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Edition 2.0 2015-12

INTERNATIONAL STANDARD

colour inside

Metallic communication cable test methods – Part 4-7: Electromagnetic compatibility (EMC) – Test method for measuring of transfer impedance Z_T and screening attenuation a_s or coupling attenuation a_C of connectors and assemblies up to and above 3 GHz – Triaxial tube in tube method

IEC 62153-4-7:2015-12(en)

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CONTENTS

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METALLIC COMMUNICATION CABLE TEST METHODS –

Part 4-7: Electromagnetic compatibility (EMC) – Test method for measuring of transfer impedance Z_T and screening attenuation a_s or coupling attenuation a_C of connectors and assemblies up to and above 3 GHz – Triaxial tube in tube method

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International Standard IEC 62153-4-7 has been prepared by IEC technical committee 46: Cables, wires, waveguides, R.F. connectors, R.F. and microwave passive components and accessories.

This second edition cancels and replaces the first edition published in 2006. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

The document is revised and updated. The changes of the revised IEC 62153-4-3:2013, and IEC 62153-4-4:2015, are included.

Measurements can be achieved now with mismatch at the generator site, impedance matching devices are not necessary.

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

FDIS	Report on voting
46/572/FDIS	46/585/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 of the IEC 62153 series, under the general title: *Metallic communication cable test methods*, 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 website 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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

The shielded screening attenuation test set-up according to IEC 62153-4-3 and IEC 62153-4-4 have been extended to take into account the particularities of electrically short elements like connectors and cable assemblies. Due to the concentric outer tube of the triaxial set-up, measurements are independent of irregularities on the circumference and outer electromagnetic fields.

With the use of an additional resonator tube (inner tube respectively tube in tube), a system is created where the screening effectiveness of an electrically short device is measured in realistic and controlled conditions. Also a lower cut off frequency for the transition between electrically short (transfer impedance Z_T) and electrically long (screening attenuation a_S) can be achieved.

A wide dynamic and frequency range can be applied to test even super screened connectors and assemblies with normal instrumentation from low frequencies up to the limit of defined transversal waves in the outer circuit at approximately 4 GHz.

METALLIC COMMUNICATION CABLE TEST METHODS –

Part 4-7: Electromagnetic compatibility (EMC) – Test method for measuring of transfer impedance Z_T and screening attenuation a_s or coupling attenuation a_C of connectors and assemblies up to and above 3 GHz – Triaxial tube in tube method

1 Scope

This triaxial method is suitable to determine the surface transfer impedance and/or screening attenuation and coupling attenuation of mated screened connectors (including the connection between cable and connector) and cable assemblies. This method could also be extended to determine the transfer impedance, coupling or screening attenuation of balanced or multipin connectors and multicore cable assemblies. For the measurement of transfer impedance and screening- or coupling attenuation, only one test set-up is needed.

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 TS 62153-4-1, *Metallic communication cable test methods – Part 4-1: Electromagnetic compatibility (EMC) – Introduction to electromagnetic screening measurements*

IEC 62153-4-3, *Metallic communication cable test methods – Part 4-3: Electromagnetic Compatibility (EMC) − Surface transfer impedance − Triaxial method*

IEC 62153-4-4, *Metallic communication cable test methods – Part 4-4: Electromagnetic compatibility (EMC) – Shielded screening attenuation, test method for measuring of the screening attenuation as up to and above 3 GHz*

IEC 62153-4-15, *Metallic communication cable test methods – Part 4-15: Electromagnetic compatibility (EMC) – Test method for measuring transfer impedance and screening attenuation – or coupling attenuation with Triaxial Cell*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
surface transfer impedance
Z_T
for an electrically short screen, quotient of the longitudinal voltage U_1 induced to the inner circuit by the current I_2 fed into the outer circuit or vice versa, see figure 1

Note 1 to entry: The surface transfer impedance is expressed in ohms.

Note 2 to entry: The value Z_T of an electrically short screen is expressed in ohms [Ω] or decibels in relation to 1 Ω.

Note 3 to entry: See Figure 1.

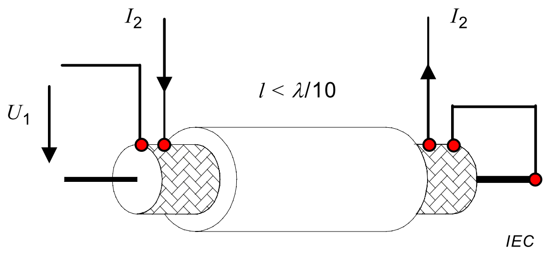


Figure 1 – Definition of Z_T

$$Z_T = \frac{U_1}{I_2} \tag{1}$$

$$Z_T \text{ dB}(\Omega) = +20 \times \log_{10}\left(\frac{|Z_T|}{1\,\Omega}\right) \tag{2}$$

3.2
effective transfer impedance
Z_{TE}
effective transfer impedance, defined as:

$$Z_{TE} = \max|Z_F \pm Z_T| \tag{3}$$

where

Z_F is the capacitive coupling impedance.

3.3
screening attenuation
a_s
for electrically long devices, i.e. above the cut-off frequency, logarithmic ratio of the feeding power P_1 and the periodic maximum values of the coupled power $P_{r,max}$ in the outer circuit

$$a_s = -10\log_{10}\left(\text{Env}\left|\frac{P_{r,max}}{P_1}\right|\right) \tag{4}$$

where

Env is the minimum envelope curve of the measured values in dB

Note 1 to entry: The screening attenuation of an electrically short device is defined as:

$$a_s = -20\log_{10}\frac{150\Omega}{Z_{TE}} \tag{5}$$

where

150 Ω is the standardized impedance of the outer circuit.

3.4
coupling attenuation
a_C
for a screened balanced device, the sum of the unbalance attenuation a_U of the symmetric pair and the screening attenuation a_S of the screen of the device under test

Note 1 to entry: For electrically long devices, i.e. above the cut-off frequency, the coupling attenuation a_C is defined as the logarithmic ratio of the feeding power P_1 and the periodic maximum values of the coupled power $P_{r,max}$ in the outer circuit.

3.5
coupling length
length of cable inside the test jig between the end of the extension tube and the screening cap (see Figure 2)

Note 1 to entry: the coupling length is electrically short, if

$$\lambda_o / l > 10 \cdot \sqrt{\varepsilon_{r1}} \quad \text{or} \quad f < \frac{c_o}{10 \cdot l \cdot \sqrt{\varepsilon_{r1}}} \tag{6}$$

or electrically long, if

$$\lambda_o / l \leq 2 \cdot \left| \sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}} \right| \quad \text{or} \quad f > \frac{C_o}{2 \cdot l \cdot \left| \sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}} \right|} \tag{7}$$

where

l is the effective coupling length in m;

λ_o is the free space wave length in m;

ε_{r1} is the resulting relative permittivity of the dielectric of the cable;

ε_{r2} is the resulting relative permittivity of the dielectric of the secondary circuit;

f is the frequency in Hz;

c_o is the velocity of light in free space.

3.6
device under test
device consisting of the mated connectors with their attached cables

4 Physical background

See respective clauses of IEC TS 62153-4-1, IEC 62153-4-3, IEC 62153-4-4 and Annexes C and D.

5 Principle of the test methods

5.1 General

The IEC 62153-4-x series describes different test procedures to measure screening effectiveness on communication cables, connectors and components with triaxial test set-up.

Table 1 gives an overview about IEC 62153-4-x test procedures with triaxial test set-up.

Table 1 – IEC 62153, Metallic communication cable test methods – Test procedures with triaxial test set-up

	Metallic Communication Cable test methods – Electromagnetic compatibility (EMC)
IEC TR 62153-4-1 Ed.3	Introduction to electromagnetic (EMC) screening measurements
IEC 62153-4-3 Ed.2	Surface transfer impedance – Triaxial method
IEC 62153-4-4Ed.2	Shielded screening attenuation, test method for measuring of the screening attenuation a_S up to and above 3 GHz
IEC 62153-4-7	Shielded screening attenuation test method for measuring the transfer impedance Z_T and the screening attenuation a_S or the coupling attenuation a_C of RF-connectors and assemblies up to and above 3 GHz, tube in tube method
IEC 62153-4-9	Coupling attenuation of screened balanced cables, triaxial method
IEC 62153-4-10	Shielded screening attenuation test method for measuring the screening effectiveness of feedtroughs and electromagnetic gaskets double coaxial method
IEC 62153-4-15	Test method for measuring transfer impedance and screening attenuation – or coupling attenuation with triaxial cell (under consideration)
IEC 62153-4-16	Technical report on the relationship between transfer impedance and screening attenuation (under consideration)

Usually RF connectors have mechanical dimensions in the longitudinal axis in the range of 20 mm to maximum 50 mm. With the definition of electrical short elements we get cut off or corner frequencies for the transition between electrically short and long elements of about 1 GHz or higher for usual RF-connectors.

To measure the screening attenuation instead of transfer impedance also in the lower frequency range, the tube in tube procedure was designed. The electrically length of the RF-connector is extended by a RF-tightly closed metallic extension tube (tube in tube). See Figure 2.

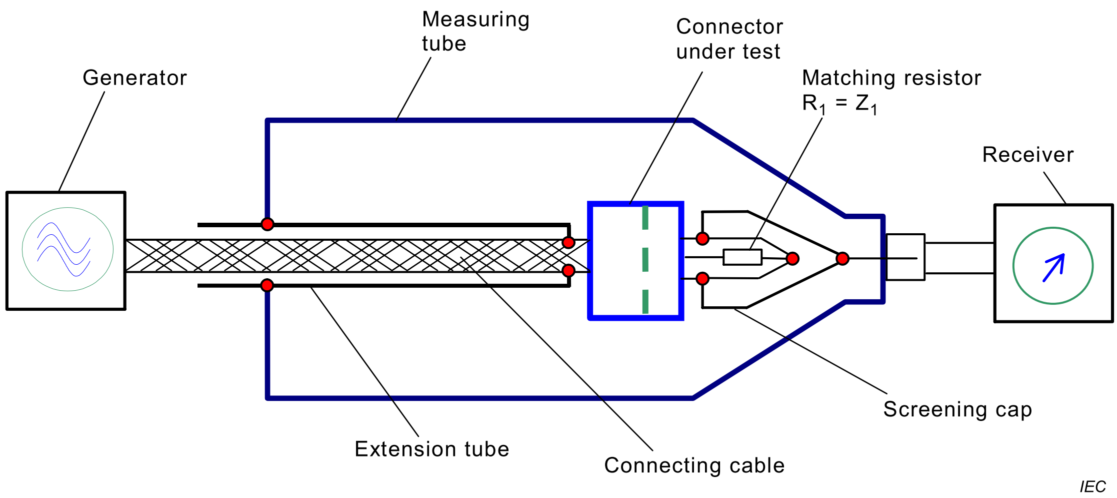


Figure 2 – Principle of the test set-up to measure transfer impedance and screening or coupling attenuation of connectors with tube in tube

The tube in tube test set up is based on the triaxial system according to IEC 62153-4-3 and IEC 62153-4-4 consisting of the DUT, a solid metallic tube and (optional) a RF-tight extension tube. The matched device under test, DUT, which is fed by a generator, forms the disturbing circuit which may also be designated as the inner or the primary circuit. The connecting cables to the DUT are additionally screened by the tube in tube.

The disturbed circuit, which may also be designated as the outer or the second circuit, is formed by the outer conductor of the device under test (and the extension tube), connected to the connecting cable and a solid metallic tube, having the DUT under test in its axis.

5.2 Transfer impedance

The test determines the screening effectiveness of a shielded cable by applying a well-defined current and voltage to the screen of the cable, the assembly or the device under test and measuring the induced voltage in secondary circuit in order to determine the surface transfer impedance. This test measures only the magnetic component of the transfer impedance. To measure the electrostatic component (the capacitance coupling impedance), the method described in IEC 62153-4-8 should be used.

The triaxial method of the measurement is in general suitable in the frequency range up to 30 MHz for a 1 m sample length and 100 MHz for a 0,3 m sample length, which corresponds to an electrical length less than 1/6 of the wavelength in the sample. A detailed description is found in Clause 9 of IEC TS 62153-4-1:2014 as well as in IEC 62153-4-3.

5.3 Screening attenuation

The disturbing or primary circuit is the matched cable, assembly or device under test. The disturbed or secondary circuit consists of the outer conductor (or the outermost layer in the case of multiscreen cables or devices) of the cable or the assembly or the device under test and a solid metallic housing, having the device under test in its axis (see Figure 3).

The voltage peaks at the far end of the secondary circuit have to be measured. The near end of the secondary circuit is short-circuited. For this measurement, a matched receiver is not necessary. The expected voltage peaks at the far end are not dependent on the input impedance of the receiver, provided that it is lower than the characteristic impedance of the secondary circuit. However, it is an advantage to have a low mismatch, for example, by selecting of housings of sufficient size. A detailed description could be found in Clause 10 of IEC TS 62153-4-1:2014 as well as in IEC 62153-4-4.

5.4 Coupling attenuation

Balanced cables, connectors, assemblies or devices which are driven in the differential mode may radiate a small part of the input power, due to irregularities in the symmetry. For unscreened balanced cables, connectors, assemblies or devices, this radiation is related to the unbalance attenuation a_{u}. For screened balanced cables, connectors or assemblies, the unbalance causes a current in the screen which is then coupled by the transfer impedance and capacitive coupling impedance into the outer circuit. The radiation is attenuated by the screen of the component and is related to the screening attenuation a_{s}.

Consequently the effectiveness against electromagnetic disturbances of shielded balanced cables, connectors or assemblies is the sum of the unbalance attenuation a_{u} of the pair and the screening attenuation a_{s} of the screen. Since both quantities usually are given in a logarithmic ratio, they may simply be added to form the coupling attenuation a_{c}:

$$a_{\text{c}} = a_{\text{u}} + a_{\text{s}} \tag{8}$$

Coupling attenuation a_{c} is determined from the logarithmic ratio of the feeding power P_1 and the periodic maximum values of the power $P_{\text{r,max}}$ (which may be radiated due to the peaks of voltage U_2 in the outer circuit):

$$a_{\text{c}} = -10 \log_{10}\left(\text{Env}\left|\frac{P_{\text{r,max}}}{P_1}\right|\right) \tag{9}$$

where

Env is the minimum envelope curve of the measured values in dB.

The relationship of the radiated power P_r to the measured power P_2 received on the input impedance R is:

$$\frac{P_s}{P_2} = \frac{P_{S\max}}{P_{2\max}} = \frac{R}{2 \cdot Z_s} \tag{10}$$

There will be a variation of the voltage U_2 on the far end, caused by the electromagnetic coupling through the screen and superposition of the partial waves caused by the surface transfer impedance Z_T ,the capacitive coupling impedance Z_F (travelling to the far and near end) and the totally reflected waves from the near end.

To feed the balanced device under test, a differential mode signal is necessary. This can be achieved with a two-port network analyser (generator and receiver) and a balun or a multiport network analyser. The procedure to measure coupling attenuation with a multiport network analyser is under consideration.

6 Test procedure

6.1 General

The measurements shall be carried out at the temperature of (23 ± 3) °C. The test method determines the transfer impedance or the screening attenuation or the coupling attenuation of a DUT by measuring in a triaxial test set-up according to IEC 62153-4-3 and IEC 62153-4-4.

6.2 Tube in tube procedure

Usually RF connectors have mechanical dimensions in the longitudinal axis in the range of 20 mm to maximum 50 mm. With the definition of electrically short elements, we get cut off or corner frequencies or corner for the transition between electrically short and long elements of about 1 GHz or higher for usual RF-connectors.

In the frequency range up to the cut off frequency, where the device under test (DUT) is electrically short, the transfer impedance of the DUT can be measured. For frequencies above the cut-off frequency, where the DUT is electrically long, the screening attenuation can be measured.

By extending the electrically length of the RF-connector by a RF-tightly closed metallic extension tube (tube in tube), the tested combination becomes electrically long and the cut-off frequency is moved towards the lower frequency range. In this way, also in the lower frequency range, the screening attenuation may be measured and the effective transfer impedance of electrical short devices calculated.

The test set up is a triaxial system consisting of the DUT, a solid metallic tube and a RF-tight extension tube. The matched device under test, DUT, which is fed by a generator forms the disturbing circuit which may also be designated as the inner or the primary circuit.

The disturbed circuit, which may also be designated as the outer or the second circuit, is formed by the outer conductor of the device under test, connected to the extension tube and a solid metallic tube having the DUT under test in its axis.

The principle of the test set-up is shown in Figure 2 and Figure 3. The set-up is the same for measuring the transfer impedance and the screening- or the coupling attenuation, whereas the length of the inner and the outer tube may vary.

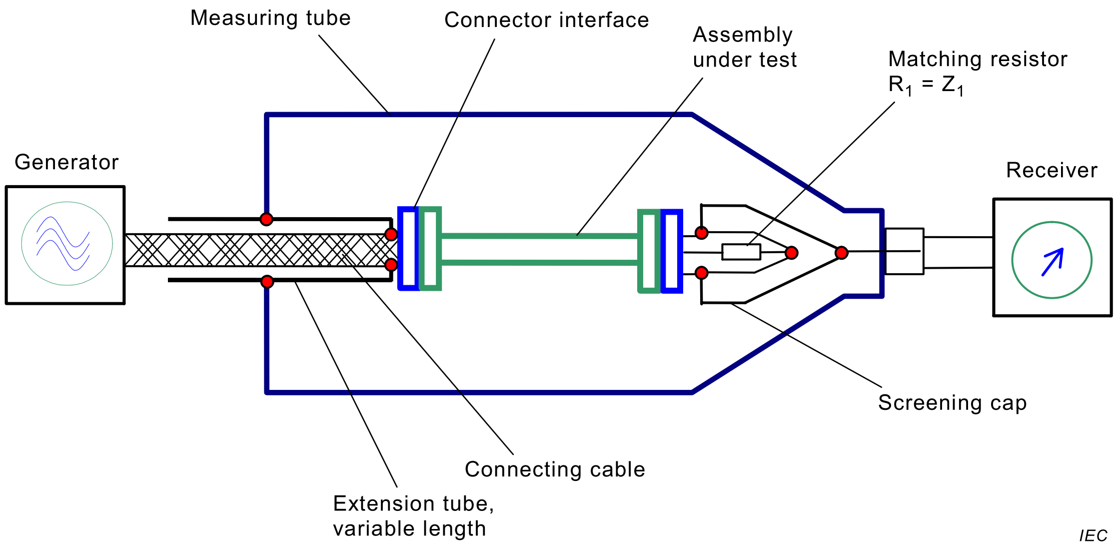


Figure 3 – Principle of the test set-up to measure transfer impedance and screening attenuation of a cable assembly

The voltage ratio of the voltage at the near end (U_1) of the inner circuit (generator) and the voltage at the far end (U_2) of the secondary circuit (receiver) shall be measured (U_1/U_2). The near end of the secondary circuit is short-circuited.

Depending on the electrical length of the tested combination, the DUT and the extension tube, the result may be expressed either by the transfer impedance, the effective transfer impedance or the screening attenuation (or the coupling attenuation).

For this measurement, a matched receiver is not necessary. The likely voltage peaks at the far end are not dependant on the input impedance of the receiver, provided that it is lower than the characteristic impedance of the secondary circuit. However, it is an advantage to have a low mismatch, for example by selecting a range of tube diameters for several sizes of coaxial cables.

6.3 Test equipment

The principle of the test set-up is shown in Figure 2 and 3 and consists of:

– an apparatus of a triple coaxial form with a length sufficient to produce a superimposition of waves in narrow frequency bands which enable the envelope curve to be drawn,

– tubes with variable lengths, e.g. by different parts of the tubes and/or by a movable tube in tube. In case of larger connectors or components, the triaxial tubes may be replaced by a triaxial cell according to IEC 62153-15.

– a RF-tight extension tube (tube in tube), variable in length, which should preferably have a diameter such that the characteristic impedance to the outer tube is 50 Ω or equal to the nominal characteristic wave impedance of the network analyser or the generator and receiver. The material of the extension tube shall be non ferromagnetic and well conductive (copper or brass) and shall have a thickness ≥1 mm such that the transfer impedance is negligible compared to the transfer impedance of the device under test,

– a signal generator and a receiver with a calibrated step attenuator and a power amplifier if necessary for very high screening attenuation. The generator and the receiver may be included in a network analyser.

– a balun for impedance matching of the unbalanced generator output signal to the characteristic wave impedance of balanced cables for measuring the coupling attenuation. Requirements for the balun are given in IEC 62153-4-9:2008, 6.2. Alternatively to a balun, a VNA with mixed mode option may be used (procedures with mixed mode VNAs are under consideration).

Optional equipment is:

– time domain reflectometer (TDR) with a rise time of less than 200 ps or network analyser with maximum frequency up to 5 GHz and time domain capability.

6.4 Calibration procedure

The calibration shall be established at the same frequency points at which the measurement is done, i.e. in a logarithmic frequency sweep over the whole frequency range, which is specified for the transfer impedance.

When using a vector network analyser with S-parameter test-set, a full two port calibration shall be established including the connecting cables used to connect the test set-up to the test equipment. The reference planes for the calibration are the connector interface of the connecting cables.

When using a (vector) network analyser without S-parameter test-set, i.e. by using a power splitter, a THRU calibration shall be established including the test leads used to connect the test set-up to the test equipment.

When using a separate signal generator and receiver, the composite loss of the test leads shall be measured and the calibration data shall be saved, so that the results may be corrected.

$$a_{\text{cal}} = 10\,\log_{10}\left(\frac{P_1}{P_2}\right) = -20\,\log_{10}\left(S_{21}\right) \qquad (11)$$

where

P_1 is the power fed during calibration procedure;

P_2 is the power at the receiver during calibration procedure.

If amplifiers are used, their gain shall be measured over the above-mentioned frequency range and the data shall be saved.

If an impedance matching adapter is used, the attenuation shall be measured over the above-mentioned frequency range and the data shall be saved. This can be achieved e.g. by connecting two impedance matching adapters of the same type and the same manufacturer “back to back” together and measure:

$$2 \cdot a_{\text{imd}} = 10\,\log_{10}\left(\frac{P_1}{P_2}\right) = -20\,\log_{10}\left(S_{21}\right) \qquad (12)$$

6.5 Connection between extension tube and device under test

The connection between the extension tube and the attached cables of the device under test shall be such that the contact resistance is negligible. A possible connection technique as well as a description of the influence of contact resistances is given in Annex D.

6.6 Dynamic range respectively noise floor

With the verification test, the residual transfer impedance respectively the noise floor due to the connection of the feeding cable to the extension tube shall be determined.

The feeding cable is matched with its characteristic impedance and connected to the test head. The extension tube shall then be connected to the feeding cable (without DUT), using the same connection technique as during the test. The piece of cable between the connection points shall be as short as possible (see Figure 4).

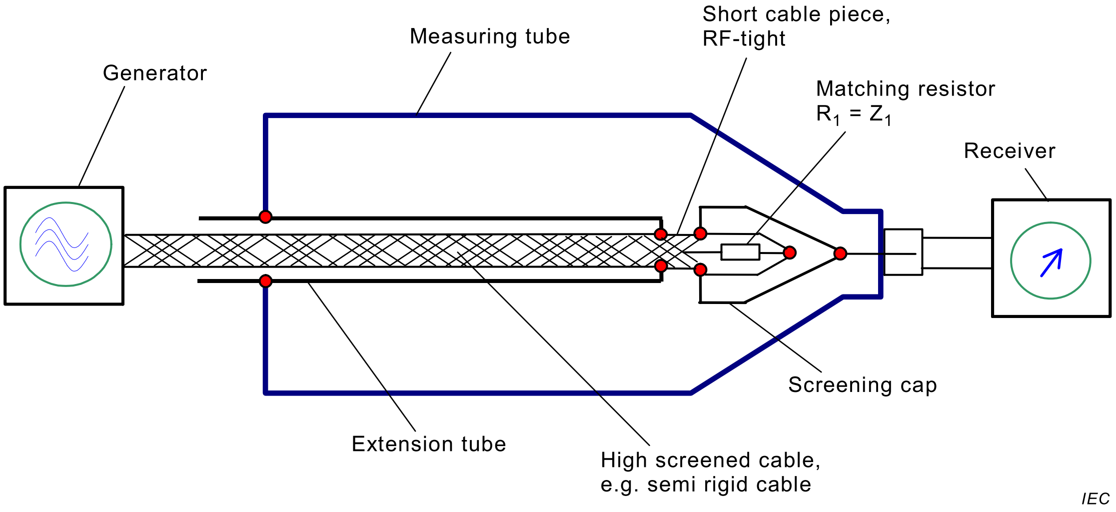


Figure 4 – Principle set-up for verification test

The voltage ratio U_1/U_2 shall be measured with the VNA.

The noise floor a_n of the connection of the extension tube to the feeding cable is then given by:

$$a_n = 20\log_{10}(U_1/U_2) \quad (13)$$

The noise floor shall be at least 10 dB better than the measured value.

The residual transfer impedance of the connection of the extension tube to the feeding cable is given by:

$$Z_{\mathrm{Tr}} = Z_1 \left| \frac{U_2}{U_1} \right| \quad (14)$$

6.7 Impedance matching

If unknown, the nominal characteristic impedance of the (quasi-)coaxial system can either be measured by using a TDR with maximum 200 ps rise time or using the method described in Annex A. An impedance matching adapter to match the impedance of the generator and the impedance of the (quasi-)coaxial system is not recommended as it reduces the dynamic range of the test set-up and may have sufficient matching (return loss) only up to 100 MHz when using self-made adapters which are necessary for impedances other than 60 Ω or 75 Ω (see Annex B).

6.8 Influence of Adapters

When measuring transfer impedance and screening attenuation or coupling attenuation on connectors or cable assemblies, test adapters are required if no mating connectors to the connectors of the DUT are available.

Test adapters and/or mating connectors may limit the sensitivity of the test set up and may influence the measurement.

The type and/or the design of the test adapter shall be stated in the test report.

A more detailed description on the design and the influence of test adapters is under consideration.

7 Sample preparation

7.1 Coaxial connector or device

A feeding cable shall be mounted to the connector under test and it’s mating part according to the specification of the manufacturer. One end shall be connected to the test head where the feeding cable is matched with the nominal characteristic impedance of the device under test. It may be short circuited, when measuring the transfer impedance with method C: (Mismatched)-short-short without damping resistor according to IEC 62153-4-3.

The other end of the connecting cable shall be passed through the extension tube and connected to the generator. On the side of the device under test, the screen of the feeding cable shall be connected to the extension tube with low contact resistance (see 6.2 and Annex B). On the generator side, the screen of the feeding cable shall not be connected to the extension tube.

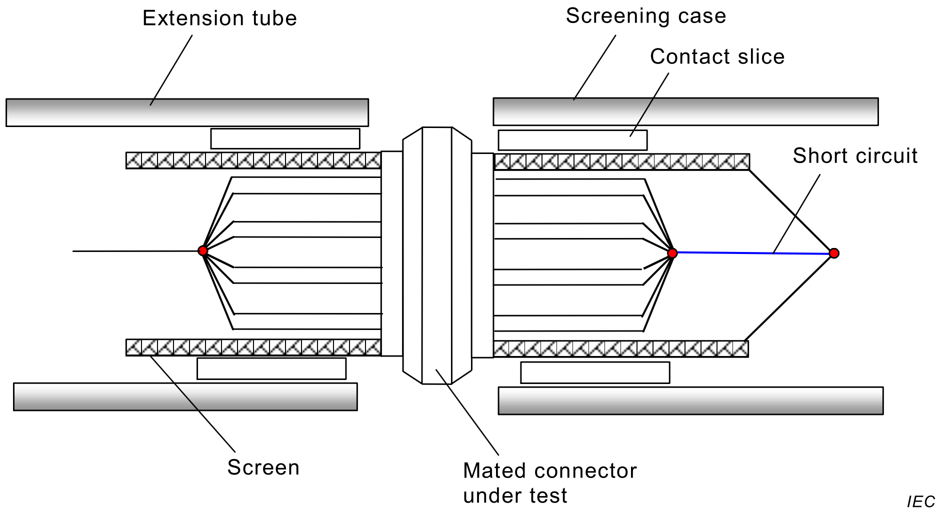
7.2 Balanced or multiconductor device

A balanced or multiconductor cable which is usually used with the connector under test shall be mounted each to the connector under test and it’s mating part according to the specification of the manufacturer.

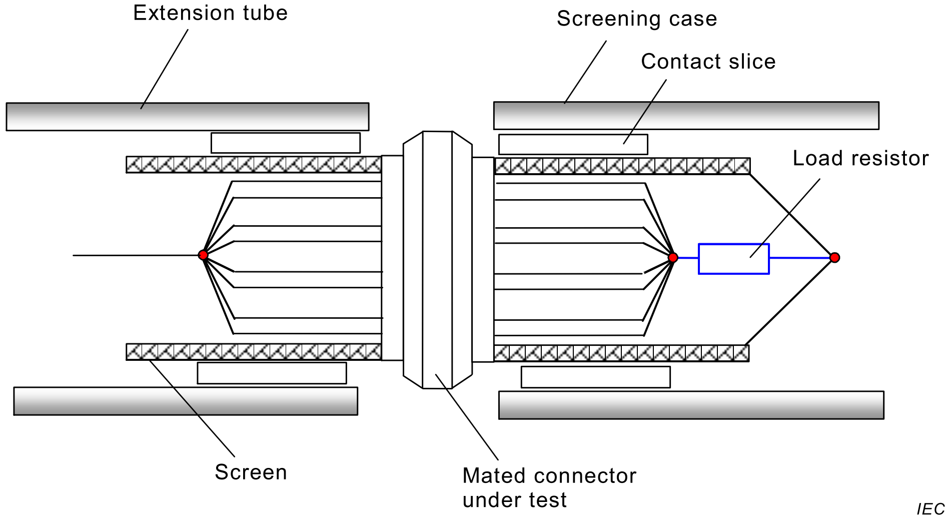
When measuring transfer impedance or screening attenuation, screened balanced or multiconductor cables are treated as a quasi-coaxial system. Therefore, at the open ends of the feeding cable, all conductors of all pairs shall be connected together. All screens, including those of individually screened pairs or quads, shall be connected together at both ends. All screens shall be connected over the whole circumference (see Figures 5a and 5b).

One end shall then be connected to the test head where the feeding cable is matched with the characteristic impedance (screening attenuation and transfer impedance with short/matched procedure) or with a short circuit (transfer impedance with short/short procedure).

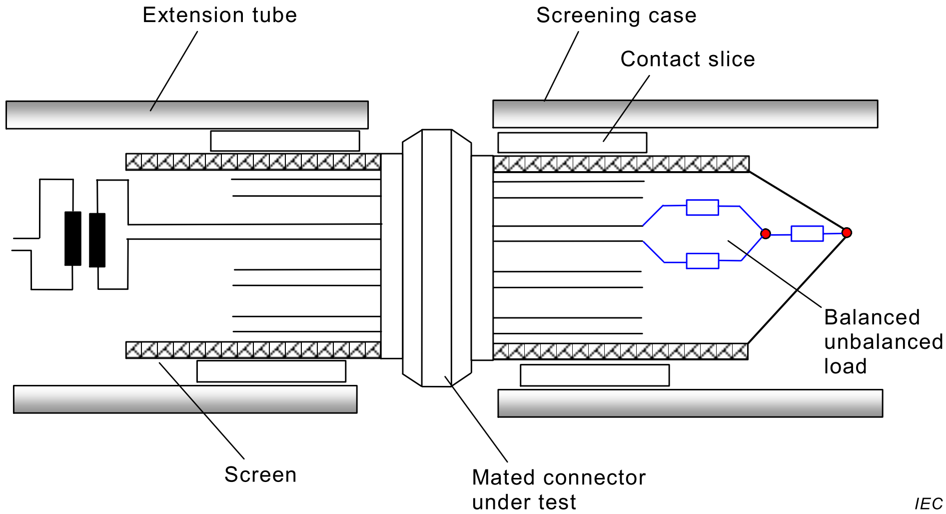
One end of the connecting cable shall then be connected to the test head where the connecting cable is matched with the characteristic impedance of the DUT.



a) Principle preparation of balanced or multiconductor connectors for transfer impedance (short/short)



b) Principle preparation of balanced or multiconductor connectors for transfer impedance (short/matched) and screening attenuation



c) Principle preparation of balanced or multiconductor connectors for coupling attenuation

Figure 5 – Preparation of balanced or multiconductor connectors

7.3 Cable assembly

If the cable assembly fits into the tube, it shall be measured according to Figure 3. Longer cable assemblies can be cut and each site measured separately.

8 Measurement of transfer impedance

8.1 General

IEC 62153-4-3 describes three different triaxial test procedures:

– Test method A: Matched inner circuit with damping resistor in outer circuit

– Test method B: Inner circuit with load resistor and outer circuit without damping resistor

– Test method C: (Mismatched)-short-short without damping resistor

The procedure described herein is in principle the same as test method B of IEC 62153-4-3: Matched inner circuit without the use of the impedance matching adapter and without the damping resistor R_2. It has a higher dynamic range than test method A of IEC 62153-4-3.

The load resistor R_1 could be either equal to the impedance of the inner circuit or be equal to the generator impedance. The latter case is of interest when using a network analyser with power splitter instead of S-parameter test set.

NOTE Other procedures of 62153-4-3 may be applied accordingly if required.

8.2 Principle block diagram of transfer impedance

A block diagram of the test set-up to measure transfer impedance according to test method B of IEC 62153-4-3 is shown in Figure 6.

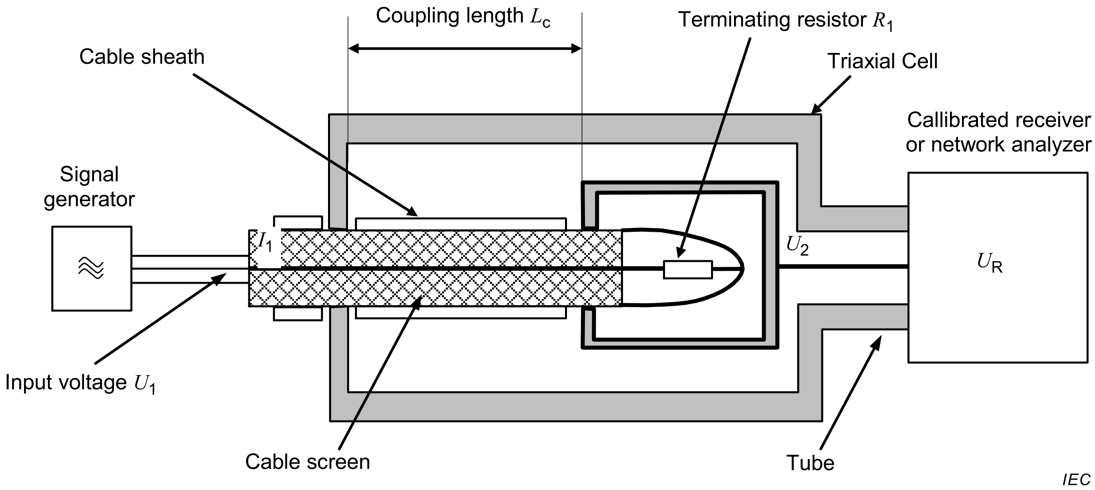


Figure 6 – Test set-up (principle) for transfer impedance measurement according to test method B of IEC 62153-4-3

8.3 Measuring procedure – Influence of connecting cables

When measuring a connector or a component without tube in tube, the transfer impedance of the connecting cables inside the tube to connect the DUT shall be measured.

The transfer impedance of the connecting cables which connects the DUT shall be measured according to IEC 62153-4-3. The measured value shall be related to the length of the connecting cables inside the test set-up to connect the DUT, the result is the transfer impedance of the connecting cables, Z_{con}.

8.4 Measuring

The DUT shall be connected to the generator and the outer circuit (tube) to the receiver.

The attenuation, a_{meas}, shall be preferably measured in a logarithmic frequency sweep over the whole frequency range, which is specified for the transfer impedance and at the same frequency points as for the calibration procedure:

$$a_{meas} = 10 \log_{10}\left(\frac{P_1}{P_2}\right) = -20 \log_{10}\left(S_{21}\right) \tag{15}$$

where

P_1 is the power fed to inner circuit;

P_2 is the power in the outer circuit.

8.5 Evaluation of test results

The conversion from the measured attenuation to the transfer impedance is given by following formula:

$$Z_T = \frac{R_1 + Z_0}{2} \cdot 10^{-\left(\frac{a_{meas} - a_{cal}}{20}\right)} - Z_{con} \tag{16}$$

or

$$Z_T = \frac{R_1 + Z_0}{2} \cdot 10^{-\left(\frac{a_{meas} - a_{cal}}{20}\right)} - Z_{Tr} \tag{17}$$

when using the tube in tube method.

where

Z_T is the transfer impedance;

Z_0 is the system impedance (in general 50 Ω);

a_{meas} is the attenuation measured at measuring procedure;

a_{cal} is the attenuation of the connection cables if not eliminated by the calibration procedure of the test equipment;

R_1 is the terminating resistor in inner circuit (either equal to the impedance of the inner circuit or the impedance of the generator);

Z_{con} is the transfer impedance of connecting cables;

Z_{Tr} is the residual transfer impedance, see 6.6.

NOTE Contrary to the measurement of the transfer impedance of cable screens, the transfer impedance of connectors or assemblies is not related to length.

8.6 Test report

The test report shall record the test results and shall conclude if requirements of the relevant detail specification are met.

The use and the design of test adapters (if any) shall be described.

9 Screening attenuation

9.1 General

This method is in principle the same as described in IEC 62153-4-4.

9.2 Impedance matching

9.2.1 General

Measuring of screening attenuation can be achieved with or without impedance matching.

If the characteristic impedance of the DUT is unknown, the nominal characteristic impedance of the quasi-coaxial system can either be measured by using a TDR with maximum 200 ps rise time or using the method described in Annex A of IEC 62153-4-4.

An impedance matching adapter to match the impedance of the generator and the impedance of the system device under test (see figure 7) is not recommended as it reduces the dynamic range of the test set-up and may have sufficient matching (return loss) only up to 100 MHz when using self-made adapters which are necessary for impedances other than 50 Ω or 75 Ω (see Annex B of IEC 62153-4-4).

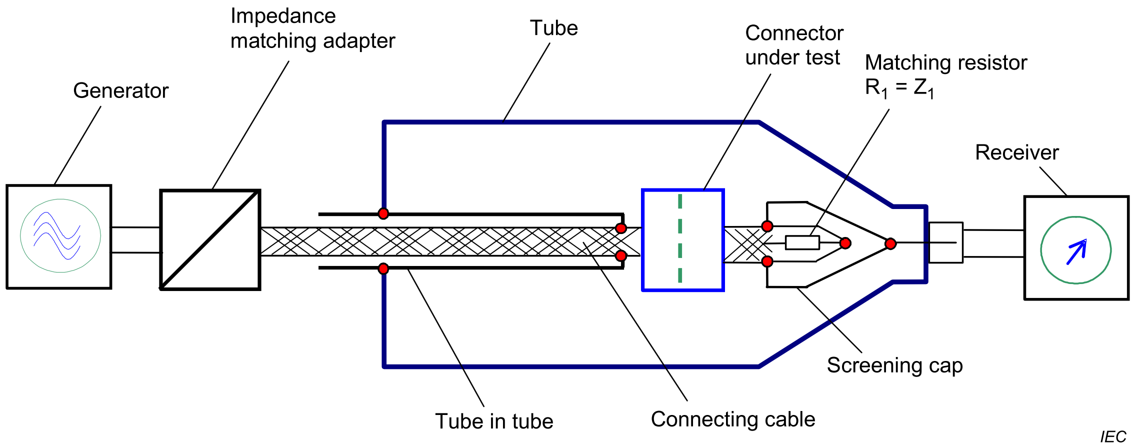


Figure 7 – Measuring the screening attenuation with tube in tube with impedance matching device

The DUT with the connected extension tube shall be installed in the measuring tube. The extension tube shall be short circuited to the measuring tube at the near end of the generator. The feeding cable shall be connected to the generator (via an impedance matching device if necessary) and the output of the measuring tube shall be connected to the receiver.

The scattering parameter S_{21} shall be measured.

Only the peak values of the obtained screening attenuation graph are used to determine the envelope curve.

9.2.2 Evaluation of test results with matched conditions

The screening attenuation a_s shall be calculated with the arbitrary determined normalised value Z_S = 150 Ω[1].

$$a_S = 10 \times \log_{10}\left|\frac{P_1}{P_{r,max}}\right| = 10 \times \log_{10}\left|\frac{P_1}{P_{2,max}} \times \frac{2 \times Z_S}{R}\right| - a_{\text{Im}\,d} \quad (18)$$

$$= Env\left\{-20 \times \log_{10}\left|S_{21}\right| + 10 \times \log_{10}\left|\frac{300\Omega}{Z_1}\right| - a_{imd}\right\} \quad (19)$$

where

a_S is the screening attenuation related to the radiating impedance of 150 Ω in dB;

a_{imd} Is the attenuation of the impedance matching device (if appropriate);

Env is the minimum envelope curve of the measured values in dB;

S_{21} is the scattering parameter S_{21} (complex quantity) of the set-up where the primary side of the two port is the DUT and the secondary side is the tube;

Z_1 is the characteristic impedance of the cable under test, in Ω.

At frequencies lower than the limit of the electrically long coupling length, the measurement will be similar to that for surface transfer impedance.

9.2.3 Measuring with mismatch

The DUT shall be connected to port 1 and the test head of the set-up shall be connected to port 2 of the vector network analyser.

If not known, the characteristic impedance Z_1 of the DUT shall be measured (see 9.2).

The scattering parameter S_{21} shall be measured.

Only the peak values of the obtained screening attenuation graph are used to determine the envelope curve.

9.2.4 Evaluation of test results

The screening attenuation a_s which is comparable to the results of the absorbing clamp method shall be calculated with the arbitrary determined normalised value Z_S = 150 Ω[1].

$$a_S = 10\log_{10}\left|\frac{P_1}{P_{r,max}}\right| = 10\log_{10}\left|\frac{P_1}{P_{2,max}} \cdot \frac{2 \times Z_S}{R}\right| \quad (20)$$

$$= Env\left\{-20\log_{10}\left|S_{21}\right| + 10\log_{10}\left|1 - r^2\right| + 10\log_{10}\left|\frac{300\Omega}{Z_1}\right|\right\} \quad (21)$$

where

---

1 Z_s is the normalised value of the characteristic impedance of the environment of a typical cable installation. It is not in relation to the impedance of the outer circuit of the test set-up.

a_S is the screening attenuation related to the radiating impedance of 150 Ω in dB;

Env is the minimum envelope curve of the measured values in dB;

S_{21} is the scattering parameter S_{21} (complex quantity) of the set-up where the primary side of the two port is the DUT and the secondary side is the tube;

r is the reflection coefficient $= \left| \left(\frac{Z_0 - Z_1}{Z_0 + Z_1} \right) \right|$;

Z_0 is the characteristic impedance of system in Ω, (usually 50 Ω);

Z_1 is the characteristic impedance (in complex form) of the device under test in Ω.

9.3 Test report

The test report shall record the test results and shall conclude if requirements of the relevant detail specification are met.

The use and the design of test adapters (if any) shall be described.

10 Coupling attenuation

10.1 Procedure

The DUT is connected to the connecting cables according to the instructions of the manufacturer and terminated at the far end by differential and common mode terminations according to Figure 5c. The sample is then centred in the tube and fed by a generator in the differential mode via a balun, see Figure 8. Alternatively, the DUT may be fed by a multiport VNA, see Figure 10 (procedure is under consideration).

The quotient of the voltages at the output of the outer circuit and the input of the cable is measured, either directly by a network analyser or with a calibrated step attenuator [assuming that the receiver has the same input impedance as the output impedance of the signal generator ($R = Z_1$)] which is inserted as an alternative to the triaxial apparatus.

Only the peak values of the maximum of the voltage ratio or the minimum of the attenuation must be measured and recorded as a function of the frequency in order to determine the envelope curve.

Attenuation introduced by the inclusion of adapters, instead of direct connection, must be taken into account when calibrating the triaxial apparatus.

The voltage ratio measured is not dependent on the diameter of the outer tube of the triaxial test set-up or on the characteristic impedance Z_2 of the outer system, provided that Z_2 is larger than the input impedance of the receiver.

NOTE The procedure to measure with a VNA with mixed mode option instead of using a balun is under consideration.

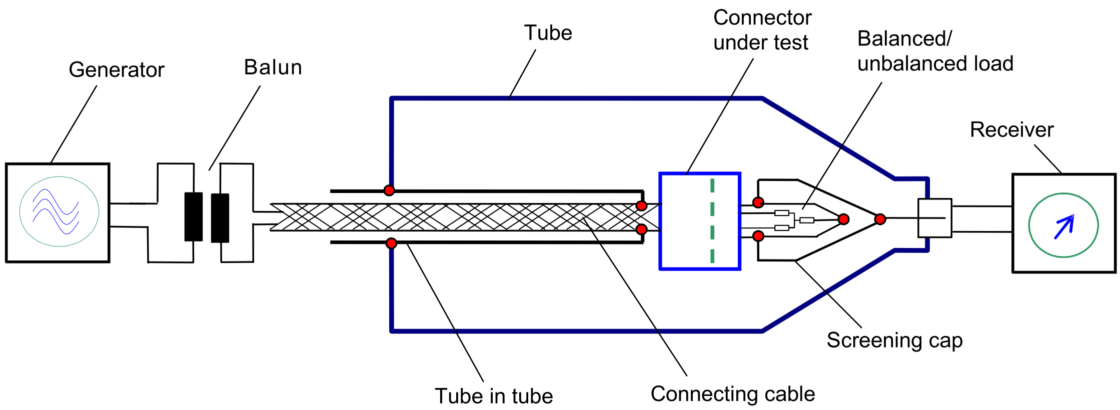


Figure 8 – Measuring the coupling attenuation with tube in tube and balun

10.2 Expression of results

The attenuation of the balun shall be subtracted from the measuring results. The coupling attenuation a_c shall be calculated with the normalised value Z_S = 150 Ω:

$$a_c = 10 \cdot \log_{10}\left|\frac{P_1}{P_{r,max}}\right| = 10 \cdot \log_{10}\left|\frac{P_1}{P_{2,max}} \cdot \frac{2 \cdot Z_S}{R}\right| \tag{22}$$

$$= 20 \cdot \log_{10}\left|\frac{U_1}{U_{2max}}\right| + 10 \cdot \log_{10}\left|\frac{300\,\Omega}{Z_1}\right| \tag{23}$$

$$= a_{m,min} - a_z + 10 \cdot \log_{10}\left|\frac{300\,\Omega}{Z_1}\right| \tag{24}$$

where

a_C is the coupling attenuation related to the normalised radiating impedance of 150 Ω in dB;

$a_{m,min}$ is the attenuation recorded as minimum envelope curve of the measured values in dB;

a_z is the additional attenuation of an inserted balun, if not otherwise eliminated e.g. by the calibration, in dB;

U_1 is the input voltage of the primary circuit formed by the cable in V;

U_2 is the output voltage of the secondary circuit in V;

Z_1 is the (differential mode) characteristic impedance of the cable under test in Ω.

10.3 Test report

The test report shall indicate whether the results of minimum coupling attenuation comply with the value indicated in the relevant cable specification.

If a limiting value of the radiating power is specified for a cable system operating with a defined power level, the difference between the power level and the limit of radiating power shall not be greater than the coupling attenuation of the cable provided for the system.

The use and the design of test adapters (if any) shall be described.

A typical measurement graph of a connector is given in Figure 9.

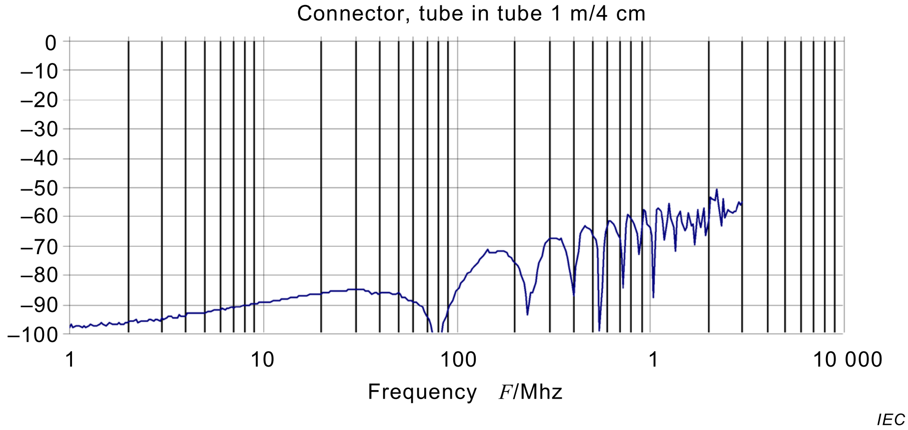


Figure 9 – Typical measurement of a connector of 0,04 m length with 1 m extension tube

10.4 Balunless procedure

To measure the coupling attenuation as well as to measure the unbalance attenuation a differential signal is required. This can, for example, be generated using a balun which converts the unbalanced signal of a 50 Ω network analyser into a balanced signal. Commercial baluns, however, are available up to 1,2 GHz only.

Alternatively, a balanced signal may be obtained with a network analyser having two generators with a phase shift of 180°. Another alternative is to measure with a multi-port VNA (virtual balun).

The balunless test procedure is under consideration.

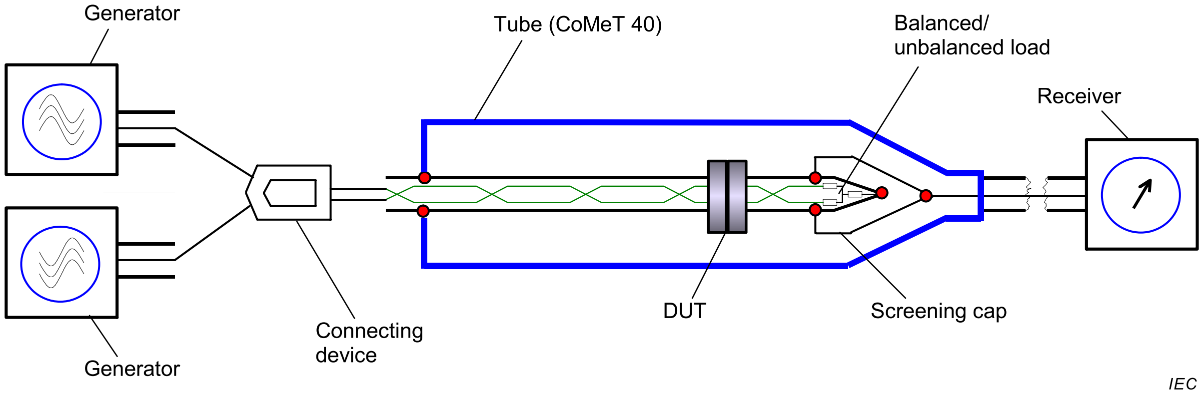


Figure 10 – Measuring the coupling attenuation with multiport VNA (balunless procedure is under consideration)

Annex A
(normative)

Determination of the impedance of the inner circuit

If the impedance Z_1 of the inner circuit is not known, it may be determined using a TDR with maximum 200 ps rise time or using the following method with a (vector) network analyser (VNA).

One end of the prepared sample is connected to the VNA, which is calibrated for impedance measurements at the connector interface reference plane. The test frequency shall be approximately the frequency for which the length of the sample is 1/8 λ, where λ is the wavelength.

$$f_{\text{test}} \approx \frac{c_0}{8 \cdot L_{\text{sample}} \cdot \sqrt{\varepsilon_{r1}}} \quad \text{(A.1)}$$

where

f_{test} is the test frequency;

c is the speed of light 3×10^8 m/s;

L_{sample} is the length of sample.

The sample is short-circuited at the far end. The impedance Z_{short} is measured.

The sample is left open at the same point where it was shorted. The impedance Z_{open} is measured.

Z_1 is calculated as:

$$Z_1 = \sqrt{Z_{\text{short}} \cdot Z_{\text{open}}} \quad \text{(A.2)}$$

Annex B
(informative)

Example of a self-made impedance matching adapter

Figure B.1 and B.2 show the attenuation and return loss of a 50 Ω to 5 Ω impedance matching adapter. A DUT impedance of 5 Ω is typical when measuring mulipair cables with individually screened pairs or when measuring high voltage cables for electrical vehicles.

The attenuation and return loss were obtained from an open/short measurement. One can obtain that the matching adapter only works up to 10 MHz.

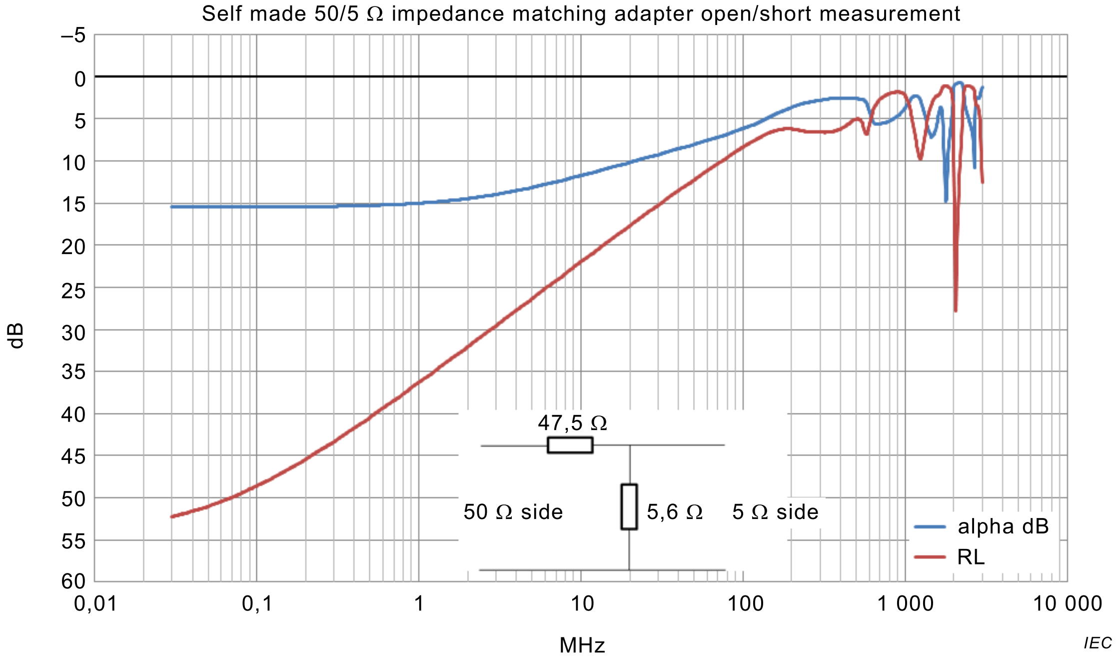


Figure B.1 – Attenuation and return loss of a 50 Ω to 5 Ω impedance matching adapter, log scale

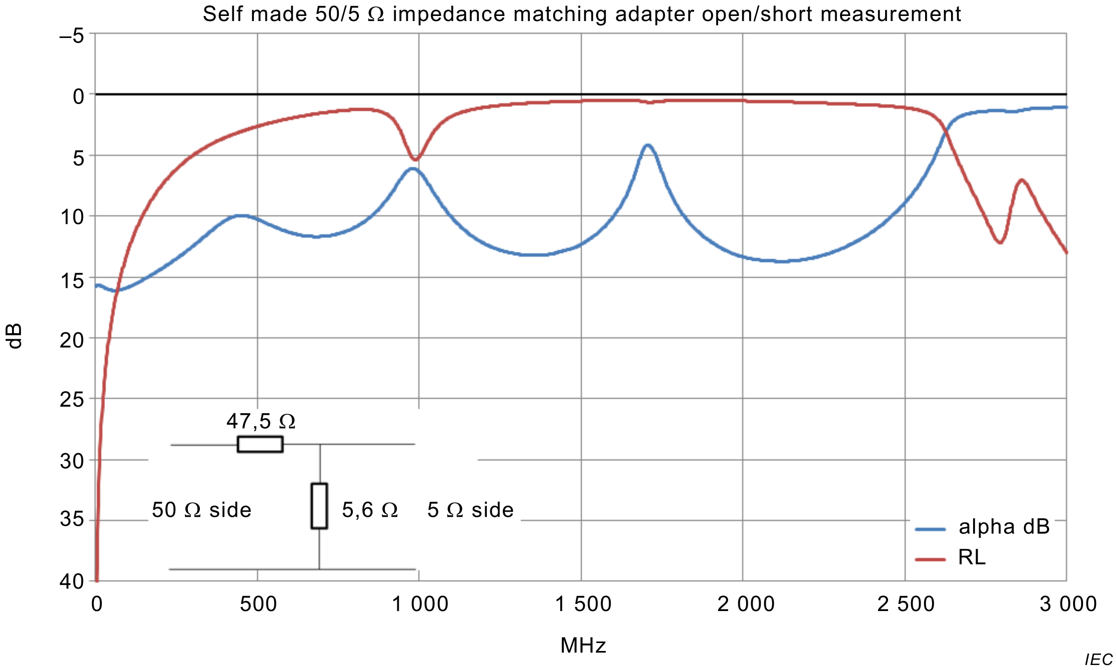


Figure B.2 – Attenuation and return loss of a 50 Ω to 5 Ω impedance matching adapter, lin scale

Annex C
(informative)

Measurements of the screening effectiveness of connectors and cable assemblies

C.1 General

Due to the increasing use of all kind of electric or electronic equipment, electromagnetic pollution is on the increase. To reduce this electromagnetic pollution, all components of a system, especially the connecting cables (assemblies) shall be screened. It is obvious that one needs standardised measuring procedures to compare the screening effectiveness of different screen designs. The basic screening parameters are the transfer impedance Z_T and the screening attenuation a_S or coupling attenuation a_C. Either the triaxial or the line injection method can be used to obtain the transfer impedance Z_T of cables, connectors and cable assemblies. However, for the measurement of the screening a_S or coupling a_C attenuation of connectors and cable assemblies, an easy and cost effective method does not exist.

The following new method, which fills this gap, is described hereafter. It is based on the recently introduced shielded screening attenuation (long triaxial) test method for the measurement of the screening or coupling attenuation of cables [1][2][2].

C.2 Physical basics

C.2.1 General coupling equation

For the measurement of the coupling, it is expedient to use the concept of operational attenuation with the square root of power waves, as in the definition of scattering parameters [3][4]. The general coupling transfer function is then defined as:

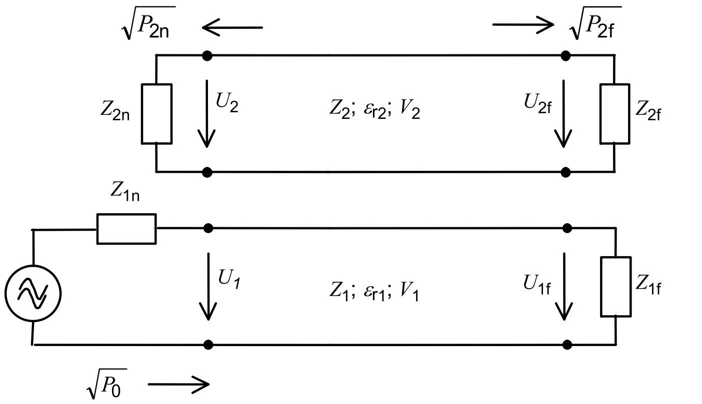
$$T_{n,f} = \frac{\underline{U}_{2n,f} \Big/ \sqrt{Z_2}}{\underline{U}_1 \Big/ \sqrt{Z_1}} = \frac{\sqrt{\underline{P}_{2n,f}}}{\sqrt{\underline{P}_0}} \tag{C.1}$$

The electromagnetic influence between the sample under test and the surrounding is in principle the crosstalk between two lines and is caused by capacitive and magnetic coupling. At the near end, the magnetic and capacitive coupling adds whereas at the far end they subtract [4][5]. The coupling along the sample length is obtained by integrating the infinitesimal coupling distribution along the sample with the correct phase. The phase effect, when summing up the infinitesimal couplings along the line is expressed by the summing function S [4]. When the sample attenuation is neglected, then S could be expressed by the following equation, where $\beta_{1,2}$ are the phase velocities of the primary respectively the secondary circuit and l the coupling length. The indices n and f denote the near respectively the far end.

The equivalent circuit for two coupled lines is given in Figure C.1.

$$S_{n,f}(lf) = \frac{\sin[(\beta_2 \pm \beta_1)\cdot l/2]}{(\beta_2 \pm \beta_1)\cdot l/2} \exp(-j(\beta_2 + \beta_1)\cdot l/2) \tag{C.2}$$

2 Figures in square brackets refer to the bibliography.



Key

$\sqrt{P_0}$	square root of the feeding power
$\sqrt{P_{2n}}$	square root of the coupled power, near end
$\sqrt{P_{2f}}$	square root of the coupled power, far end
Z_{nm}	matching resistors, 1 = primary circuit, 2 = secondary circuit,
n	= near end, f = far end
Z_n	characteristic impedance, 1 = primary circuit, 2 = secondary circuit
ε_{rn}	dielectric constant, 1 = primary circuit, 2 = secondary circuit
v_n	velocity of propagation, 1 = primary circuit, 2 = secondary circuit

Figure C.1 – Equivalent circuit of coupled transmission lines

Figure C.2 shows the summing function which is in principle a sin (x)/x function. For high frequencies, the asymptotic value becomes:

$$\left| S_{\substack{n\\f}} \right| \rightarrow \frac{2}{(\beta_1 \pm \beta_2) \cdot l} \qquad \text{(C.3)}$$

And for low frequencies the summing function be-comes:

$$\left| S_{\substack{n\\f}} \right| \rightarrow 1 \qquad \text{(C.4)}$$

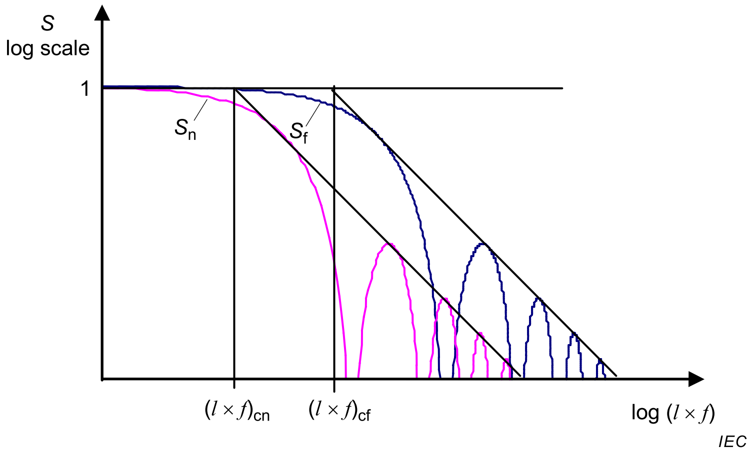


Figure C.2 – Summing function *S*

The point of intersection between the asymptotic values for low and high frequencies is the so called cut-off frequency f_c. This frequency gives the condition for electrical long samples:

$$f_{\substack{c,n\\f}} \cdot l \geq \frac{c_0}{\pi \cdot \left| \sqrt{e_{r1}} \pm \sqrt{e_{r2}} \right|} \tag{C.5}$$

where

e_{r1} is the relative dielectric permittivity of the inner system;

e_{r2} is the relative dielectric permittivity of the outer system;

l s the cable length.

C.2.2 Coupling transfer function

C.2.2.1 Homogenous screens

The primary screening quantities of a screen are the surface transfer impedance Z_T and the capacitive coupling impedance Z_F or the effective transfer impedance Z_{TE}. For homogeneous screens such as for connectors or cables, they can be assumed to be constant along the length. The integration could then be easily solved. The coupling between the sample and the surrounding could be expressed by the following coupling transfer function. For matched lines it is [3][4]:

$$T_{\substack{s,n\\f}} = \left(Z_F \pm Z_T\right) \cdot \frac{1}{\sqrt{Z_1 \cdot Z_2}} \cdot \frac{l}{2} \cdot S_{\substack{n\\f}} \tag{C.6}$$

For low frequencies, when S =1, the coupling transfer function corresponds to the frequency behaviour of the surface transfer impedance and capacitive coupling impedance. After a rise with 20 dB per decade, the coupling transfer function shows different cut-off frequencies $f_{cn,f}$ for the near and far end. Above these cut-off frequencies, the samples are considered as electrically long.

The calculated coupling transfer function of a coaxial cable is given in Figure C.3. The principle set-up of the triaxial test procedure is given in Figure C.4.

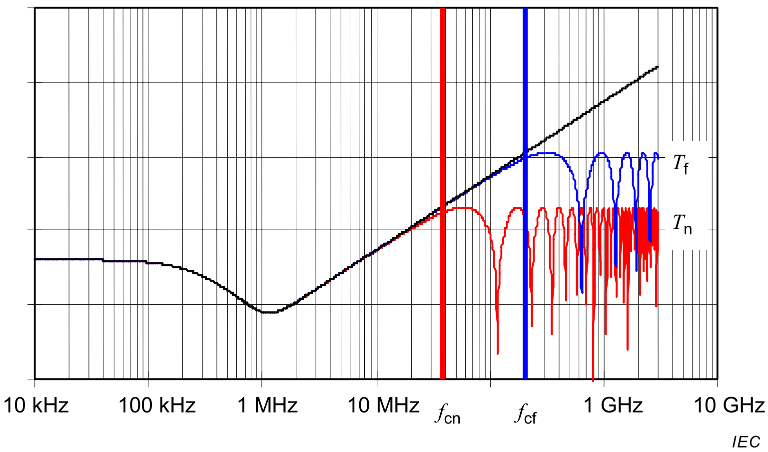


Figure C.3 – Calculated coupling transfer function (l = 1 m; e_{r1} = 2,3; e_{r2} = 1; Z_F = 0)

Below the cut-off frequencies, the surface transfer impedance Z_T is the measure of the screening effectiveness. The value of the transfer impedance Z_T increases with the sample length.

Above the cut-off frequencies in the range of wave propagation, respectively in the range where the samples are electrically long, the screening attenuation a_S is the parameter for the screening effectiveness. The screening attenuation is a length-independent quantity.

C.2.2.2 Cable assembly screens

Cable assemblies are composed by the cable itself and a connector at each end. In addition to the coupling of the components itself, the coupling of the transition between cable and connector also should be taken into account. Mounting a good connector to a good cable will not automatically lead to a good assembly because the connection between the cable and the connector may be worse.

Each part of it has a different coupling, thus one has to integrate in sections along the sample, i.e. one section for each component (connector A, transition, cable, transition, connector B). In a first approach, the velocity in each section could be assumed to be equal. The coupling transfer function for matched lines is then expressed by:

$$T_n = \frac{1}{\gamma_1 + \gamma_2} \cdot \sum_{i=1}^{n} \left[\frac{Z_{F,i} + Z_{T,i}}{2\sqrt{Z_1 \cdot Z_2}} \cdot e^{-(\gamma_1+\gamma_2)\cdot \sum_{k=1}^{i-1} L_i} \cdot \left(1 - e^{-(\gamma_1+\gamma_2)\cdot L_i}\right) \right] \tag{C.7}$$

$$T_f = \frac{e^{-\gamma_2 L_c}}{\gamma_1 - \gamma_2} \cdot \sum_{i=1}^{n} \left[\frac{Z_{F,i} - Z_{T,i}}{2\sqrt{Z_1 \cdot Z_2}} \cdot e^{-(\gamma_1-\gamma_2)\cdot \sum_{k=1}^{i-1} L_i} \cdot \left(1 - e^{-(\gamma_1-\gamma_2)\cdot L_i}\right) \right] \tag{C.8}$$

where

$\gamma_{1,2}$ is the complex wave propagation constant of inner, respectively outer circuit;

L_c is the whole coupling length (sum of the segment lengths);

L_i is the length of segment i;

n is the number of segments (for cable assemblies, 3);

$T_{n,f}$ is the coupling transfer function at the near respectively far end;

$Z_{1,2}$ is the characteristic impedance of inner, respectively outer circuit;

Z_F is the capacitive coupling impedance;

Z_T is the surface transfer impedance;

γ is the propagation constant
= (α+jβ), where α is the attenuation constant and β is the phase constant.

C.2.2.3 Coupling in the triaxial set-up

The above-mentioned coupling transfer functions are valid if the primary and secondary circuit are matched. However, in the triaxial set-up, the secondary system (outer circuit) is mismatched (see also the following section). At the near end, one has the short circuit between the sample screen. At the far end, one has the mismatch between the impedance of the outer circuit and the receiver input impedance resulting in the reflection coefficient $r_{2,f}$. In this case, the resulting coupling transfer function (at the receiver end) is obtained by:

$$T^* = \left(T_f - T_n \cdot e^{-\gamma_2 L_C}\right) \cdot \frac{1 + r_{2,f}}{1 + r_{2,f} \cdot e^{-2\gamma_2 L_C}} \quad \text{(C.9)}$$

where

γ_2 is the complex wave propagation constant of outer circuit;

L_c is the whole coupling length (sum of the segment lengths);

$r_{2,f}$ is the reflection coefficient;

$T_{n,f}$ is the coupling transfer function at the near respectively far end.

C.3 Triaxial test set-up

C.3.1 General

The triaxial test set-up is one of the classical methods to measure the transfer impedance and has been recently extended for the measurement of the screening attenuation of cable screens [1]. The triaxial set-up is described in IEC 62153-4-3 and IEC 62153-4-4 and consists of a tube of brass or aluminium with an inner diameter of about 40 mm.

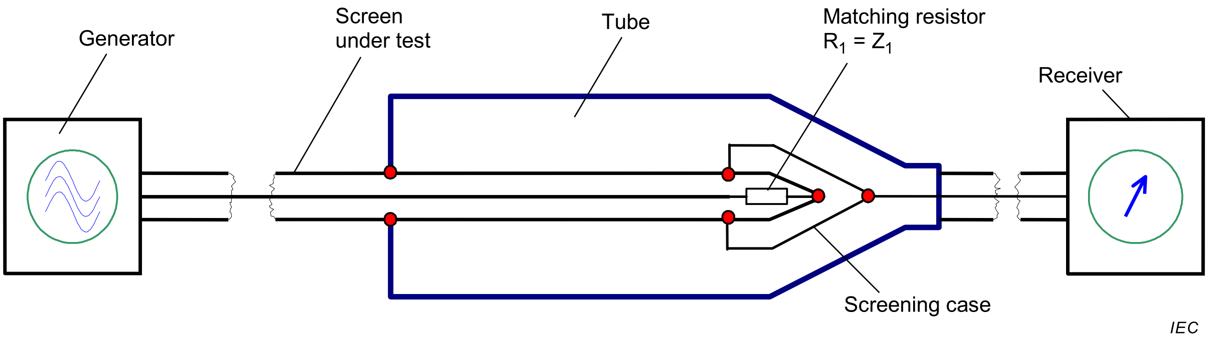


Figure C.4 – Triaxial set-up for the measurement of the screening attenuation a_S and the transfer impedance Z_T

For the measurement of the transfer impedance (electrically short coupling length), the tube length is 0,5 m to 1 m. For the measurement of the screening attenuation (electrically long coupling length), the measuring tube is extended to a length of 2 m to 3 m. (See also the above theoretical explanation).

In the outer circuit, at the near end, the screen under test is short circuited with the measuring tube. The electrical waves, which are coupled over the whole cable length from the inner system into the outer system, propagate in both directions, to the near and to the far end. At the short circuited end, they are totally reflected, so that at the measuring receiver, the superposition of near and far end coupling can be measured as the disturbance voltage ratio U_2/U_1. The screening attenuation as a power ratio is then related to a standardised characteristic impedance of the outer system Z_s = 150 Ω.

$$a_s = 20\log\left(\left|\frac{U_2}{U_1}\right|_{max}\right) + 10\log\left(\frac{2 \cdot Z_s}{Z_1}\right) \quad (C.10)$$

where

Z_1 is the characteristic impedance of the sample under test and Z_s is 150 Ω.

C.3.2 Measurement of cable assemblies

C.3.2.1 General

When measuring cable assemblies in the triaxial test set-up, there is the problem in that their lengths differ widely and are either shorter or longer than the commonly used measuring tube of 2 m or 3 m. However, the investigations of the above-given coupling functions show that:

a) for assemblies longer than the measuring tube, it is sufficient enough to measure just both accessible assembly ends;
b) for assemblies shorter than the measuring tube, one can extend the assembly by a well-screened cable inside a closed copper tube. This is the so called tube in tube method.

C.3.2.2 Assembly longer than the measuring tube

In screening attenuation measurements of cable assemblies, it is evident that the result is characterised by the weakest part. Either the cable or the connector or the transition between cable and connector. Thus, for cable assemblies which are longer than the measuring tube, it is sufficient enough to measure the assembly from both ends (provided that the cable screen is homogenous). The worst case of both measurements is then the screening attenuation of the whole assembly. The simulated graphs given in Figures C.5 and C.6 underline that evidence.

The simulation parameters are:

a) cable screen

length:	500 cm
d.c. resistance:	13 mΩ/m
magnetic coupling:	0,04 mH/m
capacitive coupling:	0,02 pF/m

b) connector screen including transition from cable to connector

length:	5 cm
d.c. resistance:	2 mΩ/m
magnetic coupling:	0,002 mH
capacitive coupling:	0 pF/m

c) outer circuit (secondary system)

impedance:	150 Ω
dielectric permittivity:	1,1

d) inner circuit (primary system)

impedance:	50 Ω

dielectric permittivity: 2,3

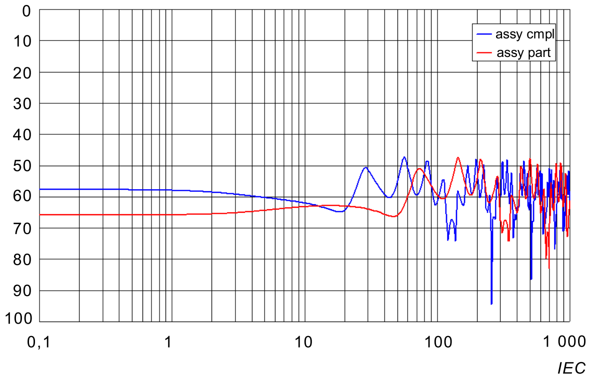


Figure C.5 – Simulation of a cable assembly (logarithmic scale)

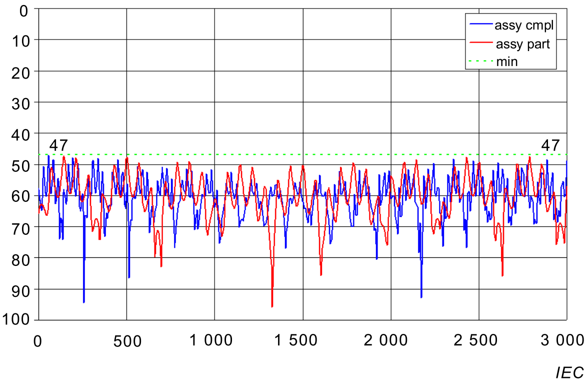


Figure C.6 – Simulation of a cable assembly (linear scale)

The blue line shows the result of the complete cable assembly, i.e. 500 cm cable and both connectors. The red line shows the result for just one part of the assembly, i.e. 195 cm of the cable and one connector. In the lower frequency range, where the samples are electrically short, one gets a length dependent result. However in the higher frequency range, where the samples are electrically long, one gets the same minimum value, i.e. the same screening attenuation of 47 dB.

C.3.2.3 Assembly shorter than the measuring tube

When the assembly is shorter than the measuring tube, the assembly can be extended by a well screened connecting cable inside a closed copper tube. The so called tube in tube method (see also Figures C.7 and C.8).

The extension tube then acts as a resonator. The same principle is also used for the measurement of connectors. Further details can be obtained from the following explanation of the measurement of connectors.

C.3.3 Measurement of connectors

C.3.3.1 General

Usual RF connectors have mechanical dimensions in the longitudinal axis in the range of 10 mm to 50 mm. With the definition of electrical long elements, we get cut-off frequencies of about 3 GHz or higher for standard RF-connectors. Above that frequency, they are considered to be electrically long.

The screening attenuation is by definition only valid in the frequency range above the cut-off frequency, where the elements are electrically long. Thus the screening attenuation of a RF connector itself can only be measured at frequencies above 3 GHz.

However, by extending the RF-connector by a RF-tight closed metallic tube, a cable assembly which is electrically long is built. Thus, the cut-off frequency, respectively the lower frequency limit, to measure the screening attenuation is extended towards lower frequencies. If one connects this extension tube directly to the connector under test, one is measuring the screening attenuation of the connector (and it's mated adapter). If one connects the extension tube to the connecting cable close to the connector, one measures the screening attenuation of the combination of the connector (and its mated adapter) and the transition between cable and connector (see also figures below).

NOTE Although the connector itself stays electrically short, the combination of the connector and the extension tube shows the behaviour (the screening attenuation) of the connector when connected to a well screened cable, which has a screening effectiveness better than the one of the connector (or the transition between cable and connector). See also the explanation in C.3.3.2.

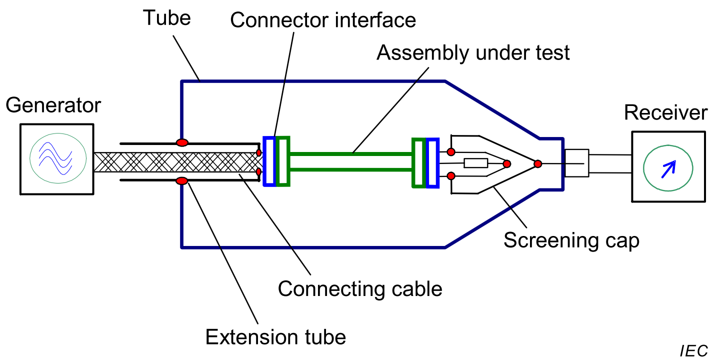


Figure C.7 – Triaxial set-up with extension tube for short cable assemblies

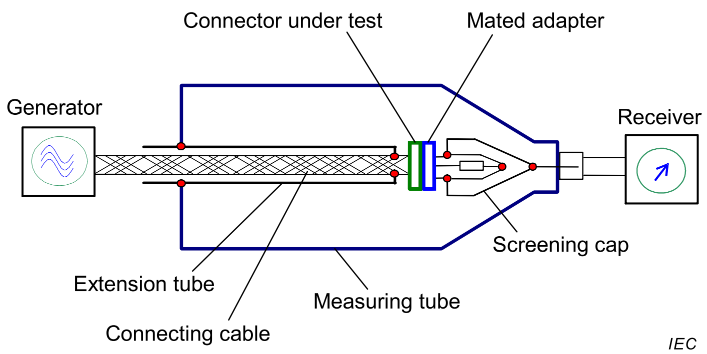


Figure C.8 – Triaxial set-up with extension tube for connectors

C.3.3.2 Measurement set-up

For the measurement of RF connectors, the triaxial set-up according to IEC IEC 62153-4-3 respectively IEC 62153-4-4 has been extended by a RF-tight closed metallic tube (see Figure 8). The extension tube is either connected to the connector under test or to the screen of the connecting cable of the connector under test. At the far end, the connector under test is connected to the screening cap of the triaxial test set-up via its mated adapter.

The measurement of the screening attenuation itself is the same as the measurement of cable screens according to IEC 62153-4-4.

C.3.3.3 Measurement results and simulations

In a first approach, one has measured short cable pieces instead of a connector. The advantage is that the results are not influenced by a mating adapter or the transition between cable and connector. The cable is a coaxial cable with an impedance of 75 Ω, foam PE dielectric and a single braid screen (not optimised, i.e. under-braided). The simulations have been done with the equations (C.7), (C.8) and (C.9) where the number of sections is 2. The first section is the connecting cable with the RF-tight extension tube.

Thus, the transfer impedance and capacitive coupling impedance of that section is neglected. The second section is the cable under test with following parameter:

d.c. resistance:	8 mΩ/m
magnetic coupling:	0,6 mH/m
capacitive coupling:	0,02 pF/m
impedance:	75 Ω

dielectric permittivity: 1,35

The comparison of the simulation (Figures C.9, C.11) with the measurement results (Figures C.10, C.12) show a good correspondence. In the lower frequency range, when the samples are electrically short, one gets the same results. However in the higher frequency range, one can see the influence of the extension tube. The 10 cm sample is electrically short over the whole frequency range, as the cut-off frequency is 5,9 GHz. Thus, the coupled power increases with increasing frequency. However, the quasi cable assembly composed of the connector and the extension tube is electrically long above 590 MHz, which results in a constant maximum coupled power. One characteristic of an electrically long object is also that the maximum coupled power is independent of the sample length (see C.2.1). This is underlined in Figures C.13 and C.14, where the simulated results of a 4 cm sample in a 1 m respectively 2 m tube, i.e. with a 96 cm, respectively 196 cm extension tube, are shown. The envelope of both curves is identical.

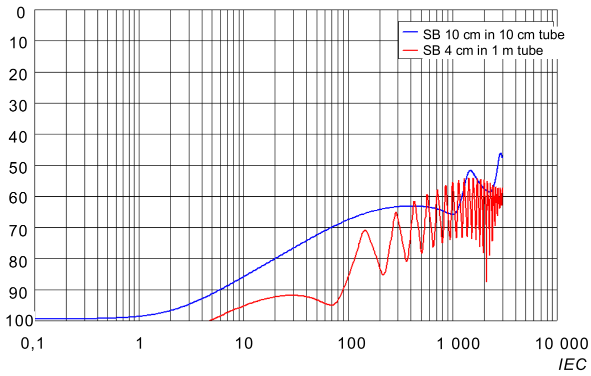


Figure C.9 – Simulation, logarithmic frequency scale

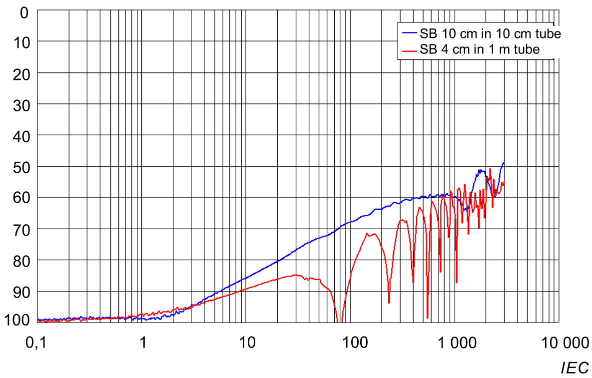


Figure C.10 – Measurement, logarithmic frequency scale

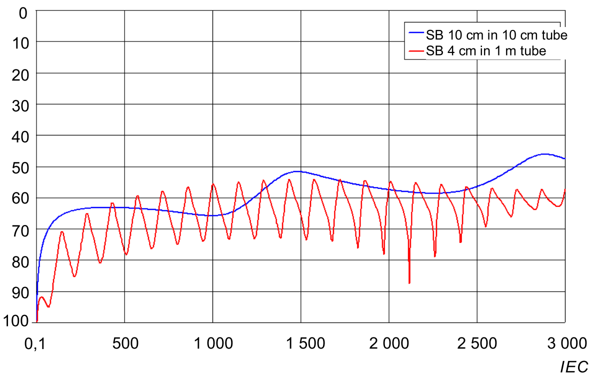


Figure C.11 – Simulation, linear frequency scale

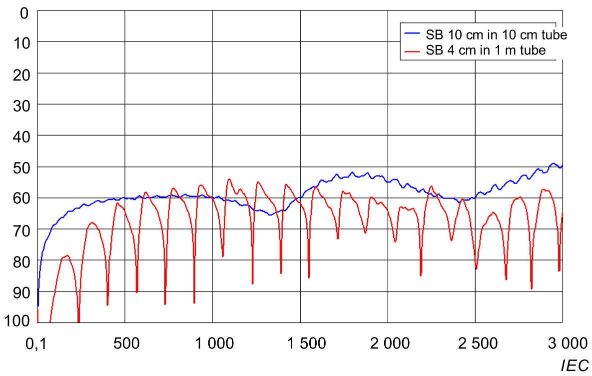


Figure C.12 – Measurement, linear frequency scale

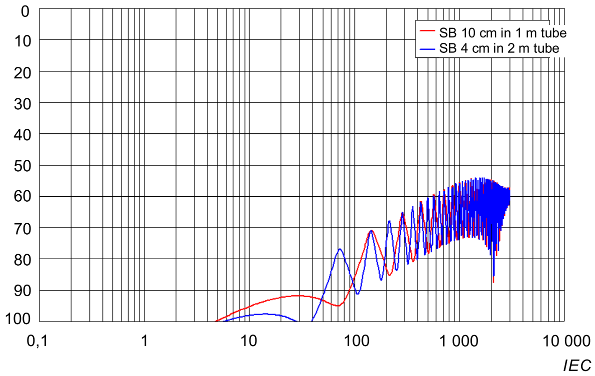


Figure C.13 – Simulation, logarithmic frequency scale

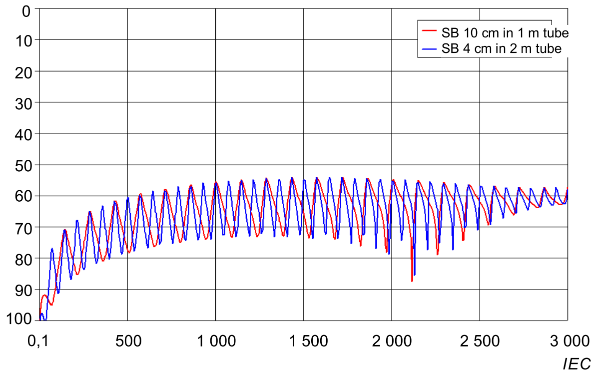


Figure C.14 – simulation, linear frequency scale

C.4 Conclusion

Customers and users of RF cables, cable assemblies and connectors ask more often for screening effectiveness values in decibels (dB) instead of transfer impedance values in mW respectively mW/m. The tube in tube method reply to that need since it offers a simple and reliable method to measure the screening attenuation in dB of connectors and cable assemblies. That method is an extension of the shielded screening attenuation (long triaxial) test set-up according to IEC 62153-4-4.

The comparison of the measured and the calculated curves show good concordance.

The advantages of the tube in tube method for connectors and assemblies are the same as for the measurement of the screening attenuation of cable screens in the tube:

- simple and easy test set-up;
- insensitive against electromagnetic disturbances from outside;
- high dynamic range >130 dB;
- good reproducibility.

Annex D
(informative)

Influence of contact resistances

Contact resistances between the feeding cable and the extension tube or the screening case in the test head may influence the test result. Contacts shall be prepared carefully with low resistance or with low impedance. Contacts shall be achieved over the complete circumference of the screen. Critical contacts are shown in Figure D.1.

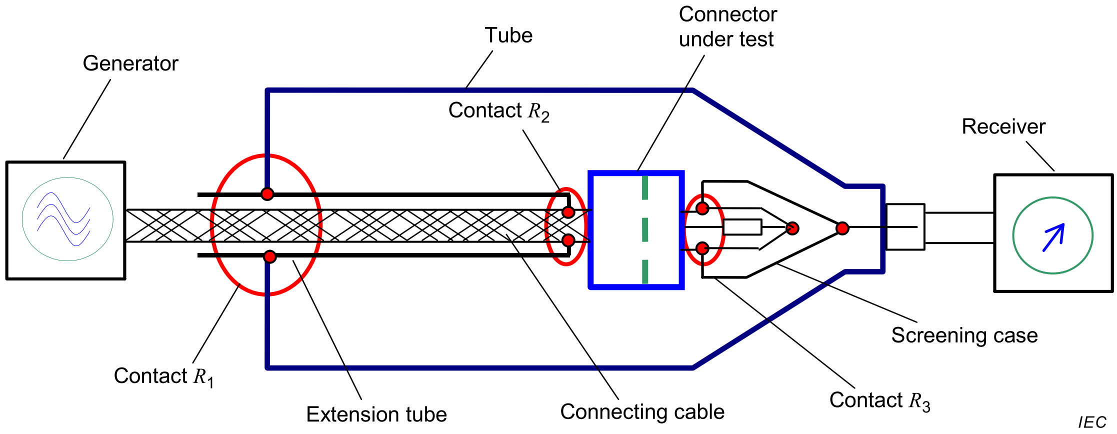
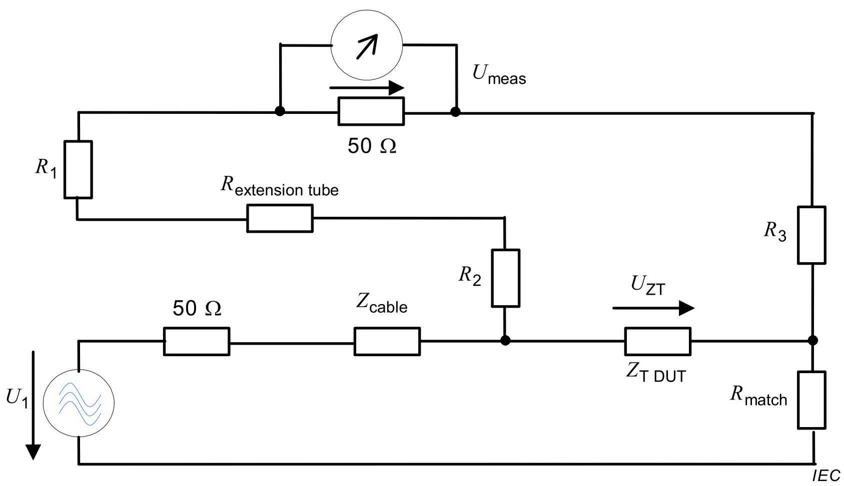


Figure D.1 – Contact resistances of the test set-up

The equivalent circuit of the complete test set-up including the contact resistances is given in Figure D.2. The test set-up shall be designed such that contact resistances of the extension tube are in series with the input impedance of the receiver and the contact resistance of the screening case including the matching load of the DUT is in series with the generator.



Key

R_1, R_2 and R_3 contact resistances depicted in Figure D.1.

$Z_{câble}$ characteristic impedance of the connecting cable (see Figure B.1).

Z_{DUT} transfer impedance of the DUT.

Figure D.2 – Equivalent circuit of the test set-up

In this case, contact resistances of a few mΩ in series with the 50 Ω input resistance of the generator or the receiver are negligible.

The test set-up should be designed such that contact resistances are not in series with the transfer impedance of the DUT. If contact resistances are in series with the transfer impedance of the DUT, they will influence the result considerably.

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