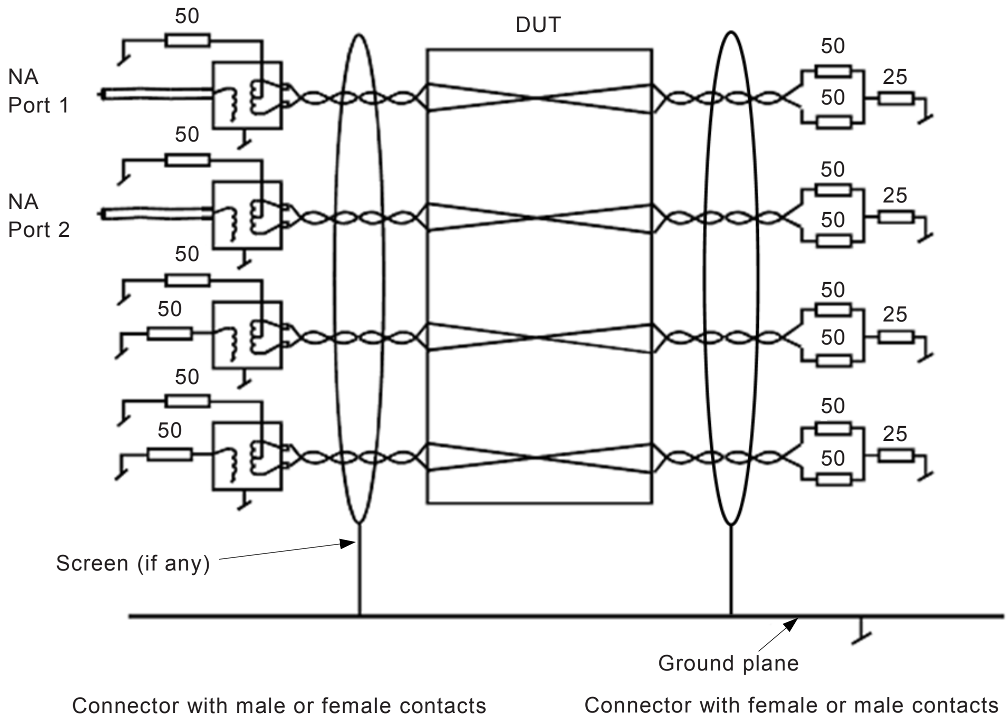



**Figure 17 – NEXT measurement**

### 5.4.5 Procedure

#### 5.4.5.1 Calibration

A full 2-port calibration shall be performed at the calibration planes.

#### 5.4.5.2 Establishment of noise floor

The noise floor of the set-up shall be measured. The level of the noise floor is determined by white noise, which may be reduced by increasing the test power and by reducing the bandwidth of the network analyser, and by residual crosstalk between the test baluns. The noise floor shall be measured by terminating the baluns with resistors and performing an $S_{21}$ measurement. The noise floor shall be 20 dB lower than any specified limit for the crosstalk. If the measured value is closer to the noise floor than 20 dB, this shall be reported.

For high crosstalk values, it may be necessary to screen the terminating resistors.

#### 5.4.5.3 Measurement

Connect the disturbing pair of the connector under test (DUT) to the signal source and the disturbed pair to the receiver port. The DUT shall be tested with differential and common mode terminations. The measurements have to be performed from both ends of the mated connector. The measurements from the connector with male or female contacts end shall be used in the calculations in 5.4.5.4, for full qualification in the forward and reverse direction. Test all possible pair combinations and record the results.

There are 6 different combinations of NEXT in a 4-pair connector from each side, which gives a total of 12 measurements for each kind of termination method. Because of reciprocity, only 6 unique non-reciprocal combinations from each side need to be tested.

#### 5.4.5.4 Connecting hardware NEXT loss measurement

a) Measure the magnitude of the NEXT loss vector for the connector with the direct fixture (DFP or DFJ) of the appropriate gender in forward and reverse direction.

b) Pass-fail qualification is determined by comparing the results to the corresponding connecting hardware requirements plus 6 dB. These higher limits for the components are necessary to ensure the limits for the corresponding connecting hardware considering all worst-case scenarios.

### 5.4.6 Test report

The results measured 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.

### 5.4.7 Accuracy

The accuracy shall be better than ±1 dB at measurements up to 60 dB and ±2 dB at measurements up to 85 dB.

## 5.5 Far-end crosstalk (FEXT), Test 29d

### 5.5.1 Object

The object of this test procedure is to measure the magnitude of the electric and magnetic coupling between disturber and disturbed pairs of mated connectors.

### 5.5.2 Connector with male or female contacts for FEXT

Connecting hardware FEXT loss is determined by measurement of connecting hardware using at least one direct fixture (DFP or DFJ) qualified per Clause 6. Measure connecting hardware FEXT loss with interconnects prepared and controlled per 4.7.

### 5.5.3 Test method

Far-end crosstalk is evaluated by measuring the scattering parameters, $S_{21}$, of the possible conductor pair combinations at one end of the mated connector, to the other end.

### 5.5.4 Test set-up

The test set-up consists of two baluns and a network analyser as defined in Clause 4. An illustration of the set-up, which also shows the termination principles, is shown in Figure 18.

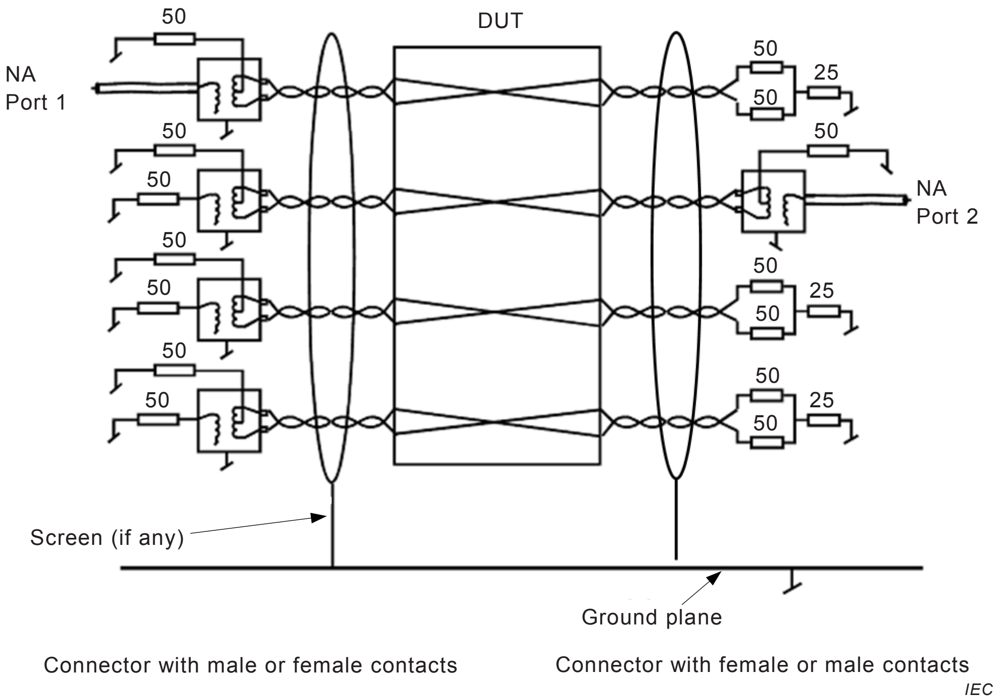



**Figure 18 – FEXT measurement for differential and common mode terminations**

### 5.5.5 Procedure

#### 5.5.5.1 Calibration

Calibration is performed as shown in 5.4.5.1.

#### 5.5.5.2 Establishment of noise floor

The noise floor of the set up is established as shown in 5.4.5.2.

#### 5.5.5.3 Measurement

Connect the disturbing pair of the DUT to the signal source and the disturbed pair to the receiver port. Test all possible pair combinations[1] and record the results.

#### 5.5.5.4 Connecting hardware FEXT loss measurement

a) Measure the magnitude of the FEXT loss vector for the connector with male or female contacts mated to the direct fixture (DFP or DFJ) in the forward direction (launch signal into the direct fixture).

b) Pass-fail qualification is determined by comparing the results to the corresponding connecting hardware requirements plus 6 dB. These higher limits for the components are necessary to ensure the limits for the corresponding connecting hardware considering all worst-case scenarios.

#### 5.5.5.5 Determining pass and fail

The response with the DUT shall meet the requirements of the detail specification for all pair combinations. These higher limits for the components are necessary to ensure the limits for the corresponding connecting hardware considering all worst-case scenarios.

1 There are 12 different combinations for far-end crosstalk in a 4-pair connector, which gives a total of 12 measurements.

#### 5.5.6 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 pair combinations shall be reported. It shall be explicitly noted if the measured results exceed the test limits.

#### 5.5.7 Accuracy

The accuracy shall be better than ±1 dB at measurements up to 60 dB and ±2 dB at measurements up to 85 dB.

### 5.6 Transfer impedance (ZT), Test 29e

The test methods of 60512-26-100, Test 26e also apply to testing connectors with frequency ranges up to 500 MHz.

### 5.7 Transverse conversion loss (TCL), Test 29f

#### 5.7.1 Object

The object of this test is to measure the mode conversion (differential to common mode) of a signal in the conductor pairs of the DUT. This is also called unbalance attenuation or Transverse conversion loss, TCL.

#### 5.7.2 Connector with male or female contacts for TCL

Connecting hardware TCL loss is determined by measurement of connecting hardware using a DFJ or DFP qualified per 6.2. Measure connecting hardware TCL loss with interconnects prepared and controlled per 4.7.

#### 5.7.3 Test method

The balance is evaluated by measuring the common-mode part of a differential-mode signal, which is launched in one of the conductor pairs of the DUT.

#### 5.7.4 Test set-up

The test set-up consists of a network analyser and a balun with a differential-and common-mode test port. An illustration of the set-up, which also shows the termination principles, is shown in Figure 19. The DUT pair under test should be connected to the differential mode balun output terminals. All unused near-end pairs should be terminated as shown in Figure 5. All far-end pairs should be terminated as shown in Figure 5. The near-end and far-end terminating resistor networks should be bonded and connected to the measurement ground plane. The DUT should be positioned 50 mm from the ground plane on the near-end. The near-end interconnects connecting the DUT to the balun and terminations should be no longer than 51 mm and they should be oriented orthogonal to each other to minimize coupling.

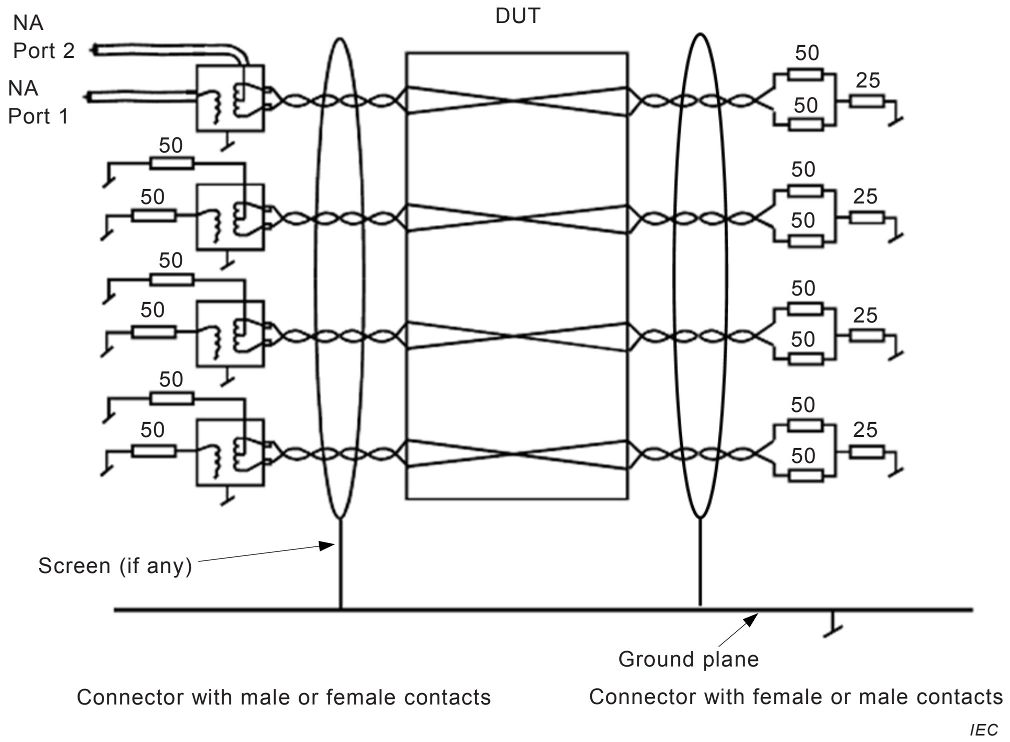



**Figure 19 – TCL measurement**

### 5.7.5 Procedure

#### 5.7.5.1 Calibration

TCL calibration is performed in three steps.

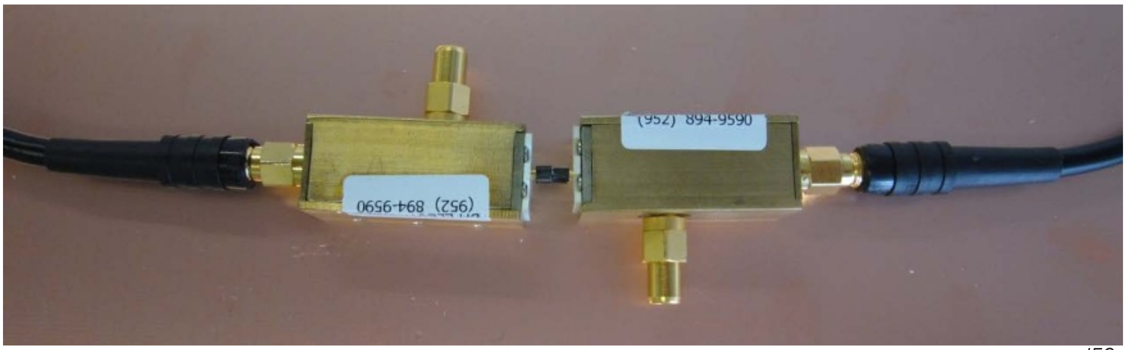
STEP 1: The coaxial interconnect attached to the network analyzer are calibrated out by performing short, open, load, and through measurements at the point of termination to the balun. An example of the test lead through connection is shown in Figure 20.


**Figure 20 – Coaxial lead attenuation calibration**

STEP 2: The attenuation of the differential signals of the test balun is measured by connecting two identical baluns back-to-back with minimal lead length an example of which is shown in Figure 21.

Notice that the baluns are positioned so as to maintain polarity and they are bonded (firmly attached, e.g. clamped) to a ground plane. The measured insertion loss is divided by 2 to approximate the insertion loss of one balun for a differential signal.

The calculated insertion loss is recorded as $IL_{\text{bal,DM}}$ .




IEC

**Figure 21 – Back to back balun insertion loss measurement**

STEP 3: The attenuation of the common mode signals of the test balun is measured by connecting the balanced port and ground reference terminals of two baluns together, and the network analyzer ports to the common mode sockets, as shown in Figure 22 and 23.

A short length of bare wire may be used to connect each of the individual balun terminals. It is important to also connect the ground references. The baluns shall be firmly clamped to the ground plane. Also, the outer shield of the coaxial test lead shall be properly bonded to the ground plane as shown in Figure 19. Divide by 2 to obtain the common mode insertion loss of one balun. The resulting insertion loss is recorded as $IL_{\text{bal,CM}}$.


**Figure 22 – Configuration for balun common mode insertion loss calibration**

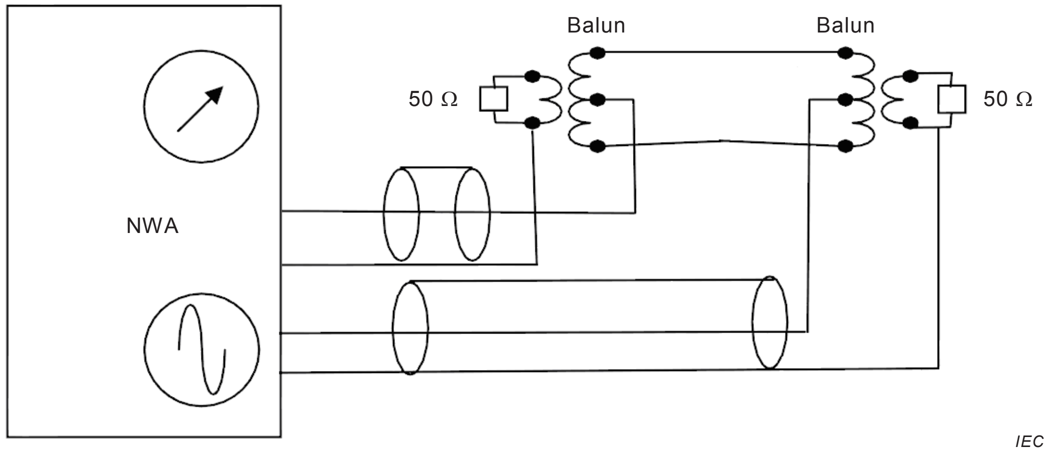



**Figure 23 – Schematic for balun common mode insertion loss calibration**

Additionally, a correction term for the impedance ratio of the balun transformer converting from 50 Ω on the network analyzer to 100 Ω on the DUT is needed.

### 5.7.5.2 Noise floor

The noise floor of the set-up shall be measured. The level of the noise floor is determined by white noise, which may be reduced by increasing the test power and by reducing the bandwidth of the network analyser, and by the longitudinal balance (see Table 1) of the test balun. The noise floor, $a_{noise,m}$ shall be measured by terminating the differential output of the balun with a 100 Ω resistor and perform a $S_{21}$ measurement between the differential-mode and the common-mode test port of the balun. $a_{noise}$ is calculated as:

$$a_{noise,m} = -20\log|S_{21}| \quad (2)$$

$$a_{noise} = a_{noise,m} - a_{bal,DM} - a_{bal,CM} \quad (3)$$

The noise floor shall be 20 dB lower than any specified limit for balance. If the measured value is closer to the noise floor than 10 dB, this shall be reported.

### 5.7.5.3 Measurement

Connect the measured pair of the DUT to the differential output of the test balun. Terminate the DUT according to 5.7.4. Perform a $S_{21}$ measurement between the differential-mode and the commonmode test port of the balun. The balance, *TCL*, is calculated as:

$$a_{meas} = -20\log|S_{21}| \quad (4)$$

$$TCL = a_{meas} - a_{bal,DM} - a_{bal,CM} \quad (5)$$

### 5.7.6 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.

### 5.7.7 Accuracy

The accuracy shall be better than ±1 dB at the specification limit.

## 5.8 Transverse conversion transfer loss (TCTL), Test 29g

### 5.8.1 Object

The object of this test is to measure the mode conversion (differential to common mode) of a signal in the conductor pairs of the DUT. This is also called unbalance attenuation or Transverse conversion transfer loss, TCTL.

### 5.8.2 Connector with male or female contacts for TCTL

Connecting hardware TCTL loss is determined by measurement of connecting hardware using a TFP qualified per 6.2. Measure connecting hardware TCTL loss with interconnects prepared and controlled per 4.7.

### 5.8.3 Test method

The balance is evaluated by measuring the common-mode part of a differential-mode signal, which is launched in one of the conductor pairs of the DUT.

### 5.8.4 Test set-up

The test set-up consists of a network analyser and a balun with a differential-and common-mode test port. An illustration of the set-up, which also shows the termination principles, is shown in Clause 4. All unused pairs on both ends of the connecting hardware shall be terminated with 50 Ω common and 100 Ω differential resistor terminations as shown in Figure 24. There shall be a common ground at each end. The grounds of the two ends of the connecting hardware under test shall be connected securely to the same ground plane.

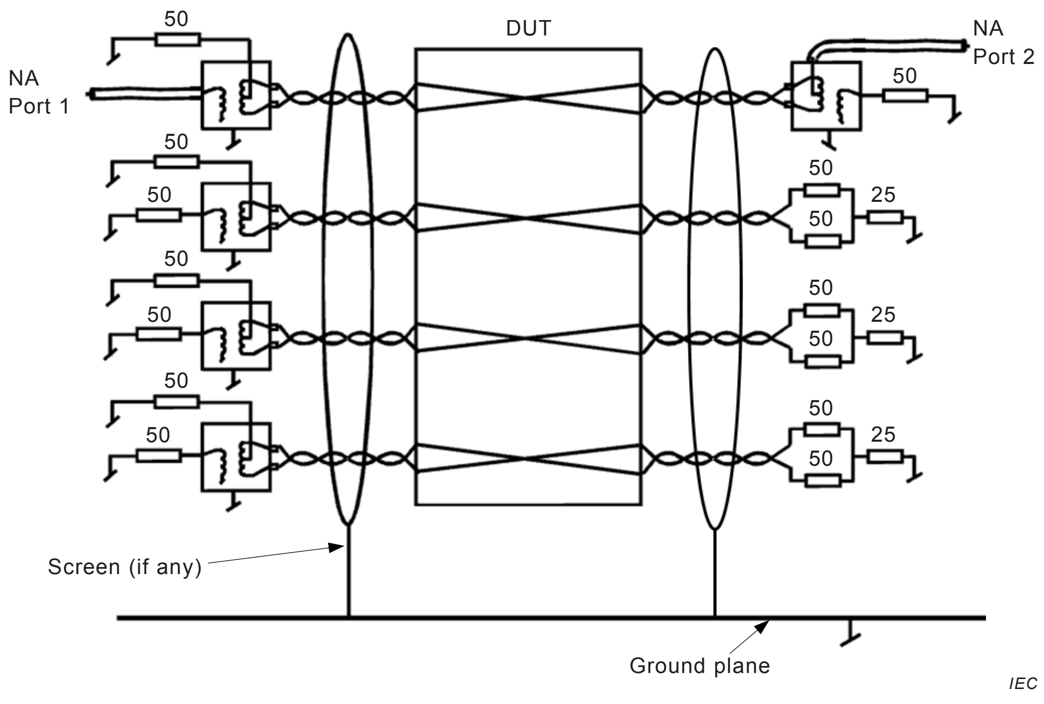



**Figure 24 – TCTL measurement**

#### 5.8.5 Procedure

##### 5.8.5.1 Calibration

The calibration of the test hardware for TCTL measurements shall follow the procedure outlined in 5.7.5.1 for both baluns being used in the measurement and both the common and differential mode calibration values should be recorded for both baluns, a total of four calibration values. The calibration values should be recorded as

$a_{\text{bal ,DM.1}}$, $a_{\text{bal DM.2}}$, $a_{\text{bal CM.1}}$, and $a_{\text{bal CM.2}}$

##### 5.8.5.2 Noise floor

The same requirements as described in 5.7.5.2 for TCL measurements apply.

##### 5.8.5.3 Measurement

Connect the measured pair of the DUT to the differential output of the test balun. Terminate the DUT according to 5.8.4. Perform a $S_{21}$ measurement between the differential-mode and the common-mode test port of the balun. The balance, *TCTL*, is calculated as

$$a_{\text{meas}} = -20\log S_{21} \quad (6)$$

$$TCTL = a_{\text{meas}} - a_{\text{bal,DM}} - a_{\text{bal,CM}} \quad (7)$$

#### 5.8.6 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.

#### 5.8.7 Accuracy

The accuracy shall be better than ±1 dB at the specification limit.

### 5.9 Coupling attenuation

Coupling attenuation measurements, when required by the detail specification, apply only to shielded connectors.

Coupling attenuation shall be performed according to ISO/IEC 11801 Am2 for limiting values and test methods, over the frequency range of 100 MHz to 500 MHz.

## 6 Construction and qualification of direct fixtures (DFP and DFJ)

### 6.1 General

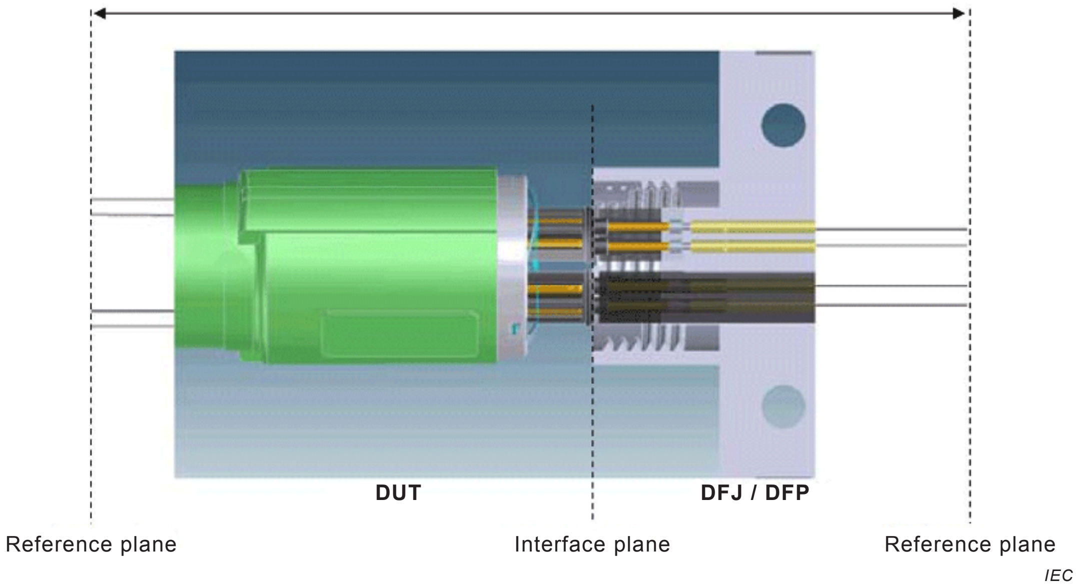
For the qualification of M12-Connectors it is necessary to use suitable direct fixtures.

This clause describes the construction, qualification, and requirements of direct fixtures for verifying connecting hardware performance.

For the purposes of this Standard, a direct fixture consists of an assembly that meets the dimensional requirements of a M12-connector with male or female contacts.

Direct fixtures shall be qualified for all requirements of 5.4 (NEXT loss), 5.5 (FEXT loss), 5.2 (Insertion loss) and 5.3 (return loss).

The reference planes should be as close as possible to the interface plane as shown in Figure 25.




NOTE Shown with a mating interface according to IEC 61076-2-109 and only with two pairs.

**Figure 25 – Reference planes**

## 6.2 Direct fixtures for DUT testing

### 6.2.1 Requirements for direct fixture up to 100 MHz

A direct fixture up to 100 MHz is used during DUT NEXT and FEXT measurements and may also be used for DUT return loss measurements. The performance of the direct fixture is according Table 6. See Annex A for an example and source of a direct fixture. This fixture shall conform to the dimensional requirements of IEC 61076-2-101 and to the transmission requirements of Clause 5. Figure 26 and Figure 27 show an example for the connector according to IEC 61076-2-101, M12, d-code. The respective direct fixture (DFJ or DFP) is compatible with connectors with male contacts or female contacts as defined by IEC 61076-2-101. Test fixtures described in Annex A are designed to provide suitable interface and termination.

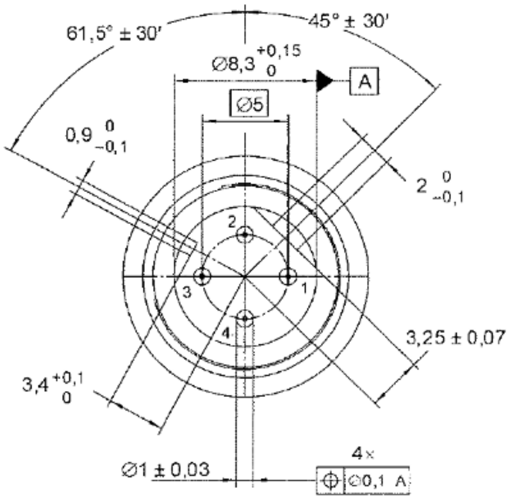



**Figure 26 – Direct fixture M12, d-code mating face**

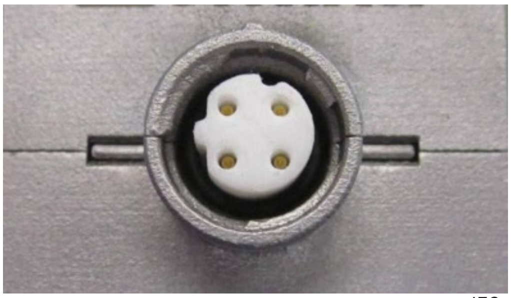



**Figure 27 – Direct fixture M12, d-code**

**Table 6 – Direct fixture M12, performance up to 100 MHz**

| Direct fixture M12, d-code performance parameter | Value dB |
|---|---|
| Pair-to-pair residual NEXT loss | > 103 – 20 log($f$) ,75 dB max |
| Pair-to-pair residual FEXT loss | > 95,1 – 20 log($f$) ,75 dB max |
| Return loss | > 66 – 20 log($f$) ,40 dB max |
| Insertion loss | 0,04$\sqrt{f}$ , 0,1 dB max |

### 6.2.2 Requirements for direct fixture up to 500 MHz

A direct fixture up to 500 MHz is used during DUT NEXT and FEXT measurements and may also be used for DUT return loss measurements. The performance of the direct fixture is according Table 7. See Annex A for an example and source of a direct fixture. This fixture shall conform to the dimensional requirements of IEC 61076-2-109 and to the transmission requirements of Clause 5. Figure 28 and Figure 29 show an example for the connector according to IEC 61076-2-109, M12, x-code. The respective direct fixture (DFJ or DFP) is compatible with connectors with male contacts or female contacts as defined by IEC 61076-2-109. Test fixtures described in Annex A are designed to provide suitable interface and termination.

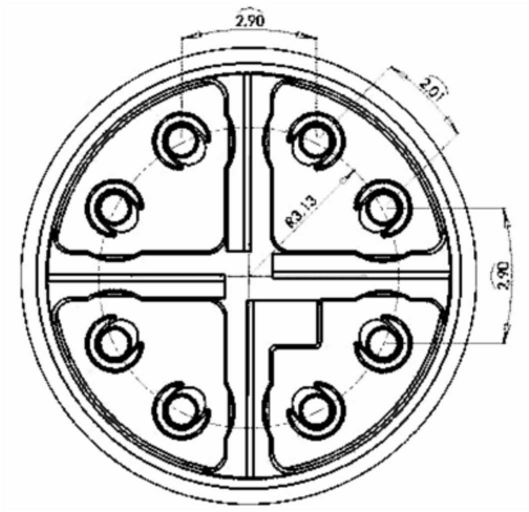



**Figure 28 – Direct fixture M12, x-code mating face**

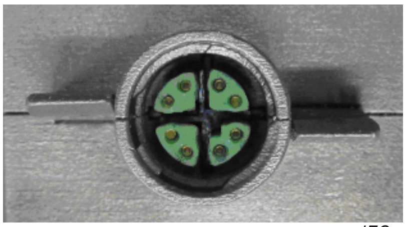



**Figure 29 – Direct fixture M12, x-code**

**Table 7 – Direct fixture M12, performance up to 500 MHz**

| **Direct fixture M12, x-code performance parameter** | **Value** dB |
|---|---|
| Pair-to-pair residual NEXT loss | > 109 – 20log($f$) ,75 dB max |
| Pair-to-pair residual FEXT loss | > 103,1 – 20log($f$) ,75 dB max |
| Return loss | > 74 – 20log($f$) ,40 dB max |
| Insertion loss | 0,02$\sqrt{f}$ , 0,1 dB max |

# Annex A
(normative)

# Impedance controlled measurement fixture

## A.1 General

An impedance controlled measurement fixture consists of a device designed to provide controlled interconnections to the DUT. The fixture provides an interface that is designed to maintain correct DM and CM impedance of the pairs in the transmission line when they are separated for interfacing between the DUT and the port interfaces of test equipment. The port interfaces of test equipment, which are typically 50 Ω, coaxial ports are further conditioned by the use of balun transformers presenting a 100 Ω balanced port to the DUT. The interface, in addition to providing impedance control of the balanced leads of the DUT, also provides shielding for the pairs to reduce unwanted pair-to-pair couplings. The interface is electrically connected to the balun and instrument ground reference through pin and socket connectors. An example fixture, as shown in Figure A.1 and A.2, provides pin and socket connections to the DUT. Termination adapters which provide DMCM resistor terminations for the inactive ports are provided for making NEXT loss and FEXT loss measurements where the highest accuracy is required.

NOTE Photos are for illustrative purposes only and do not constitute an endorsement by IEC.

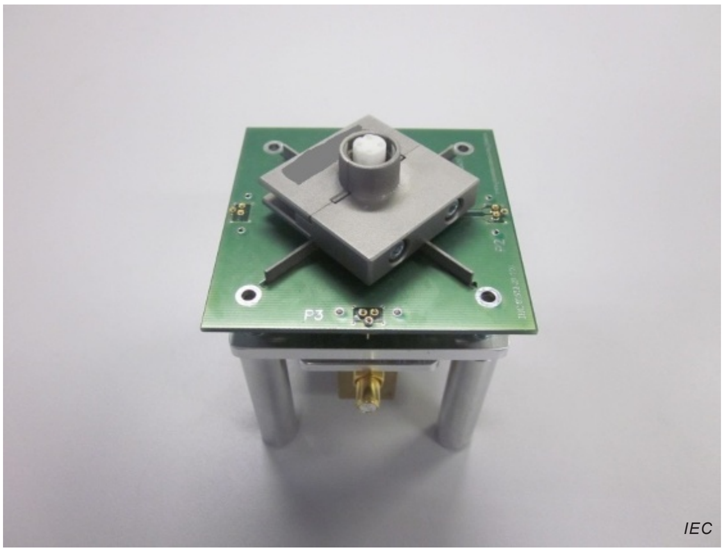



**Figure A.1 – Test head assembly M12, d-code with baluns attached**

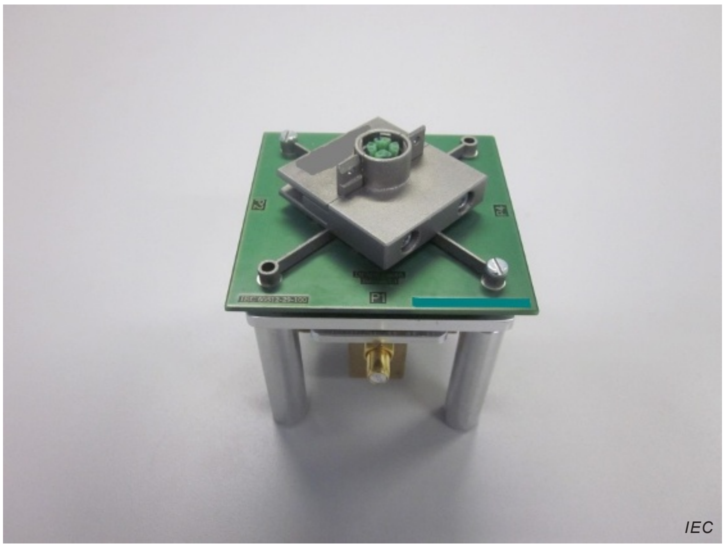



**Figure A.2 – Test head assembly M12, x-code with baluns attached**

Calibration standards are provided which use the same materials and positioning. The calibration plane is thereby located at the top (open end) of the sockets of the adapter mounting plate. A mounting plate with socket interfaces connects directly to the test baluns. Two such fixtures will provide 8 test ports for connection to both near and far ends of a four pair DUT.

The balun interfaces are designed to mate to BH electronics 040-0192 baluns.

Alternative equivalent components may also be used.

Future developments of test fixtures are expected. Such fixtures may be used in place of or in addition to those specified and recommended in this Standard, if they meet the relevant requirements specified in this Standard.

## A.2 Load

The load is needed to evaluate the direct fixture M12. The Figure A.3 shows the evaluation of the direct fixture M12.

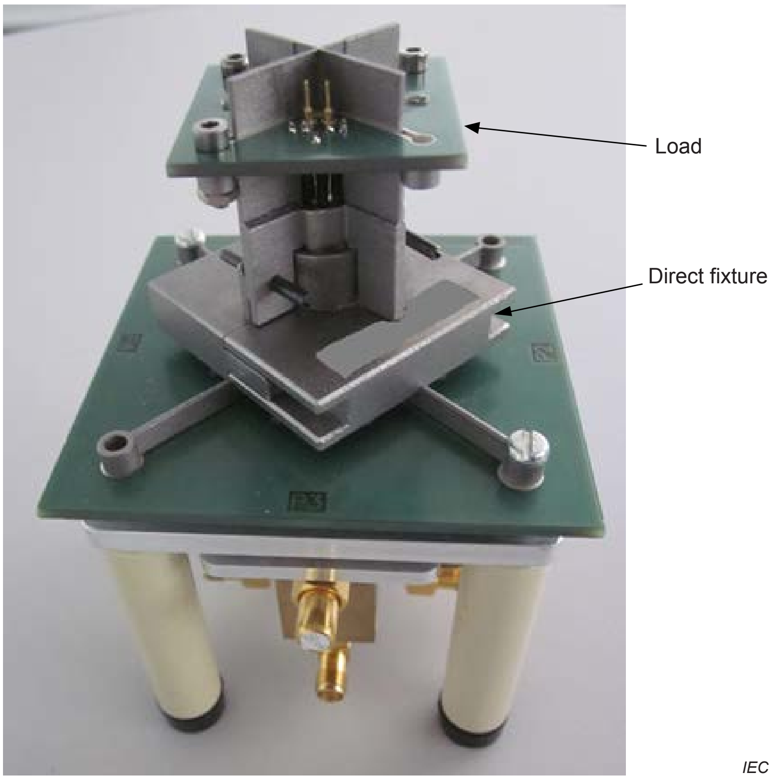



**Figure A.3 – Test head assembly M12 mated with the load M12**

In the connected state, the requirements from the direct fixture are observed from Table 6 for M12, d-code and Table 7 for M12, x-code. The requirements from the loads are measured in the reverse direction. Figure A.4, A.5 and A.6 show the test setup for evaluating the loads.

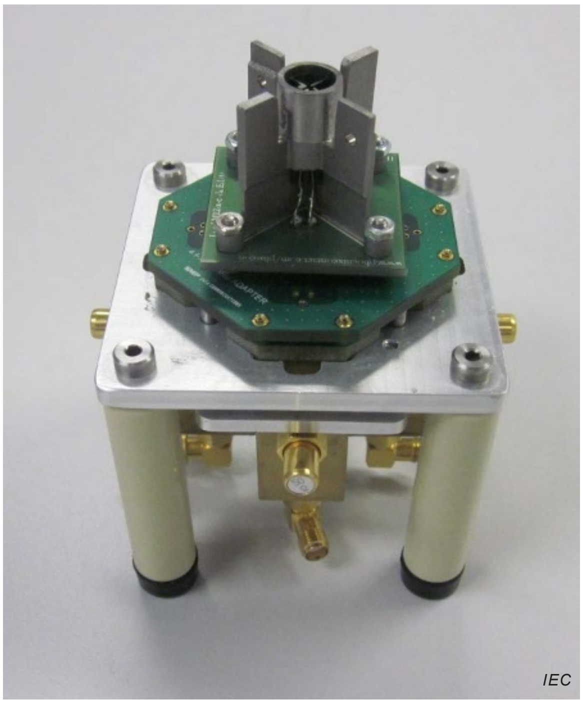
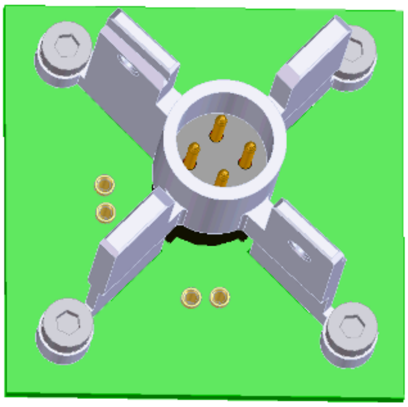



**Figure A.4 – Balun test fixture with the load M12**


**Figure A.5 – Load M12, x-code**



IEC

**Figure A.6 – Load M12, d-code**

Table A.1 and Table A.2 are the requirements from the loads when measured in the reverse direction.

**Table A.1 – Load M12, performance up to 500 MHz**

| Load M12, up to 500 MHz performance parameter | Value dB |
|---|---|
| Pair-to-pair residual NEXT loss | > 104 – 20 log(*f*) ,75 dB max |
| Return loss | > 71 – 20 log(*f*) ,40 dB max |

**Table A.2 – Load M12, performance up to 100 MHz**

| Load M12, up to 100 MHz performance parameter | Value dB |
|---|---|
| Pair-to-pair residual NEXT loss | 103 – 20 log(*f*) ,75 dB max |
| Return loss | > 63 – 20 log(*f*) ,40 dB max |

## A.3 Additional components for connection to a network analyzer

SMA cables, connectors, 50Ω SMA terminations, are necessary for interfacing the coaxial ports of the baluns to network analyzer ports as shown in Figures A.7 and A.8. Mounting brackets are recommended for holding the test interface assemblies at convenient positions for attachment to connectors under test. Foil tape with conductive adhesive 3M 5012C or equivalent may be used for where additional shielding is needed for various components. Alternative equivalent components may also be used. This information does not constitute an endorsement by IEC.


**Figure A.7 – Test head showing shielding between baluns**

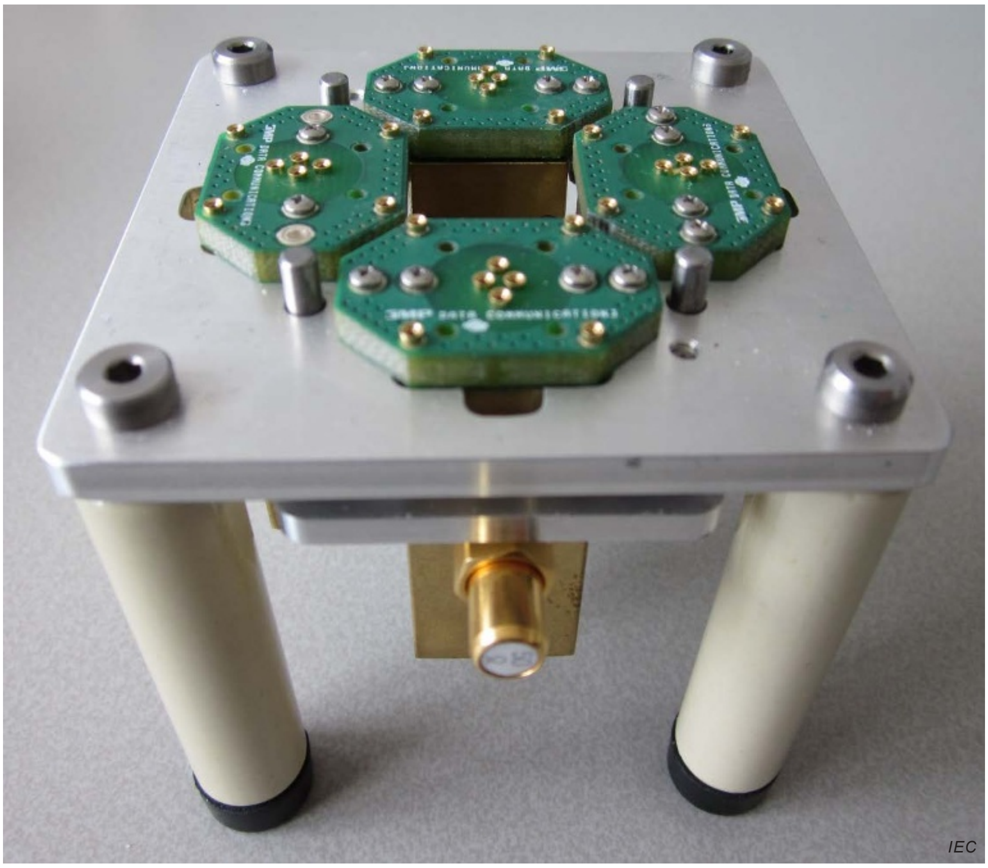



**Figure A.8 – Balun test fixture assembly**

## A.4 Direct fixture

A fixture for direct measurement of DUT properties has shielded probes that make contact with the connector with male (DFP) or female (DFJ) contacts. A construction for a DFJ is shown in Figures A.9 to A.13

The fixture has levels of crosstalk and return loss compliant with Table 6. Insertion loss, NEXT loss, FEXT loss, return loss and TCL/TCTL measurements can be made using this fixture.

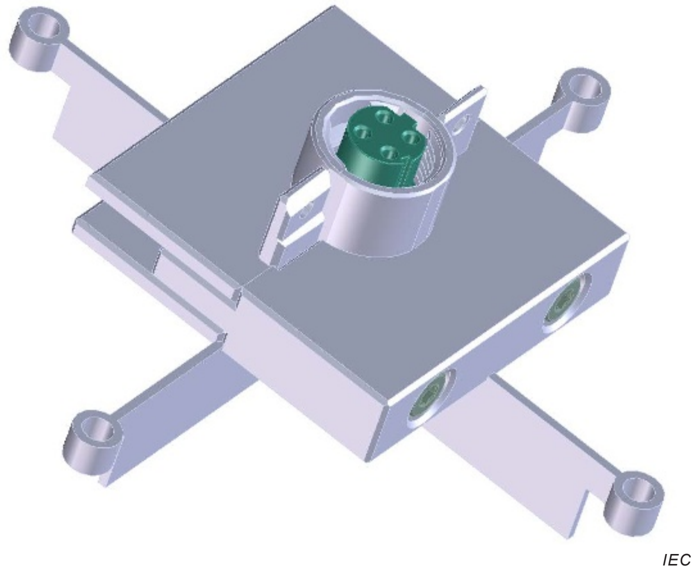



**Figure A.9 – Direct fixture M12, d-code (DFJ) for DUT with male contacts**

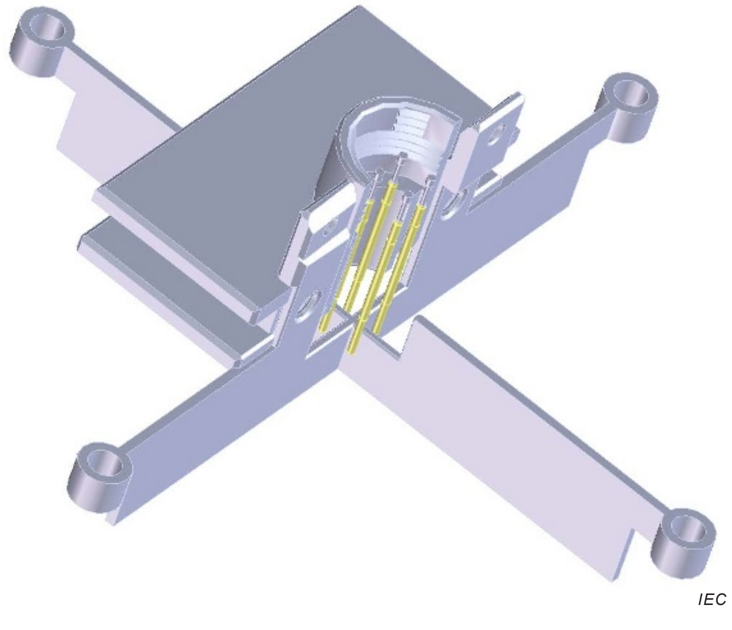



**Figure A.10 – Direct fixture M12, d-code (DFJ) for DUT with male contacts**

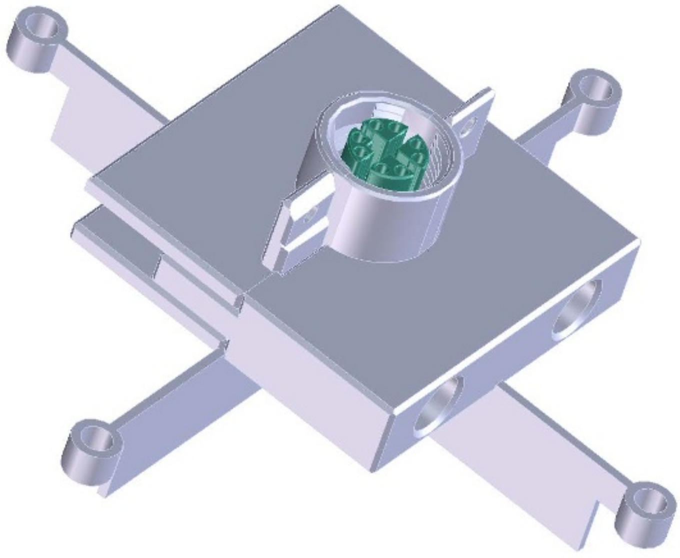



**Figure A.11 – Direct fixture M12, x-code (DFJ) for DUT with male contacts**

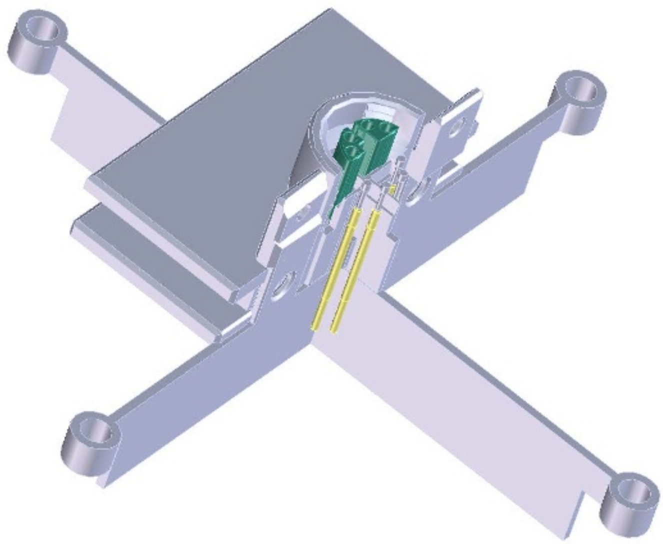
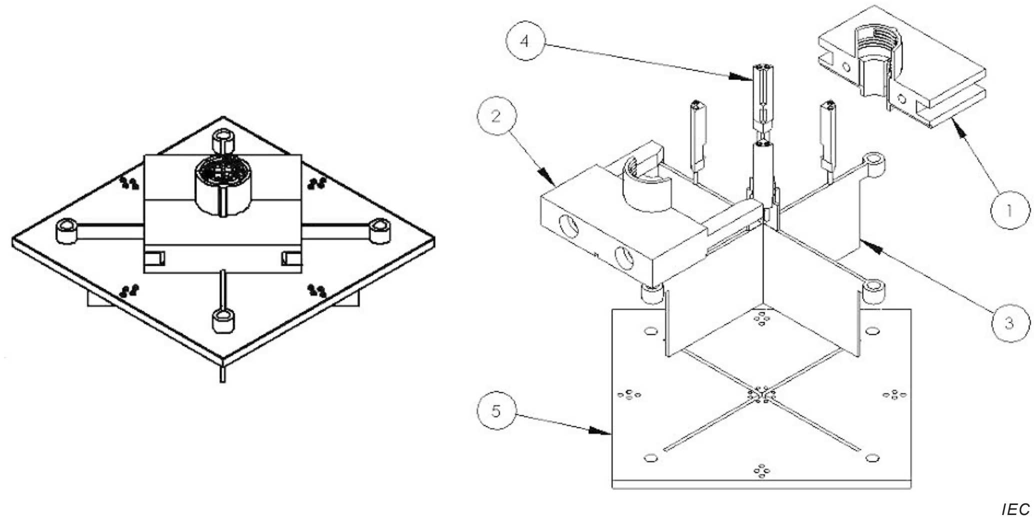



**Figure A.12 – Direct fixture M12, x-code (DFJ) for DUT with male contacts – Cross-cut**




**Key**

1) Half-shell from metal
2) Half-shell from metal
3) Shielding cross
4) Contact needles
5) PCB direct fixture

**Figure A.13 – Exploded assembly of the direct fixture (DFJ)**

## A.5 Connecting hardware measurement 1 configuration

Figure A.14 shows an example of a connecting hardware measurement configuration.

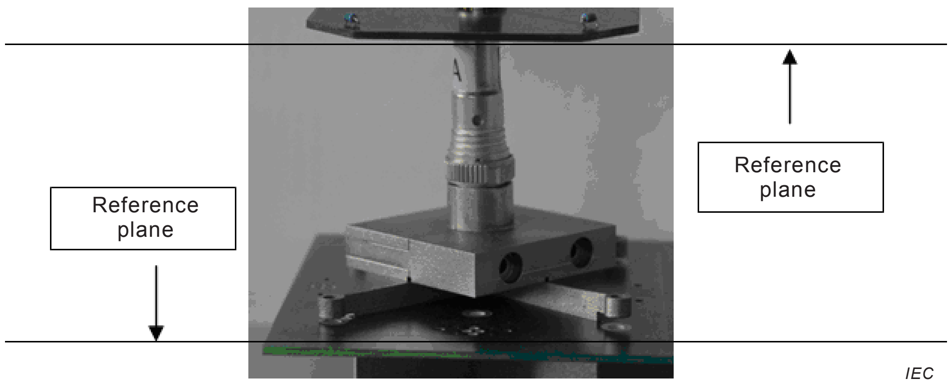



**Figure A.14 – Example of a connecting hardware measurement configuration**

## A.6 DUT connections using header PCB assemblies

One method to minimize the effects of interconnecting leads is to use dedicated PCB header assemblies to connect between the DUT and the test equipment. These PCB headers contain connections to interface to the test port and also connections to interface to the DUT terminals or IDC slots.

NOTE For reference sources, see Annex B.

# Annex B
(informative)

# Reference source

## B.1 Test fixture components

All test fixture components referenced in Annex A including the direct fixture DFJ or DFP may be obtained from: Phoenix Contact GmbH Co.KG, Flachsmarktstrasse 8, D-32825 Blomberg, Germany, www.phoenixcontact.com. These test fixtures are provided in kit form including adapter plates, balun mounting plates, baluns and calibration references.

NOTE Reference sources are for illustrative purposes only and do not constitute an endorsement by IEC.

# Annex C
(informative)

# Related connectors

The test methods described in this standard apply especially to the connectors according to Table C.1.

**Table C.1 – Related connectors**

| **Connector standard** | **Poles** | **Coding** | **Max. frequency** MHz |
|---|---|---|---|
| IEC 61076-2-101 | 4 | D | 100 |
| IEC 61076-2-109 | 8 | X | 500 |
| IEC PAS 61076-2-110 | 8 | H | 500 |

# Annex D
(informative)

## Interface to test fixtures

For ease of interfacing to test fixtures, a pin and socket interface with dimensions as shown in Figure D.1 and Figure D.2 is recommended. Gold plated sockets are recommended.

NOTE Mill-Max part number 1001-0-15-15-30-27-04-0 as shown in Figure D.2. Alternative equivalent components may also be used. This information does not constitute an endorsement by IEC.

*Dimensions in mm*

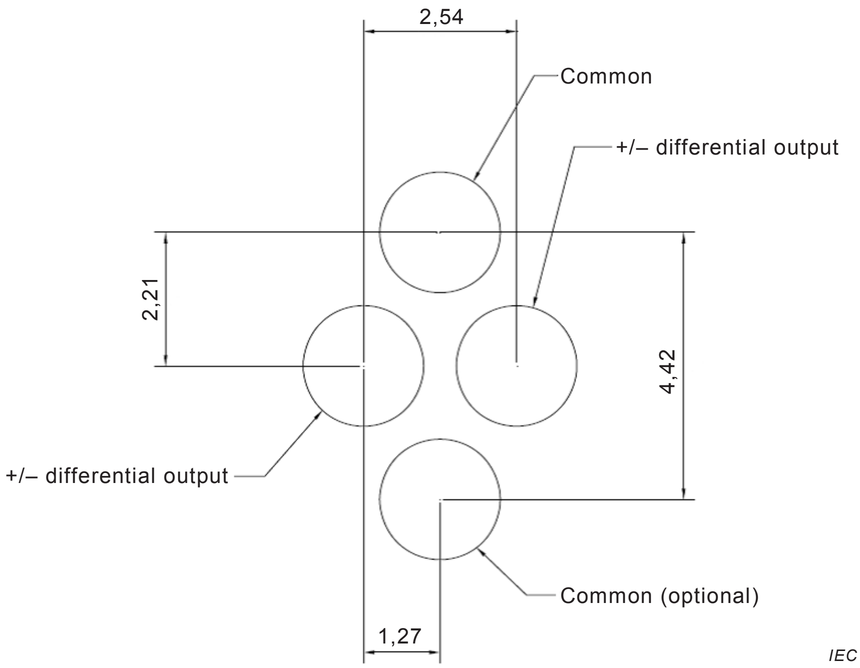



**Figure D.1 – Test balun interface pattern**

*Dimensions in mm*

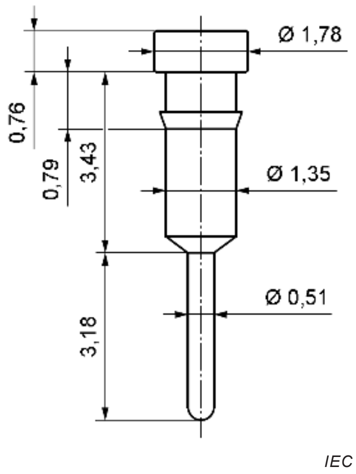



**Figure D.2 – Example pin and socket dimension**

Example socket description:

Mill-Max 1001-0-15-15-30-27-04-0

Material: Brass alloy

Contact: 30 = Standard 4 finger contact

Contact material: Beryllium copper

Shell plating: 0,254 μm (10 μ") gold over nickel

Contact plating: 0,762 μm (30 μ") gold over nickel

Press-in 1,45 mm (0,057 in) mounting hole

# Bibliography

IEC 60050-581, *International Electrotechnical Vocabulary – Part 581: Electromechanical components for electronic equipment*

IEC 60512-27-100, *Connectors for electronic equipment – Tests and measurements – Part 27-100: Signal integrity tests up to 500 MHz on IEC 60603-7 series connectors – Tests 27a to 27g*

IEC PAS 61076-2-110, *Connectors for electronic equipment – Product requirements – Part 2-110: Circular connectors – Detail specification for circular connectors M12 x 1 with screw-locking, for high speed Ethernet and high speed data communication with frequencies up to 500 MHz and 10 gigabits/s*

IEC 61156 (all parts), *Multicore and symmetrical pair/quad cables for digital communications*

___________

*This page deliberately left blank*

# British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

## About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

## Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

## Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

## Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

**PLUS** is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

## Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

## Copyright



## Useful Contacts:

**Customer Services**
**Tel:** +44 845 086 9001
**Email (orders):** orders@bsigroup.com
**Email (enquiries):** cservices@bsigroup.com

**Subscriptions**
**Tel:** +44 845 086 9001
**Email:** subscriptions@bsigroup.com

**Knowledge Centre**
**Tel:** +44 20 8996 7004
**Email:** knowledgecentre@bsigroup.com

**Copyright & Licensing**
**Tel:** +44 20 8996 7070
**Email:** copyright@bsigroup.com

**BSI Group Headquarters**

389 Chiswick High Road London W4 4AL UK