

INTERNATIONAL STANDARD

NORME INTERNATIONALE



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

**Connecteurs pour équipements électroniques – Essais et mesures –
Partie 27-100: Essais d'intégrité des signaux jusqu'à 500 MHz sur les
connecteurs de la série CEI 60603-7 – Essais 27a à 27g**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**CONNECTORS FOR ELECTRONIC EQUIPMENT –
TESTS AND MEASUREMENTS –**
**Part 27-100: Signal integrity tests up to 500 MHz
on 60603-7 series connectors –
Tests 27a to 27g**
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International Standard IEC 60512-27-100 has been prepared by subcommittee 48B: Connectors, of IEC technical committee 48: Electromechanical components and mechanical structures for electronic equipment.

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

FDIS	Report on voting
4B/2262/FDIS	48B/2275/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.

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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

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CONNECTORS FOR ELECTRONIC EQUIPMENT – TESTS AND MEASUREMENTS –

Part 27-100: Signal integrity tests up to 500 MHz on 60603-7 series connectors – Tests 27a to 27g

1 Scope and object

This part of IEC 60512 specifies the test methods for transmission performance for IEC 60603-7 series 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.

The test methods provided here are:

- insertion loss, test 27a;
- return loss, test 27b;
- near-end crosstalk (NEXT) test 27c;
- far-end crosstalk (FEXT), test 27d;
- transverse conversion loss (TCL), test 27f;
- transverse conversion transfer loss (TCTL), test 27g;

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

For the coupling attenuation, see IEC 62153-4-12.

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 60050–581, *International Electrotechnical Vocabulary (IEV) – Part 581: Electromechanical components for electronic equipment*

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

IEC 60512-1-100, *Connectors for electronic equipment – Tests and measurements – Part 1-100: General - Applicable publications*

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 60603-7 (all parts), *Connectors for electronic equipment*

IEC 60603-7, 2008: *Connectors for electronic equipment – Part 7: Detail specification for 8-way, unshielded, free and fixed connectors*

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

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

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 – Characteristic impedance 50 ohms (75 ohms) (Type N)*

IEC 62153-4-12, *Metallic communication cable test methods – Part 4-12: Electromagnetic compatibility (EMC) – Coupling attenuation or screening attenuation of connecting hardware – Absorbing clamp method*

3 Terms, definitions, acronyms and symbols

NOTE It should be noted that this document, although having a close relationship with corresponding documents, which use different terminology to that used in those documents.

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, IEC 60603-7 as well as the following, apply.

3.1.1 Test Free Connector (TFC)

free connector, which is constructed such that it is a test artefact, is known as a Test Free Connector (TFC)

3.2 Acronyms

For ease of reference, acronyms used in this standard are given below.

ACRF	Attenuation to crosstalk ratio, far-end
CM	Common mode
CMR	Common mode rejection
DM	Differential mode
DMCM	Differential mode plus common mode
DUT	Device under test
EIA	Electronic Industries Alliance
ELTCTL	Equal level transverse conversion transfer loss
FEXT	Far-end crosstalk
F/UTP	Foil (surrounding) unscreened twisted-pairs
ICEA	Insulated Cable Engineers Association
IDC	Insulation displacement connection
IPC	Insulation piercing connection
NEXT	Near-end crosstalk
OSB	Output signal balance
PSAACRF	Power sum attenuation to alien crosstalk ratio, far-end
PSACRF	Power sum attenuation to crosstalk ratio, far-end
PSANEXT	Power sum alien near-end crosstalk
PSFEXT	Power sum far-end crosstalk

PSNEXT	Power sum near-end crosstalk
RL	Return Loss
TCTL	Transverse conversion transfer loss
TFC	Test free connector
TIA	Telecommunications Industry Association
U/UTP	Unshielded twisted-pair
Z _t	Transfer impedance

3.3 Symbols

A	terminal of balun
<i>a</i>	insertion loss; equation coefficient
B	terminal of balun
<i>b</i>	equation coefficient
C	terminal of balun
D	terminal of balun
<i>f</i>	frequency
J	fixed connector; socket
<i>k</i>	equation coefficient
P	free connector
R _x	resistor
S _{xy}	normalized S-parameter
T _{xy}	T-parameter
<i>TD</i>	time delay
Z _t	transfer impedance
Ω	Ohms
%	percent
°	degree

4 Overall test arrangement

4.1 Test instrumentation

All test instrumentation shall be qualified for use over the frequency range of 1 MHz to 500 MHz.

These test procedures require the use of a vector network analyser. The analyser should have the capability of full 2-port calibrations. The analyser shall cover the frequency range of 1 MHz to 500 MHz 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 4.4.

Optionally; multi-port network analyzers for balun-less test set-up may be used.

Reference loads and cables are needed for the calibration of the set-up. Requirements for the reference loads, and cables are given in 4.6.1 and 4.6.2 respectively.

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 4.7.

An absorbing clamp and ferrite absorbers are needed for the coupling attenuation measurements. The requirements for these items are given in IEC 62153-4-12.

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 between the test equipment and the connector under test shall meet the requirements given in 4.9.2.

4.3 Measurement precautions

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

- Any measurement that is to be used in a de-embedding or re-embedding process, whether vector or matrix, shall have its phase adjusted to the free connector phase reference plane. Methods to do this are provided.
- Consistent and stable balun and resistor loads shall be used for each pair throughout the test sequence.
- Cable and adapter discontinuities, as introduced by physical flexing, sharp bends and restraints shall be avoided before, during and after the tests.
- 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.

- The balance of the cables is maintained to the greatest extent possible by consistent conductor lengths and pair twisting to the point of load.
- The sensitivity to set-up variations for these measurements at high frequencies demands attention to details for both the measurement equipment and the procedures.

4.4 Balun requirements

The baluns may be balun transformers or 180° hybrids with attenuators to improve matching if needed. Figure 1 shows such an arrangement.

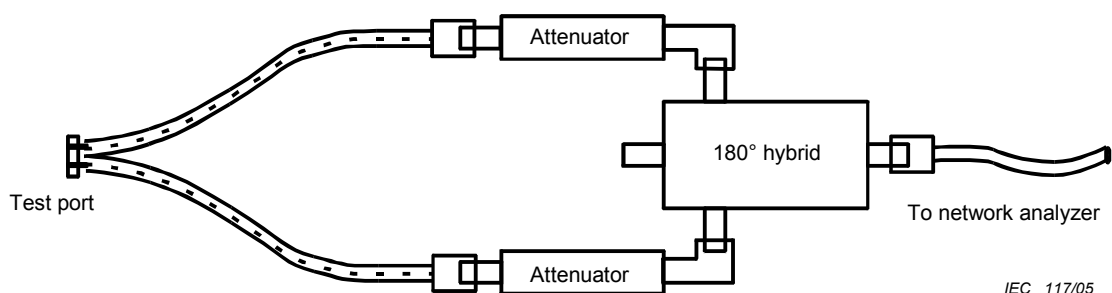


Figure 1 – Optional 180° hybrid used as a balun

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.

Table 1 – Test balun performance characteristics

Parameter	Frequency (MHz)	Value
Impedance, primary ^a	$1 \leq f \leq 500$	50 Ω unbalanced
Impedance, secondary	$1 \leq f \leq 500$	100 Ω balanced
Insertion loss	$1 \leq f \leq 500$	2,0 dB maximum
Return loss, bi-directional ^b	$1 \leq f < 15$	12 dB minimum
	$15 \leq f \leq 500$	20 dB minimum
Return loss, CM ^b	$1 \leq f < 15$	15 dB minimum
	$15 \leq f < 400$	20 dB minimum
	$400 \leq f \leq 500$	15 dB minimum
Power rating	$1 \leq f \leq 500$	0,1 watt minimum
Longitudinal balance ^b	$1 \leq f < 100$	60 dB minimum
	$100 \leq f \leq 500$	50 dB minimum
Output signal balance ^b	$1 \leq f \leq 500$	50 dB minimum
CM rejection ^b	$1 \leq f \leq 500$	50 dB minimum
^a Primary impedance may differ, if necessary, to accommodate analyzer outputs other than 50 Ω . ^b Measured per ITU-T (formerly CCITT) Recommendation G.117 with the network analyzer calibrated using a 50 Ω load.		

4.5 Interfacing

For ease of interfacing to test fixtures, a pin and socket interface with dimensions as shown in informative Clause A.2 is recommended.

Figure 2 depicts the proper test configurations for qualifying test baluns to the requirements of this Standard.

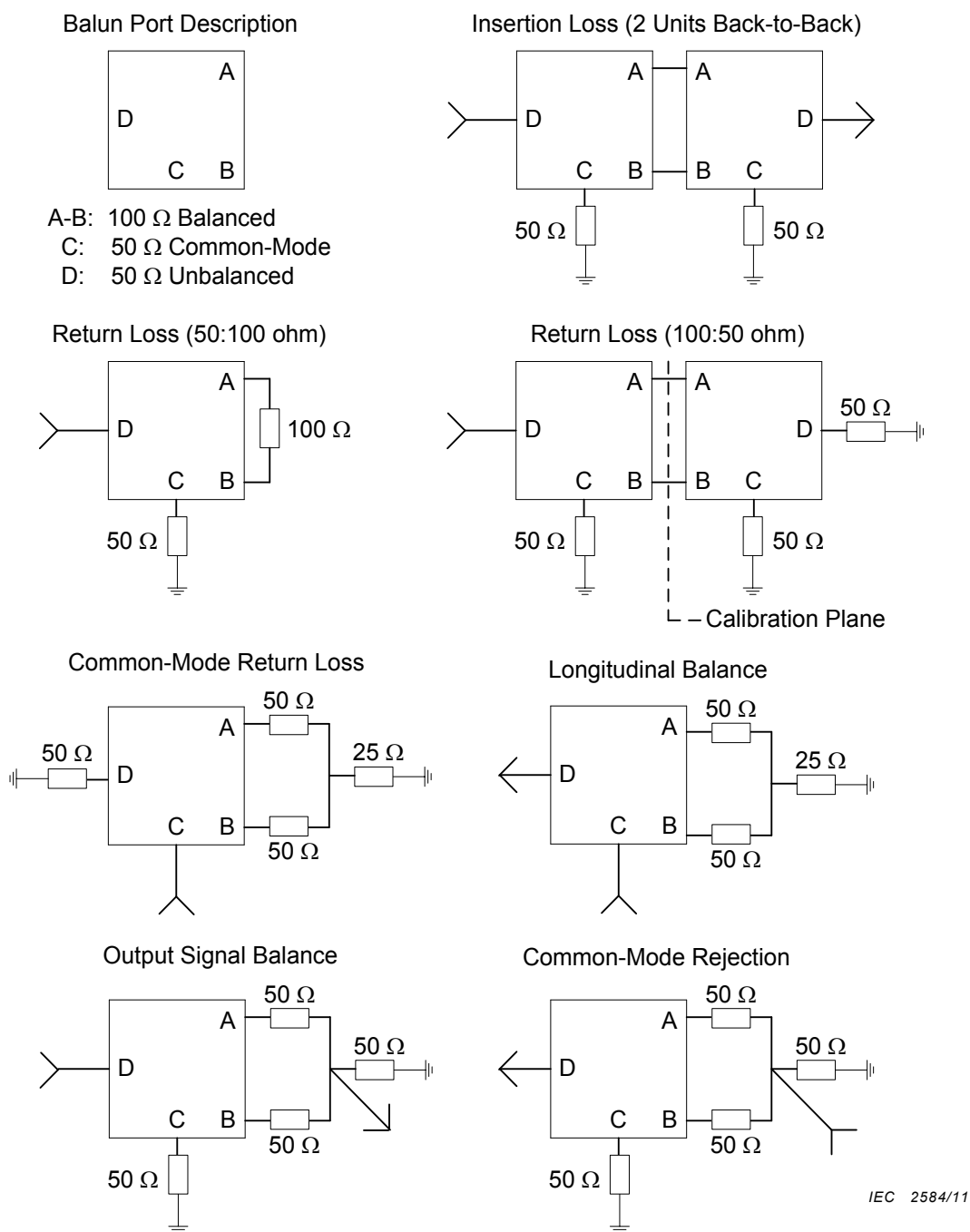


Figure 2 – Measurement configurations for test balun qualification

4.6 Reference components for calibration

4.6.1 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 60169-16, meant for panel mounting.

which is machined flat on the back side (see Figure 3). 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.

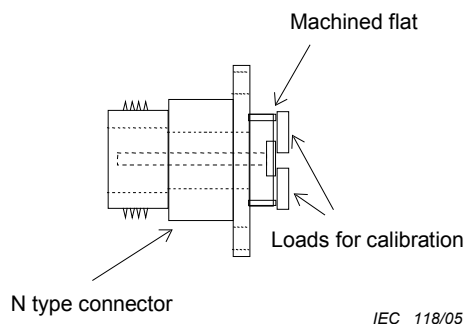


Figure 3 – Calibration of reference loads

4.6.2 Reference cables for calibration

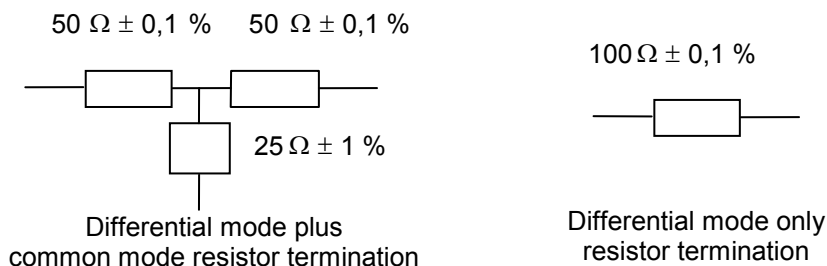
As a minimum, the reference cable that is used to perform the calibration of the test set-up shall satisfy the requirement of the same performance according to the IEC 61156 series as the performance of the connector. The reference cable shall be a length of horizontal cable for which the sheath is preserved. One of the pairs of the reference cable is used for the calibrations. The total length of the reference cable shall be according to the length of the measurement cables as outlined in the calibration procedures for the various tests. Both ends of the reference cable shall be well prepared, so that the twisting is maintained up to the test ports.

4.7 Termination loads for termination of conductor pairs

4.7.1 General

DM plus CM (DMCM) terminations, as shown in Figure 4 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. Balun terminations may be used on the far-end of all inactive pairs provided that their DM and CM return loss performance characteristics meet the minimum performance of the specified resistor networks.

4.7.2 Resistor terminations



IEC 2585/11

Figure 4 – 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.

4.7.3 Balun terminations

Baluns used for termination shall comply with the requirements of 4.4. The CM termination resistor applied to the CM port of the balun shall be 50 $\Omega \pm 1$ %.

4.7.4 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 4.6.

The DM return loss of the load termination shall exceed 20-20log ($f/500$). Calculations that result in return loss limit values greater than 40 dB shall revert to a requirement of 40 dB minimum. The CM return loss shall exceed 15 dB. The residual NEXT loss between any two impedance termination networks shall exceed the requirements of equation (1). Calculations that result in residual NEXT loss limit values greater than 90 dB shall revert to a requirement of 90 dB minimum.

$$NEXT_{\text{residual_term}} \geq 120 - 20 \cdot \log(f) \text{ dB.} \quad (1)$$

4.8 Termination of screens

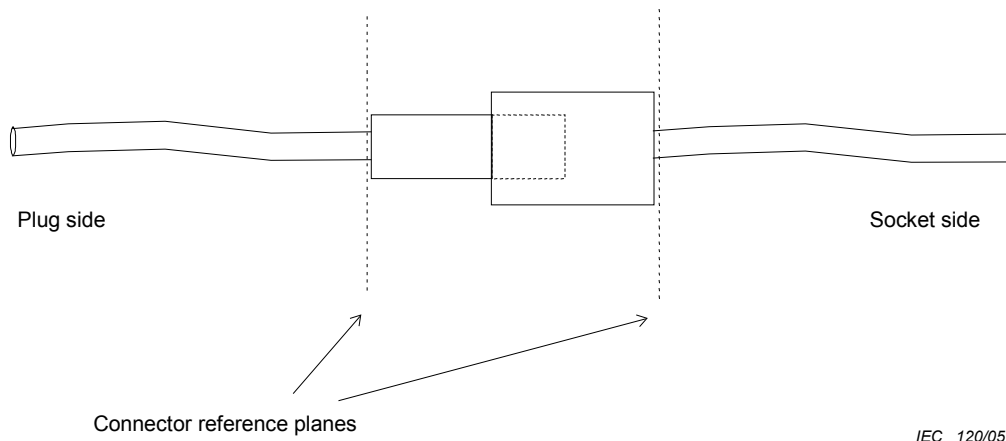
If the connector under test is screened, screened measurement cables shall be applied.

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

4.9 Test specimen and reference planes

4.9.1 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 5). This definition applies to both ends of the test specimen. The fixed connector shall be terminated in accordance with the manufacturer's instructions and shall be compatible with the measurement test set up and fixtures.



IEC 120/05

Figure 5 – Definition of reference planes

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

4.9.2.1 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 CM 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 2. The insertion loss performance of the interconnections is assumed to be less than 0,1 dB over the frequency range from 1 MHz to 500 MHz.

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

4.9.2.2 Impedance matching interconnect

When used, twisted-pair interconnect shall have 100 Ω nominal DM characteristic impedance. The twisted-pairs should not exhibit gaps between the conductors insulation. Interconnect shall be qualified for DM return loss. There are two different methods to obtain interconnect it may be obtained as individual twisted-pairs, or it may be part of a cable. If CM 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.

4.9.2.2.1 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% (e.g. a component known as a 0603 size or similar) chip resistor or similar chip resistor as described in 4.6.1. 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 DM test port using a test fixture yielding CM impedance stabilization. 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.

4.9.2.2.2 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 TFCs, cut from the ends of assembled cords, but can also be used with fixed connectors. 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) DM 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. TFCs cut from assembled cords may be used if the return loss requirements of the cord cable, and of the assembled cord, are met, and the return loss requirements of TFCs per this standard in Table 10 are met.

4.9.2.3 Interconnection return loss requirements

The interconnection shall meet the requirements in Table 2 relative to the calibration resistor specified in 4.6.

Table 2 – Interconnection return loss

Frequency MHz	Return loss dB
$1 \leq f < 80$	40 dB
$80 \leq f \leq 500$	$78 - 20\log(f)$ dB

5 Connector measurement up to 500 MHz

5.1 General

The measurements described in this clause apply to a mated combination of a free connector and a fixed connector. Free connectors, or TFCs, for use in these tests, shall meet all the requirements of Clause 6.

5.2 Insertion loss, Test 27a

5.2.1 Object

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

5.2.2 Free connector for insertion loss

It is not necessary to qualify the free connector for insertion loss testing of the fixed connector.

5.2.3 Test method

Insertion loss (IL) is evaluated by measuring the scattering parameters, S_{21} , of each pair.

5.2.4 Test set-up

The test set-up consists of a network analyser and two baluns as defined in 4.4.

It is not necessary to terminate the pairs which are not under test.

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. 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. CM termination is required on the pair under test at least at one end. See Figure 6.

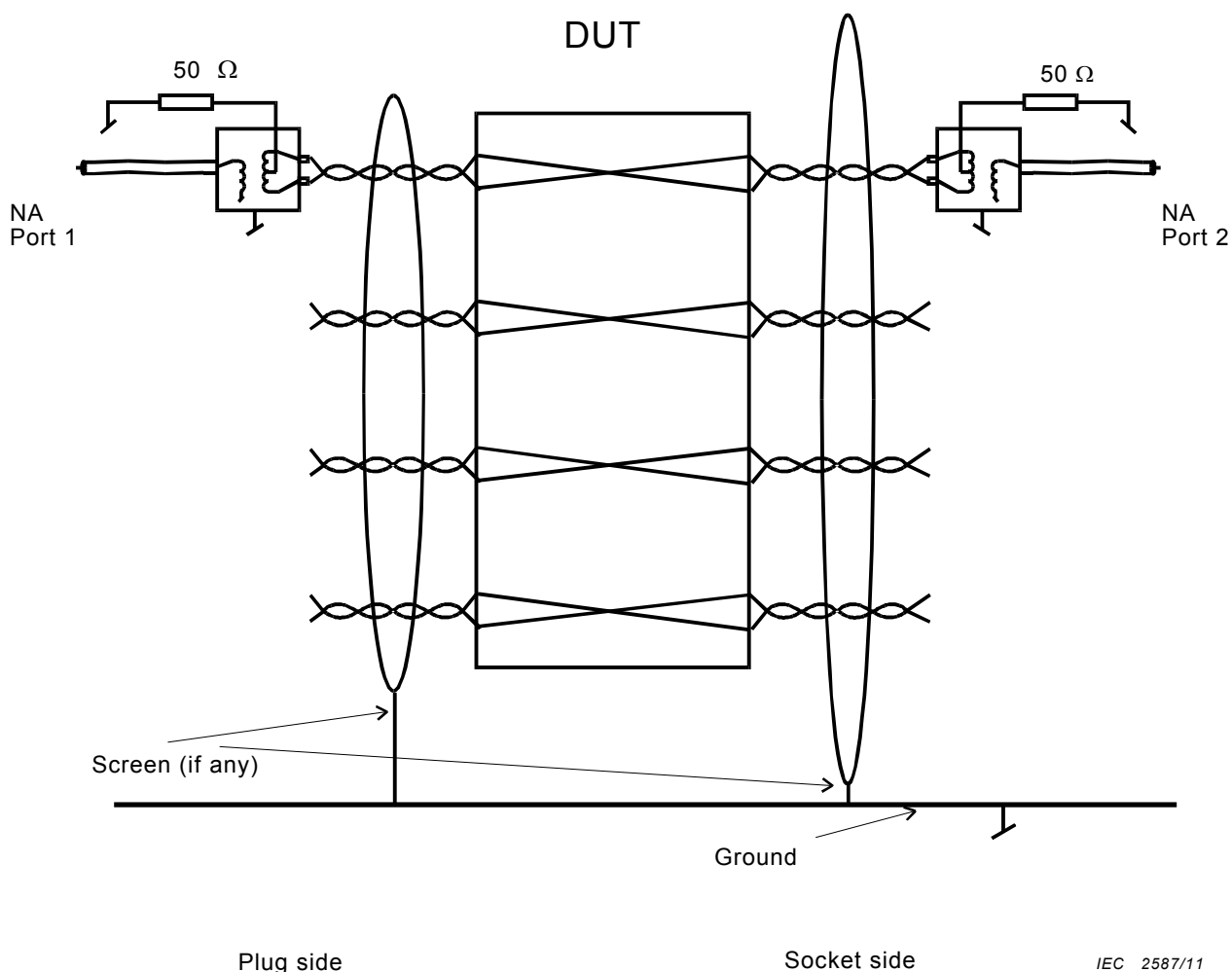


Figure 6 – Measuring set-up

Fixed connectors shall be measured with at least one free connector in at least one direction. There are no insertion loss requirements for free connectors. 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 $\pm 0,05$ dB.

5.3 Return loss, Test 27b

5.3.1 Object

The object of this test is to measure the return loss (RL) of a mated connector pair at the two reference planes.

5.3.2 Free connector for return loss

Connecting hardware shall be tested in both directions for return loss using at least one free connector. This free connector shall satisfy the requirements of 6.4.4.

5.3.3 Test method

Return loss is measured by measuring the scattering parameters, S_{11} and S_{22} , of each pair.

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. DM only termination resistors are recommended and shall satisfy the requirements of 4.7.4. 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 4.9.2 and shall satisfy the requirements of 4.9.2.3.

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 4.7.4.

5.3.5.2 Measurement

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

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 each pair 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 Tables 3 and 4.

Table 3 – Uncertainty band of return loss measurement at frequencies below 100 MHz

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

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

Measured RL	10	12	15	18	20	22	25	28	30
Lower uncertainty limit	–0,5	–0,7	–0,9	–1,3	–1,6	–1,9	–2,6	–3,5	–4,2
Higher uncertainty limit	+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 27c

5.4.1 Object

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

5.4.2 Free connector for NEXT

Connecting hardware shall be tested in both directions for NEXT loss using at least one free connector. This free connector shall satisfy the requirements of Clause 6. Modular connector performance on all pair combinations shall be qualified with the TFC and with the full set of TFC NEXT loss limit vectors specified in Table 5 a or b as appropriate.

5.4.3 Test method

NEXT is evaluated by measuring the scattering parameters, S_{21} , of the possible 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 7.

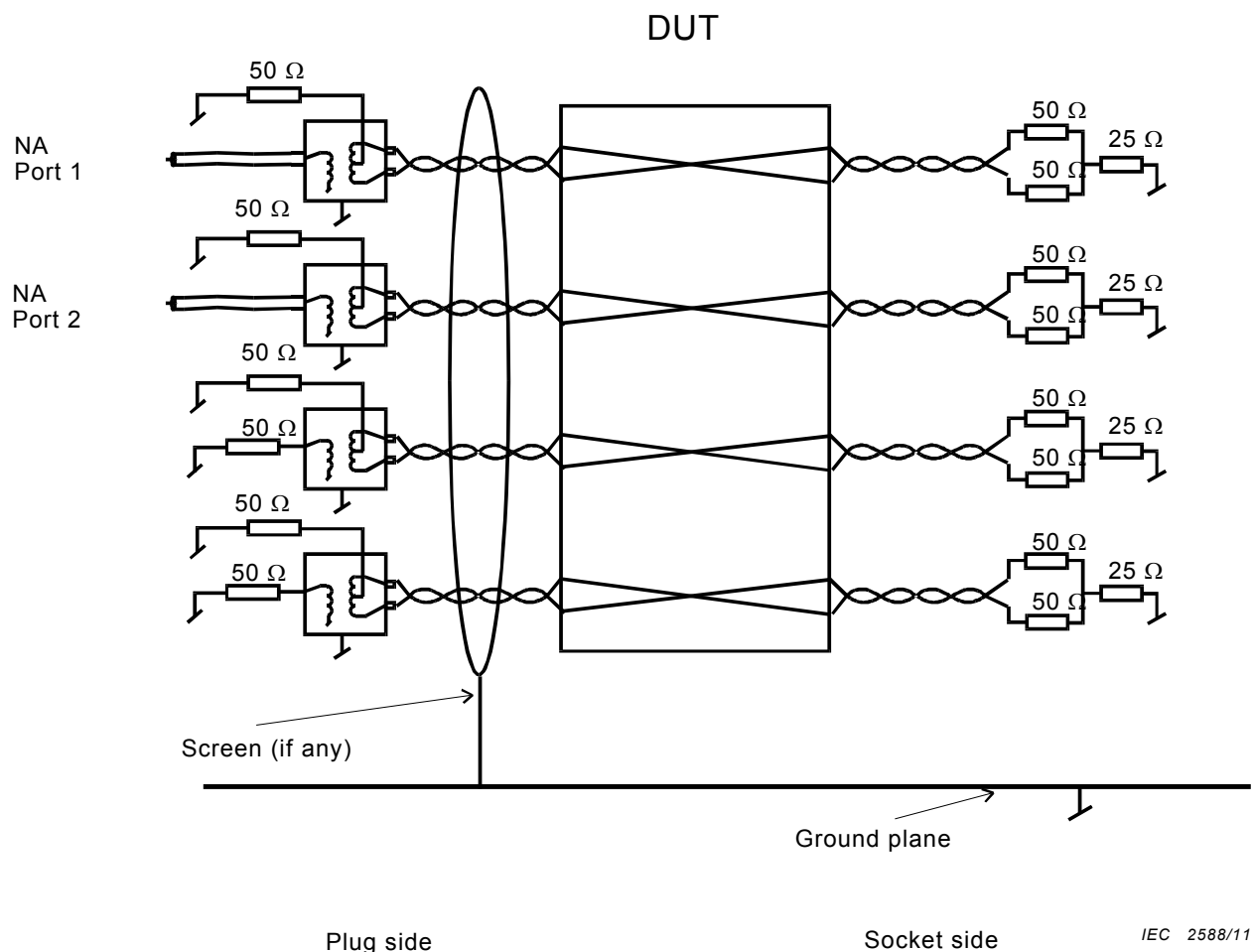


Figure 7 – Example for NEXT measurements

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.

NOTE 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 DM and CM terminations. The measurements have to be performed from both ends of the mated connector. The measurements from the free connector end shall be used in the calculations in 5.4.5.4 below, for full qualification in the forward direction. The measurements from the fixed connector end shall be used in 5.4.5.5 below, for full qualification in the reverse direction. Test all possible pair combinations and record the results.

NOTE There are 6 different combinations of NEXT in a 4-pair connector from each side, which gives a total of 12 measurements. 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 and calculation of free connector vector responses in the forward direction

- a) Measure the NEXT loss vector (magnitude and phase) for the fixed connector mated to the TFC in the forward direction (launch signal into the TFC).
- b) Correct the phase to the interface between the free connector and the fixed connector using the delay procedures in 6.1.2.
- c) Subtract the corrected TFC NEXT loss forward vectors obtained using Clause 6 from the corrected mated NEXT loss vectors obtained in steps a and b. This will yield de-embedded fixed connector vectors. This is an intermediate result not used for compliance verification; these fixed connector vectors are used in step d.
- d) Add the free connector NEXT loss limit vectors in Table 5 for each pair combination to the de-embedded fixed connector vectors obtained in step c for each pair combination. This yields 14 “re-embedded” connecting hardware NEXT loss responses.
- e) Pass-fail qualification is determined by comparing the results in step d to the corresponding connecting hardware requirements.

5.4.5.5 Connecting hardware NEXT loss measurement and calculation of free connector vector responses, reverse direction

- a) Determine the delay of the fixed connector by measuring the TFC delay, mating the TFC to the fixed connector, and measuring the delay of the assembly. Subtract the TFC delay from the delay of the assembly to get the fixed connector delay.
- b) Measure the NEXT loss vector (magnitude and phase) for the fixed connector mated to the TFC, in the reverse direction (launch signal into the fixed connector).
- c) Correct the phase to the interface plane using the results obtained in step a.
- d) Subtract the corrected TFC NEXT loss reverse vectors obtained using Clause 6 from the corrected mated NEXT loss vectors obtained in steps b and c. This will yield de-embedded fixed connector vectors.
- e) Add the free connector NEXT loss limit vectors in Table 5 a or b as appropriate, to the de-embedded fixed connector vectors obtained in step d. This yields 14 “re-embedded” connecting hardware NEXT loss responses.
- f) Pass-fail qualification is determined by comparing the results in step e to the corresponding connecting hardware requirements.

5.4.5.6 Determining the free connector NEXT loss limit vectors

The free connector NEXT loss limit vectors are determined by combining the magnitude values with the phase values as shown in Table 5a or 5b as appropriate.

Table 5a – Free connector TFC NEXT loss limit vectors for connectors specified up to 100 MHz

Case #	Pair combination	Limit	Free connector NEXT loss limit magnitude dB	Free connector NEXT loss limit phase degrees ^{1), 2)}
Case 1	3,6-4,5	Low	75,8-20log(f)	TFC NEXT loss phase
Case 2	3,6-4,5	Central	n/a	n/a
Case 3	3,6-4,5	Central	n/a	n/a
Case 4	3,6-4,5	High	79,5-20log(f)	TFC NEXT loss phase
Case 5	1,2-3,6	Low	82-20log(f)	TFC NEXT loss phase
Case 6	1,2-3,6	High	90-20log(f)	TFC NEXT loss phase
Case 7	3,6-7,8	Low	82 -20log(f)	TFC NEXT loss phase
Case 8	3,6-7,8	High	90 -20log(f)	TFC NEXT loss phase
Case 9	1,2-4,5	Low	90 -20log(f)	90° or -90°
Case 10	1,2-4,5	High	n/a	n/a
Case 11	4,5-7,8	Low	90 -20log(f)	90° or -90°
Case 12	4,5-7,8	High	n/a	n/a
Case 13	1,2-7,8	Low	100 -20log(f)	90° or -90°
Case 14	1,2-7,8	High	n/a	n/a

1) TFC NEXT loss phase is determined by following the procedure in Clause 6.

2) The reference plane for measuring TFC NEXT loss phase and mated NEXT loss shall be the TFC phase reference plane as described in Clause 6.

Table 5b – Free connector TFC NEXT loss limit vectors for connectors specified from 1 MHz to 250 MHz and from 1 MHz to 500 MHz

Case #	Pair combination	Limit	Limit free connector NEXT loss magnitude dB	Limit free connector NEXT loss phase degrees ^{1), 2)}
Case 1	3,6-4,5	Low	78,1-20log(f)	Measured TFC phase
Case 2	3,6-4,5	Central	78,6-20log(f)	Measured TFC phase
Case 3	3,6-4,5	Central	79,0-20log(f)	Measured TFC phase
Case 4	3,6-4,5	High	79,5-20log(f)	Measured TFC phase
Case 5	1,2-3,6	Low	86,5-20log(f)	Measured TFC phase
Case 6	1,2-3,6	High	89,5-20log(f)	Measured TFC phase
Case 7	3,6-7,8	Low	86,5-20log(f)	Measured TFC phase
Case 8	3,6-7,8	High	89,5-20log(f)	Measured TFC phase
Case 9	1,2-4,5	Low	97-20log(f)	+90
Case 10	1,2-4,5	High	110-20log(f)	-90
Case 11	4,5-7,8	Low	97-20log(f)	+90
Case 12	4,5-7,8	High	110-20log(f)	-90
Case 13	1,2-7,8	Low	106-20log(f)	Measured TFC phase
Case 14	1,2-7,8	High	106-20log(f)	Measured TFC phase minus 180°

1) TFC NEXT loss phase is determined by following the procedure in Clause 6.

2) The reference plane for measuring TFC NEXT loss phase and mated NEXT loss shall be the interface plane as described in Clause 6.

5.4.5.7 Determining pass and fail

The response with all free connector limit vectors shall meet the requirements of the detail specification. In addition, connecting hardware NEXT loss for all pair combinations, with the exception of case 1 and case 4 of connectors specified from 1 MHz to 250 MHz, or from 1 MHz to 500 MHz, shall satisfy the requirements of the detail specification. Connecting hardware NEXT loss for those cases shall meet the values determined using equations specified in Table 6.

Table 6 – Connecting hardware NEXT loss for Case 1 and Case 4

Frequency MHz	NEXT loss dB
$1 \leq f \leq 250$	$92,5-20\log f$
$250 < f \leq 500$	$44,54-30\log(f/250)$

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 (uncertainty band) 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 27d

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 Free connector for FEXT

Connecting hardware FEXT loss is determined by measurement of connecting hardware using at least one TFC qualified per Clause 6. Measure connecting hardware FEXT loss with interconnects prepared and controlled per 4.9.2.

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 8.

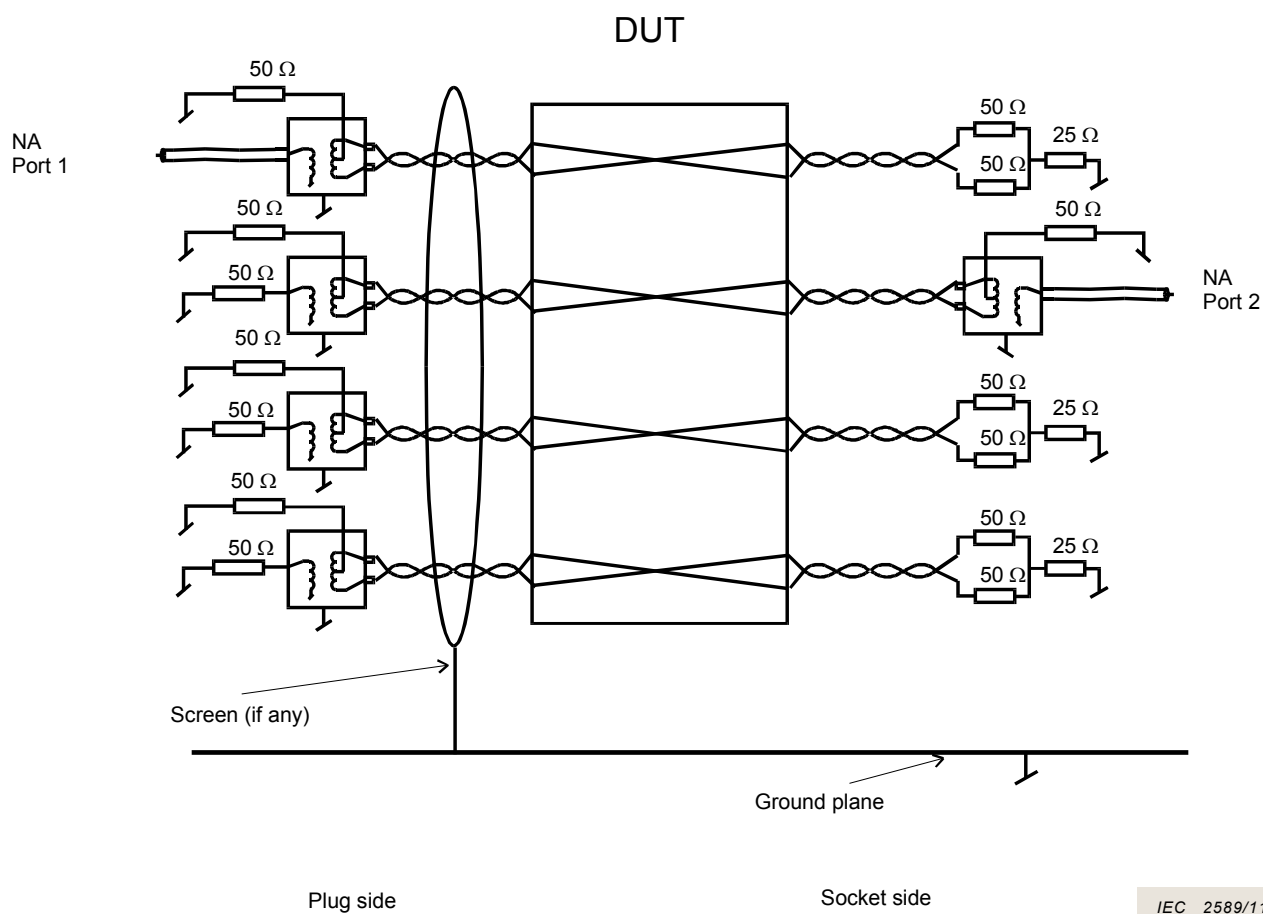


Figure 8 – Example for FEXT measurements for DM and CM terminations

5.5.5 Procedure

5.5.5.1 Calibration

Calibration is performed as shown in 5.2.5.1.

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 and record the results.

NOTE 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 (Z_t)

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

5.7 Transverse conversion loss (TCL), Test 27f

5.7.1 Object

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

5.7.2 Free connector for TCL

Connecting hardware TCL loss is determined by measurement of connecting hardware using a TFC qualified per Clause 6. Measure connecting hardware TCL loss with interconnects prepared and controlled per 4.9.2.

5.7.3 Test method

The balance is evaluated by measuring that part of the DM signal, launched in one of the conductor pairs, which is converted to CM by the DUT at the same conductor pair at the opposite side.

5.7.4 Test set-up

The test set-up consists of a network analyser and a balun with a DM- and CM test port. An illustration of the set-up, which also shows the termination principles, is shown in Figure 9. The DUT pair under test should be connected to the DM balun output terminals. All unused pairs, near end and far end, shall be DMCM terminated. 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 not be longer than 51 mm and they should be oriented orthogonal to each other to minimize coupling.

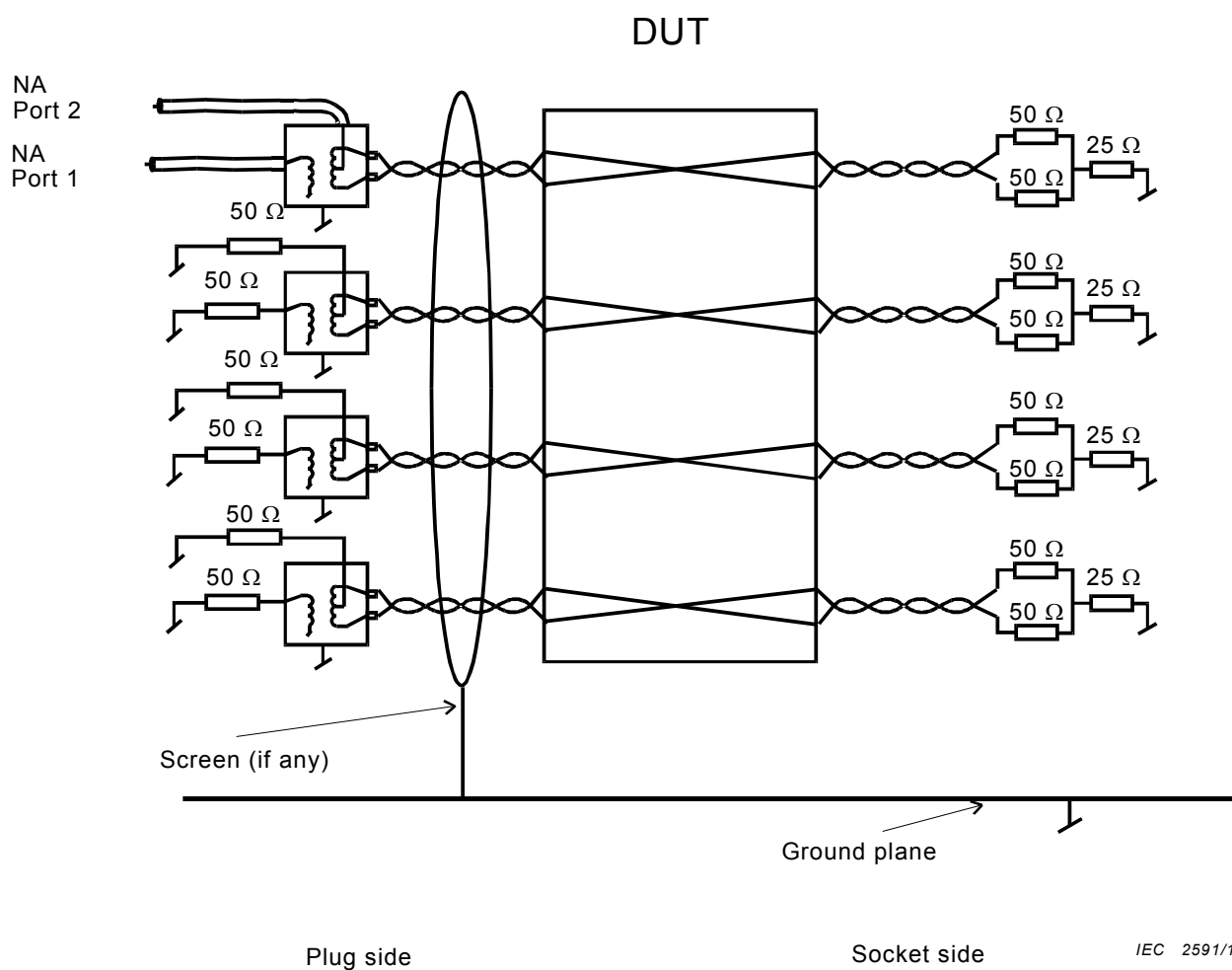


Figure 9 – Example of TCL measurement

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 is 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 10.



Figure 10 – Coaxial lead attenuation calibration

STEP 2: The attenuation of the DM 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 11. Note 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 DM signal.

The calculated insertion loss is recorded as $a_{bal,DM}$.

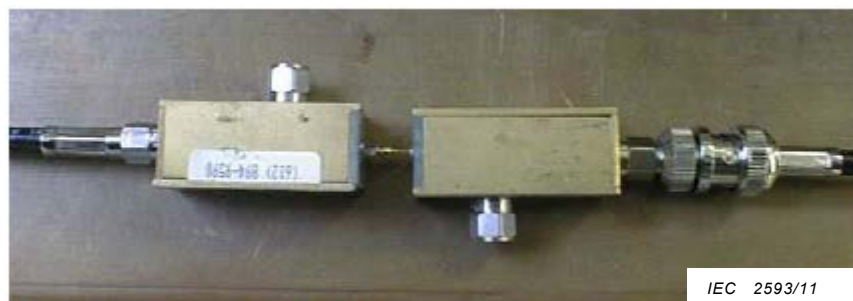


Figure 11 – Back-to-back balun insertion loss measurement

STEP 3: The attenuation of the CM 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 CM sockets, as shown in Figures 12 and 13. A short length of bare wire may be used to connect each of the individual balun terminals. It is important to connect also the ground references. The baluns shall be firmly clamped to the ground plane. Also, the outer screen of the coaxial test lead shall be properly bonded to the ground plane as shown in Figures 12 and 13. Divide by 2 to obtain the CM insertion loss of one balun. The resulting insertion loss is recorded as $a_{bal,CM}$.



Figure 12 – Configuration for balun CM insertion loss calibration

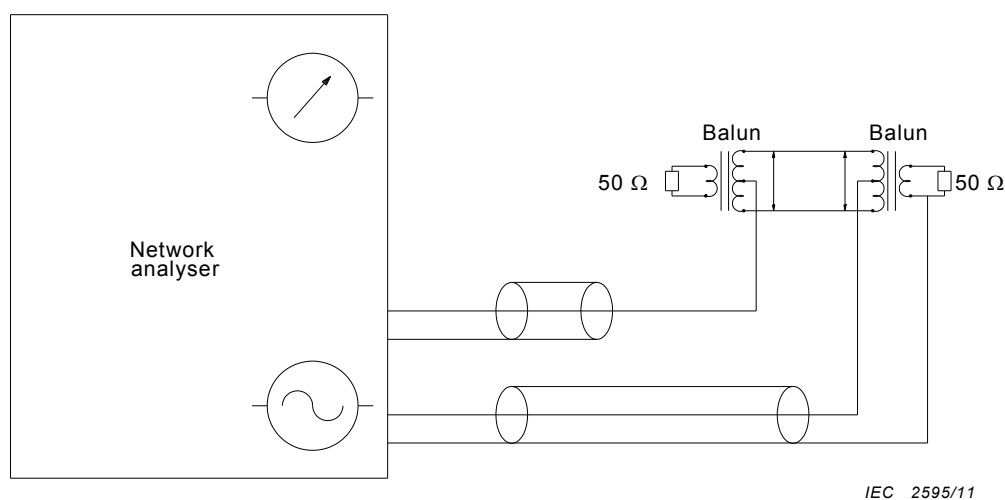


Figure 13 – Schematic for balun CM insertion loss calibration

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, $a_{\text{noise},m}$ shall be measured by terminating the DM output of the balun with a 100 Ω resistor and perform a S_{21} measurement between the DM and the CM test port of the balun. a_{noise} is calculated as

$$a_{\text{noise},m} = -20 \log |S_{21}|$$

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

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 DM output of the test balun. Terminate the DUT according to 5.7.4. Perform a S_{21} measurement between the DM and the CM test port of the balun. The balance, TCL , is calculated as

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

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

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 27g

5.8.1 Object

The object of this test is to measure the mode conversion (DM to CM) 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 Free connector for TCTL

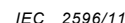
Connecting hardware TCTL loss is determined by measurement of connecting hardware using a TFC qualified per Clause 6. Measure connecting hardware TCTL loss with interconnects prepared and controlled per 4.9.2.

5.8.3 Test method

The balance is evaluated by measuring that part of the DM signal, launched in one of the conductor pairs, which is converted to CM by the DUT at the same conductor pair at the opposite side.

5.8.4 Test set-up

The test set-up consists of a network analyser and two baluns with DM and CM test ports. An illustration of the set-up, which also shows the termination principles, is shown in Figure 14. All unused pairs shall be DMCM terminated. The ground terminals of the termination shall be connected securely to the same ground plane.



5.8.5 Procedure

5.8.5.1 Calibration

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

It is possible to calibrate each balun uniquely, however the method given here is based on the assumption that they are equal.

5.8.5.2 Noise floor

$$TCTL_{noise,m} = -20\log|S_{21}|$$

$$TCTL_{noise} = TCTL_{noise,m} - IL_{bal,DM} + IL_{bal,CM}$$

Other (equivalent and valid) methods of measuring the noise floor are permitted.

5.8.5.3 Measurement

Connect the measured pair of the DUT to the DM output of the test balun. Terminate the DUT according to 5.7.4. Perform a S_{21} measurement between the DM and the CM test port of the balun. The balance, $TCTL$, is calculated as

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

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

Make sure to use the correct mode attenuation of the correct balun in both cases.

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 per IEC 62153-4-12, over the frequency range of 100 MHz to 500 MHz.

6 Construction and qualification of TFCs for NEXT, FEXT and return loss measurements

6.1 General

6.1.1 Introductory remarks

Due to variations that are inherent in terminating cables to modular free connectors, the TFC used to qualify modular outlet performance shall be carefully controlled.

This clause describes the construction, qualification, and requirements for TFCs for verifying connecting hardware performance.

For the purposes of this Standard, a modular TFC consists of an assembly that meets the dimensional requirements of IEC 60603-7 with suitable connections from the electrical contacts. The modular TFC for the qualification of fixed connectors qualified to 500 MHz can be PCB based, an example of which is shown in Figures A.9 and A.10, or wire terminated using a suitable free connector or free connector assembly.

NOTE The direct fixture, as referenced in 6.5, is compatible with free connectors having a contact area $\geq 2,60$ mm as defined by dimension H2 of IEC 60603-7, 3.2.2.

TFCs shall be qualified for all requirements of 6.2 (NEXT loss), 6.3 (FEXT loss) and 6.4 (return loss).

NEXT loss and FEXT loss of TFCs shall be measured using the direct fixture or equivalent described in 6.5.1. Use the delay procedure specified in 6.1.2 to correct the phase of the TFC measurement when it is measured with the direct fixture.

The test free connector shall be qualified relative to the phase reference plane at the tip of the free connector where it connects to the fixed connector contacts. The calibration planes should be as close as possible to the interface plane as shown in Figure 15. Refer to 4.9.1 for requirements of the interconnections between each appropriate calibration plane and the TFC. Alternatively, the direct fixture can be calibrated at the tips of the coaxial probes (examples of which are shown in Figure 16) using suitable calibration artefacts.

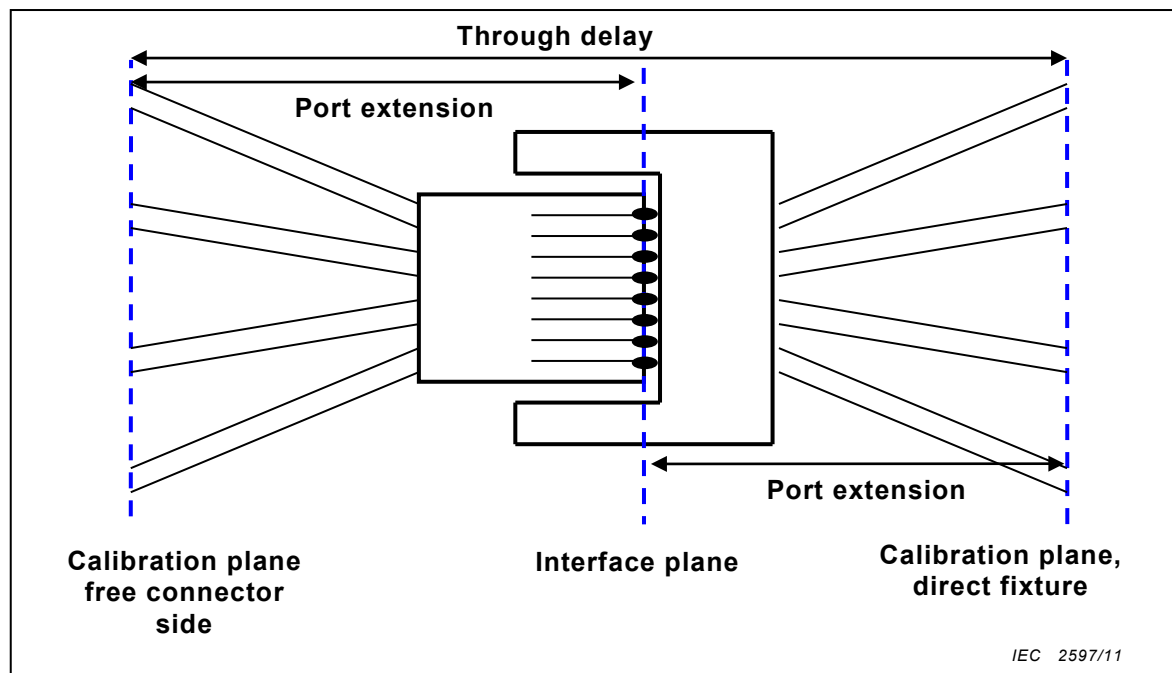


Figure 15 – Calibration and interface planes and port extensions

6.1.2 Delay measurements

6.1.2.1 General

Use these measurement procedures for all test free connector measurements, and for fixed connector and direct fixture measurements to be used in de-embedding calculations.

The port extension values calculated according to equation (8) are applied to each port (for each pair) to align measurement reference planes to the interface plane where contact is made with the fixed connector.

For all measurements subsequently used in vector or matrix calculations and/or where phase requirements are specified, the appropriate port extensions shall be applied after calibration to adjust the measurement to the interface plane. This may be done by applying the port extensions directly to the network analyzer or by adjusting the phase after measurement using equation (8).

$$phase_{(testplugphase_ref_plane)} (deg) = phase_{(calibration_plane)} (deg) \dots$$

$$\dots + 360 \cdot frequency (Hz) \cdot delay (sec)$$

The settings of the network analyzer shall be sufficient to achieve a maximum of +/-5 ps of random variation. Recommended settings are as follows:

- a) Measurement function is *S11* delay.
- b) Averaging 4x or higher.
- c) Intermediate frequency bandwidth (IFBW) 300 Hz or less.
- d) Frequency range from 100 MHz to 500 MHz with at least 100 data points.
- e) Output power level in the range of –5 dBm to 0 dBm for phase critical measurements.

6.1.2.2 TFC delay and port extension – shorting fixed connector method

The procedure is as follows:

- a) With the TFC connected to the test baluns, measure the *S11* time delay determined with an open circuit at the interface plane for each pair.
- b) Place a short on the TFC. This short shall connect the contacts of the pair under test at the interface plane and be no further than 3 mm from the point of contact with the fixed connector. Measure the *S11* delay for each pair shorted in this manner.
- c) The delay value for each pair is calculated by averaging the open and short delay measurements over the frequency range of 100 MHz to 500 MHz using linear spacing and a minimum of 100 frequency points. These measurements represent round-trip time delays. The one-way delay is ½ of the round trip *S11* delay.

6.1.2.2.1 Calculation of port extension

The one-way measured delays (open and short) shall be used to calculate the port extension for each pair as determined by equation (9). It is recognized that there is an inherent error in the delay measurements due to the finite length of the short. To correct this error, a correction factor $TD_{shortingjack}$ described in 6.1.1.2 shall be applied to each port extension.

$$PortExtension = average\left(\frac{TD_{open} + TD_{short} - TD_{shortingjack}}{4}\right) \quad (9)$$

6.1.2.2.2 Free connector delay correction

A recommended procedure for establishing a suitable short delay correction factor is as follows:

- a) Select a free connector that can be used for this procedure and is then discarded. Three or more free connectors are recommended.
- b) Mount the free connector rigidly onto a pyramid or other suitable impedance management fixture.
- c) Measure the *S11* round trip delay of the free connector mated to the shorting fixed connector on all pairs and record these values as *Delay_{round trip free connector}*.
- d) Without removing the free connector from the pyramid, trim the plastic ribs separating the contacts, and solder a wire across all 8 contacts where they make contact with a mating fixed connector.
- e) Measure the *S11* round trip delay of the free connector on each pair and record these values as *Delay_{round trip free connector}*.
- f) Subtract 5 ps for pairs 1,2; 4,5; and 7,8 and 14 ps for pair 3,6 from *Delay_{round trip free connector}* to account for the delay of the short spanning the free connector contacts. Record these values as *Delay_{adjusted round trip free connector}*.
- g) Determine the difference in round trip delay for each pair of the shorting fixed connector as follows:

$$TD_{shortingjack} = Delay_{roundtripplugjack} - Delay_{adjustedroundtripplug}$$

NOTE 1 The delay measurements are dependent on the proximity to ground planes. The positioning of the interconnections (e.g. wire pairs) should remain fixed during all measurements.

NOTE 2 The measurement accuracy of this method is approximately 20 ps in a round trip measurement, corresponding to a one-way distance of approximately 2 mm.

6.1.2.3 Direct fixture delay measurements

The procedure for measuring the delay of the direct fixture is as follows:

- Insert a short artefact into the direct fixture and measure the S11 delay for each pair of the direct fixture.
- Subtract 14 ps for pair 3,6 and 5 ps for the other three pairs (1,2 and 4,5 and 7,8) from the measured short delay to account for the delay of the short spanning the coaxial probes.
- Remove the short artefact, insert an open artefact into the direct fixture and measure the S11 delay for each pair of the direct fixture.
- The delay value for each pair is calculated by averaging the open and short delay measurements over the frequency range of 100 MHz to 500 MHz using linear spacing and a minimum of 100 frequency points. These delay measurements represent round-trip delays. The one-way delay is half of the round trip S11 delay.

Ensure that the extended length of the coaxial probes during the measurement using the open and short artefacts is consistent with the extended length when mated to a test free connector.

Short and open artefacts shall be compatible with the dimensional requirements of the direct fixture as shown in Figures 27, 28, and 29. The mating surface of these artefacts to the coaxial probes of the direct fixture shall be the same as the terminated free connector contact height specified in IEC 60603-7 series (i.e. 5,89 mm to 6,17 mm). Examples of these are shown in Figure 16. Artefacts can also be created from free connectors as long as they meet these requirements.

NOTE For calculating port extension, only the open and the short artefacts are necessary. The remaining artefacts can be used for other calibrations.

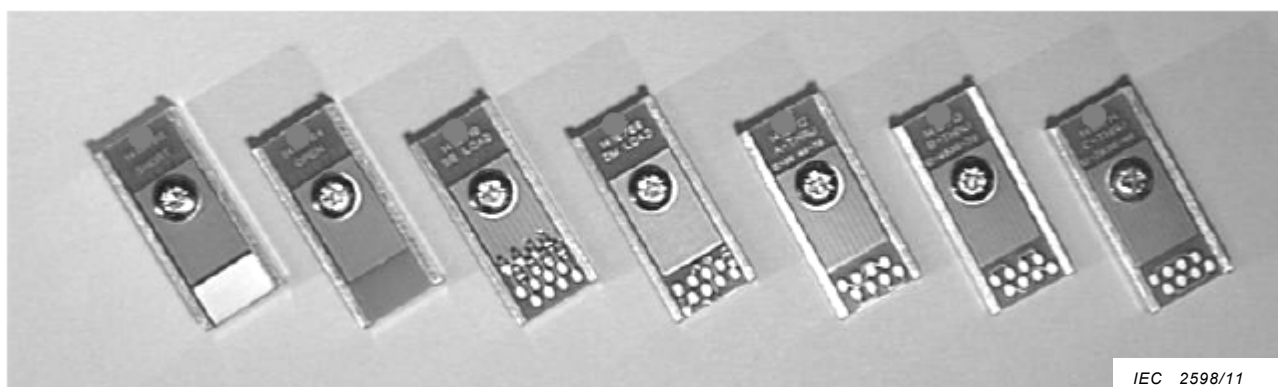


Figure 16 – Examples of direct fixture short, open, load, and through artefacts

NOTE The direct fixture artefacts shown in Figure 16 may be obtained from: ADC Telecommunications, Inc., Eden Prairie, MN 55344 (ADC catalogue number 6529 1200-00; contact ADC directly or through directfixture.artefacts@adc.com).¹

¹ These artefacts are an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by the IEC of these products.

6.1.2.4 Through delay method for a TFC

The delay of the TFC may also be determined by measuring the direct fixture delay per 6.1.2.3, connecting the TFC to the direct fixture, and then measuring the through delay of the assembly (TFC plus direct fixture). Subtract the fixture delay from the through delay of the assembly to get the TFC delay.

6.1.2.5 Fixed connector delay measurements

Many designs of fixed connectors have leads which extend beyond the interface plane. Therefore an open measurement will not produce a valid estimate of the delay from the calibration plane to the interface. Therefore, fixed connector delay shall be measured by first measuring the delay of a free connector per 6.1.2, then mating the free connector to the fixed connector and measuring the through delay of the mated pair, and finally subtracting the free connector delay.

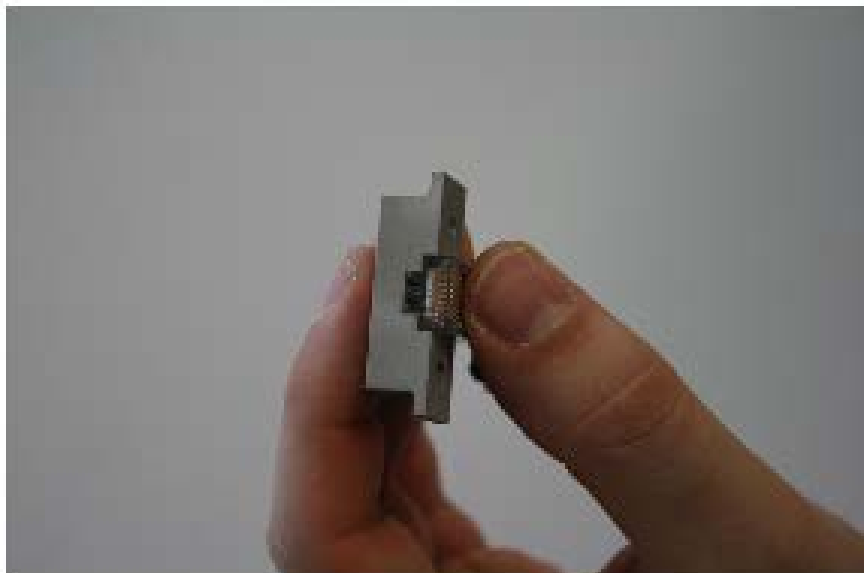
6.2 TFC near-end crosstalk (NEXT)

6.2.1 General

To measure connecting hardware NEXT loss, TFCs need only be qualified in the near-end test direction, with the cable end of the free connector designated as the near-end. TFCs thus qualified are used to characterize mated connecting hardware performance from both the near-end and far-end measurement orientations. For the purposes of connecting hardware NEXT loss qualification in the reverse direction, the TFC NEXT loss needs to also be measured in the reverse direction.

6.2.2 Procedure for mating a TFC to the direct fixture

- a) Place the TFC into the free connector clamp as shown in Figure 17.



IEC 2599/11

Figure 17 – Modular free connector placed into the free connector clamp

- b) Holding the free connector in place, slide the free connector clamp onto the clamp block guide pins as shown in Figures 18 and 19.

NOTE The spring loaded pin in the clamp block pushes against the free connector and holds it in position against the free connector clamp.



IEC 2600/11

Figure 18 – Guiding the free connector into position

- c) Guide the test free connector into position against the coaxial contact pins making certain that the free connector does not rock in the free connector clamp and that it slides vertically onto the coaxial contact pins. Avoid any side loading on the pins as they may distort if pushed sideways.



IEC 2601/11

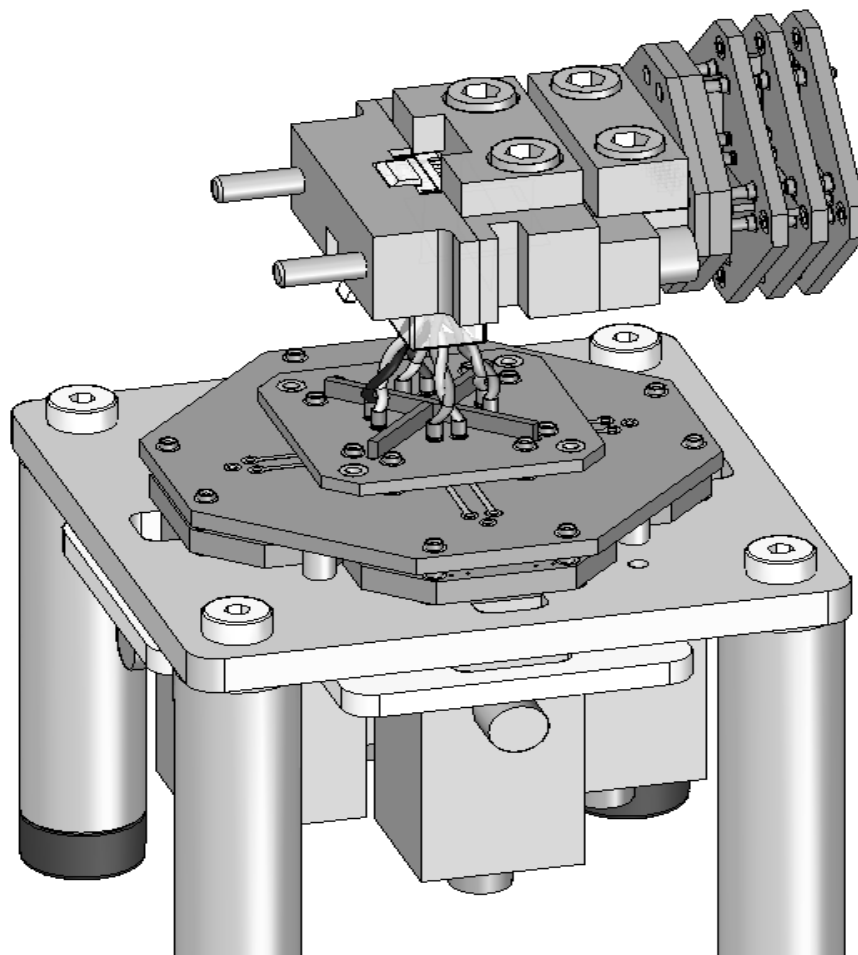
Figure 19 – TFC direct fixture

- d) Secure the free connector clamp and the clamp block together using suitable spring clips as shown in Figure 19.

6.2.3 TFC NEXT loss measurement

Measure the TFC NEXT loss vectors for all pair combinations in both directions. Figure 20 shows suitable apparatus. Use a direct fixture qualified per 6.5.1. Correct the phase of all NEXT loss measurements to the interface between the free connector contacts and the fixture. Use the procedures in 6.1.2. The corrected vector measurement results for NEXT loss

of the TFC will be used to calculate the mated NEXT loss for compliance with connecting hardware requirements for high limit and low limit TFCs.



IEC 2602/11

Figure 20 – illustration of TFC NEXT measurement in the forward direction

6.2.4 TFC NEXT loss requirements

The corrected NEXT loss vectors (magnitude and phase) of the TFC in the forward direction shall be within the free connector NEXT loss ranges of Table 7. TFC NEXT loss requirements apply in the forward direction only. TFC NEXT loss in the reverse direction shall also be measured so that data can be used in the reverse direction connecting hardware NEXT loss qualification procedure as described in Clause 5.

Table 7 – TFC NEXT loss ranges

Pair combination	NEXT loss magnitude range dB ¹⁾	NEXT loss phase range degrees ²⁾
3,6-4,5	$78,1-20\log(f) \leq \text{NEXT loss} \leq 79,5-20\log(f)$	50 – 100 MHz: $(-90 + 0,015 \cdot f) \pm 1$ 100 – 500 MHz: $(-90 + 0,015 \cdot f) \pm f/100$
1,2-3,6	$86,5-20\log(f) \leq \text{NEXT loss} \leq 89,5-20\log(f)$	$(-90 + 0,015 \cdot f) \pm 3 \cdot f/100$
3,6-7,8	$86,5-20\log(f) \leq \text{NEXT loss} \leq 89,5-20\log(f)$	$(-90 + 0,015 \cdot f) \pm 3 \cdot f/100$
1,2-4,5	$\text{NEXT loss} \geq 97-20\log(f)$ ⁴⁾	$90 \pm (30 \cdot f/100)$ ³⁾
4,5-7,8	$\text{NEXT loss} \geq 97-20\log(f)$ ⁴⁾	$90 \pm (30 \cdot f/100)$ ³⁾
1,2-7,8	$\text{NEXT loss} \geq 106-20\log(f)$ ⁴⁾	Any phase
1) Magnitude limits apply over the frequency range from 10 MHz to 500 MHz. 2) Phase limits apply over the frequency range from 50 MHz to 500 MHz. 3) When the measured free connector NEXT loss magnitude is greater than $110-20\log(f)$ or 70 dB, the phase limit does not apply. 4) When the NEXT loss magnitude limit calculation results in a value greater than 70 dB, the limit shall revert to 70 dB. 5) When fixture N447059 DPMF described in Annex A is used, the magnitude high limit for pair combination 36-45 $79,5-20\log(f)$ shall be $79,5-20\log(f) + 0,5(f-300)/200$ for the frequency range from 300 MHz to 500 MHz.		

6.3 TFC far-end crosstalk (FEXT)

6.3.1 TFC FEXT loss measurement

Connect the TFC to the direct fixture as described in 6.2.2. Measure the TFC FEXT loss vectors for all pair combinations. Use the direct fixture specified in 6.5.1 or equivalent.

Correct the phase of all FEXT loss measurements to the test free connector phase reference plane. Use the procedures in 6.1.2.

6.3.2 TFC FEXT loss requirements

The corrected FEXT loss vectors (magnitude and phase) of all 12 pair combinations of the TFC shall be within the free connector FEXT loss ranges of Table 8.

Table 8 – TFC FEXT loss ranges

Pair combination	Frequency range MHz	FEXT loss ^{3), 4)} magnitude range dB	Phase ^{1), 2)} degrees
3,6-4,5	10-500	$86-20\log(f) \leq \text{FEXT loss} \leq 96-20\log(f)$	$-90 \pm (0,3 \cdot f)$
1,2-3,6	10-500	$86-20\log(f) \leq \text{FEXT loss} \leq 96-20\log(f)$	$-90 \pm (0,3 \cdot f)$
3,6-7,8	10-500	$86-20\log(f) \leq \text{FEXT loss} \leq 96-20\log(f)$	$-90 \pm (0,3 \cdot f)$
1,2-4,5	10-500	$\geq 95-20\log(f)$	any phase
4,5-7,8	10-500	$\geq 95-20\log(f)$	any phase
1,2-7,8	10-500	$\geq 95-20\log(f)$	any phase
1) When the measured free connector FEXT loss is greater than 70 dB, the phase requirement does not apply. 2) Phase limits apply over the frequency range from 100 MHz to 500 MHz. 3) When upper limit FEXT loss calculations result in values greater than 70 dB, there shall be no upper limit for FEXT loss. 4) When lower limit FEXT loss calculations result in values greater than 70 dB, the lower limit FEXT shall revert to a limit of 70 dB.			

6.4 TFC return loss

6.4.1 General

This subclause describes procedures for TFC return loss testing. At least one TFC shall be qualified for connecting hardware return loss testing. TFC return loss shall be qualified in at least one direction, in the reverse direction per 6.4.2 or in the forward direction per 6.4.3.

The interconnections used to construct the TFC shall be qualified using the procedure in 4.9.1. The TFC may be terminated with the direct fixture provided that qualified reference load terminations are used. The far-end of the direct fixture should be terminated with the calibration reference load resistor terminations. The impedance effects of the direct fixture shall be removed using the de-embedding procedure.

6.4.2 TFC return loss reverse direction qualification procedure

TFC return loss may be verified by testing in the reverse direction, with load resistors applied to the interconnections of the TFC and the TFC attached to the test ports through a direct fixture that has been calibrated to the TFC phase reference plane. The TFC phase reference plane is shown in Figure 15. Use precision 0,1 % 0603, or similar, chip resistors as described in 4.7 for DM terminations. Application of the resistors at the far-end of the TFC shall be done in such a way as to minimize the disturbance of the interconnections. An interconnection length of 12 mm is suggested.

6.4.3 Test plug return loss forward direction qualification procedure

6.4.3.1 General

The forward direction test plug return loss test procedure is applicable for determination of test plug return loss properties when measured in the forward direction and where a reference socket is used for termination. This method relies on the consistency of the selected socket. This procedure uses three sockets; one terminated as short, one terminated as open, and one as load. The properties of the reference socket are mathematically removed using a matrix de-embedding process.

This method assumes that it is difficult or inconvenient to terminate a modular plug with chip resistors directly across its contacts where connection is made. However, for the following de-embedding method to work, a plug shall be terminated in this way (return loss reference plug), here done by soldering chip resistors to the plug contacts.

An alternative procedure that facilitates connection of chip resistors directly to the contacts of a test plug without soldering, or other destructive technique, may be used and the de-embedding calculations avoided. If this procedure is used, correct the phase of all return loss measurements to the test plug phase reference plane as, shown in Figure 15, using the procedures specified in 6.1.2.

6.4.3.2 Procedure overview

Measurement of the return loss vectors (magnitude and phase) of a return loss test plug involves the following steps:

- a) Measure the mated return loss (S_{11}) of the return loss reference plug mated with each of the open, short, and load, the return loss reference sockets.
- b) Measure the return loss (S_{11}) of the return loss reference plug.
 - 1) Leave each wire pair of the return loss reference plug un-terminated.
 - 2) Terminate each wire pair at the tips of the contacts with a short.
 - 3) Terminate each pair of at the tips of the contacts with an RF $100\ \Omega \pm 0,1\ \%$ chip resistor.
- c) Calculate the S-parameters of the return loss reference socket from the measurements of steps 1 and 2 using the return loss reference plug S-parameters (step 2) and the mated S-parameters (step a).
- d) As an alternative to steps a) to c), the reference socket matrix provided in Table 9, (which has been measured using steps a) to c) above), may be used for the return loss reference socket matrix if the reference socket described in 6.4.3.3 is used.
- e) Measure the return loss (S_{11}) of a test plug mated with each of the open, short, and load reference sockets.
- f) Calculate the S-parameters of this test plug using the results from step c) or d) and step e) using the matrix method of 6.4.3.5.

6.4.3.3 Selection of a return loss de-embedding reference socket

This procedure can be applied to any terminating fixture (socket or the direct fixture). The use of a reference socket is described in this subclause. The ideal terminating fixture should have transparent return loss performance. The reference socket should have minimal lead length from the interface plane to the point where precision termination loads are connected. In addition, a PCB mount type return loss reference socket takes advantage of the consistency of surface mount resistors and dimensionally controlled interconnects (traces) to the loads.

NOTE 1 An example of a reference socket that satisfies these parameters is Fluke Networks P/N DTX-PLCAL. Figure 21 shows a rear view of a reference socket assembly with OPEN, SHORT and LOAD terminations on each reference socket and a front view of the socket opening.

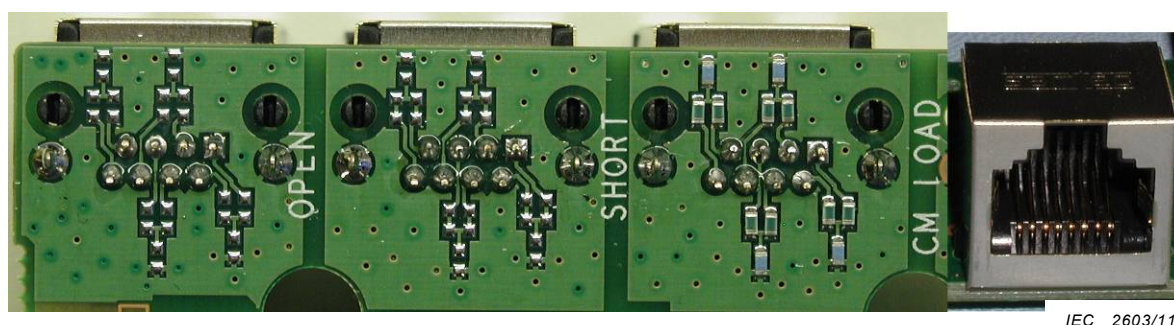


Figure 21 – Example of suitable return loss de-embedding reference socket

NOTE 2 Table 9 defines the nominal S-parameter values of the Fluke Networks P/N DTX-PLCAL socket assembly as shown in Figure 21. The polynomials are defined for a frequency span of 1 MHz to 500 MHz.

The S-parameters are computed using equation (11).

$$S_{xx} = k + a \cdot f + b \cdot f^2 \quad (11)$$

Where f is the frequency in MHz.

Table 9 – De-embedding return loss reference fixed connector assembly standard vectors

	<i>Poly Coef</i>	12 real	12 imag	36 real	36 imag	45 real	45 imag	78 real	78 imag
<i>S</i> 11	<i>k</i>	0	0	0	0	0	0	0	0
and	<i>a</i>	0	-1,778E-5	1,21E-5	1,61E-4	0	-1,778E-5	0	-1,778E-5
<i>S</i> 22	<i>b</i>	0	0	6,64E-8	-8,18E-8	0	0	0	0

	<i>Poly Coef</i>	12 real	12 imag	36 real	36 imag	45 real	45 imag	78 real	78 imag
<i>S</i> 12	<i>k</i>	1	0	1	0	1	0	1	0
and	<i>a</i>	-1,61E-05	-6,44E-04	-2,51E-05	-6,63E-04	-1,95E-05	-6,21E-04	-1,92E-05	-6,30E-04
<i>S</i> 21	<i>b</i>	-2,11E-07	0	-2,31E-07	0	-1,82E-07	0	-1,97E-07	0

NOTE For purposes of the development of the standard fixed connector vector, *S*22 is assumed equal to *S*11.

6.4.3.4 Return loss de-embedding reference fixed connector S-parameters

The S-parameters of a return loss reference fixed connector are determined by first mating the return loss reference fixed connector with a return loss reference free connector, (see Figure 22). The S-parameters of this return loss reference free connector will be determined destructively after the mated return loss measurements have been obtained.