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INTERNATIONAL STANDARD

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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

IEC 62153-4-15:2015-12(en)

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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

FOREWORD

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International Standard IEC 62153-4-15 has been prepared by IEC technical committee 46: Cables, wires, waveguides, R.F. connectors, R.F. and microwave passive components and accessories.

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

FDIS	Report on voting
46/573/FDIS	46/586/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 the parts in the IEC 62153-4 series published under the general title *Metallic Communication Cable test methods – Electromagnetic compatibility (EMC),* 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- withdrawn,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.

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

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

1 Scope

This part of IEC 62153 specifies the procedures for measuring with triaxial cell the transfer impedance, screening attenuation or the coupling attenuation of connectors, cable assemblies and components, e.g. accessories for analogue and digital transmission systems and equipment for communication networks and cabling (in accordance with the scope of IEC technical committee 46).

Measurements can be achieved by applying the device under test direct to the triaxial cell or with the tube in tube method in accordance with IEC 62153-4-7.

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 61196-1, *Coaxial communication cables – Part 1: Generic specification – General, definitions and requirements*

IEC TS 62153-4-1:2013, *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 62153-4-7, *Metallic communication cable test methods – Part 4-7: Electromagnetic compatibility (EMC) – Test method for measuring the transfer impedance and the screening – or the coupling attenuation – Tube in tube method*

IEC 62153-4-8, *Metallic communication cable test methods – Part 4-8: Electromagnetic compatibility (EMC) – Capacitive coupling admittance*

IEC 62153-4-9:2009, *Metallic communication cable test methods – Part 4-9: Electromagnetic compatibility (EMC) – Coupling attenuation of screened balanced cables, triaxial method*

IEC 62153-4-10, *Metallic communication cable test methods – Part 4-10: Shielded screening attenuation test method for measuring the screening effectiveness of feed-troughs and electromagnetic gaskets double coaxial method*

IEC TS 62153-4-16, *Metallic communication cable test methods – Part 4-16: Extension of the frequency range to higher frequencies for transfer impedance and to lower frequencies for screening attenuation measurements using the triaxial set-up*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61196-1 and the following apply.

3.1
triaxial cell
rectangular housing in analogy to the principles of the triaxial test procedure, consisting of a non-ferromagnetic metallic material

Note 1 to entry: The triaxial test procedure is described in IEC 62153-4-3 and IEC 62153-4-4.

3.2
surface transfer impedance
$\boldsymbol{Z_T}$
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 [Ω] (see Figure 1)

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

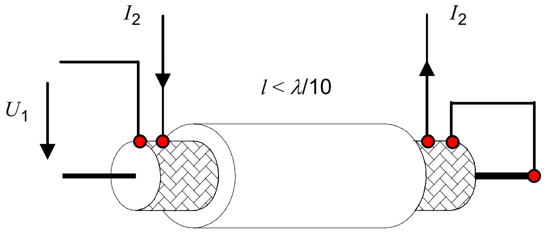

Figure 1 – Definition of Z_T

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

$$Z_T \text{ dB}(\Omega) = 20 \cdot \lg\left(\frac{|Z_T|}{1\Omega}\right) \tag{2}$$

3.3
effective transfer impedance
$\boldsymbol{Z_{TE}}$
impedance defined as:

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

where Z_F is the capacitive coupling impedance

3.4
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

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

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:

$$a_s = 20 \cdot \lg\frac{150\Omega}{Z_{TE}} \tag{5}$$

where

150 Ω is the standardized impedance of the outer circuit.

3.5
coupling attenuation
a_c
for a screened balanced device, 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.

3.6
coupling length
length of cable which is inside the test jig, i.e. the length of the screen under test

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

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

or electrically long, if <

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

where

L is the effective coupling length in m;

λ_0 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_0 is the velocity of light in free space.

3.7
device under test
DUT
connector with mating connector and attached connecting cables or cable assembly consisting of the assembly with their attached mated connectors and with connecting cables

4 Physical background

See 62153-4-1, 62153-4-3, 62153-4-4 and Annexes A to F.

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.

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

Table 1 – IEC 62153-4-x, Metallic communication cable test methods – Test procedures with triaxial test set-up

IEC 62153- 4-x	Metallic communication cable test methods – Electromagnetic compatibility (EMC)
IEC TS 62153-4-1	Introduction to electromagnetic screening measurements
IEC 62153-4-3	Surface transfer impedance – Triaxial method
IEC 62153-4-4	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
IEC TS 62153-4-16	Extension of the frequency range to higher frequencies for transfer impedance and to lower frequencies for screening attenuation measurements using the triaxial set-up

Larger connectors and cable assemblies do not fit into the commercial available test rigs of the triaxial test procedures of the IEC 62153-4-x series according to Table 1, which have been designed originally to measure transfer impedance and screening attenuation on communication cables, connectors and assemblies.

Since rectangular housings with RF-tight caps are easier to manufacture than tubes, the “triaxial cell” was designed to test larger components like connectors and assemblies. The principles of the triaxial test procedures according to the IEC 62153-4-x series can be transferred to rectangular housings. Tubes and rectangular housings can be operated in combination in one test set-up, see Figure 2 and Figure 3.

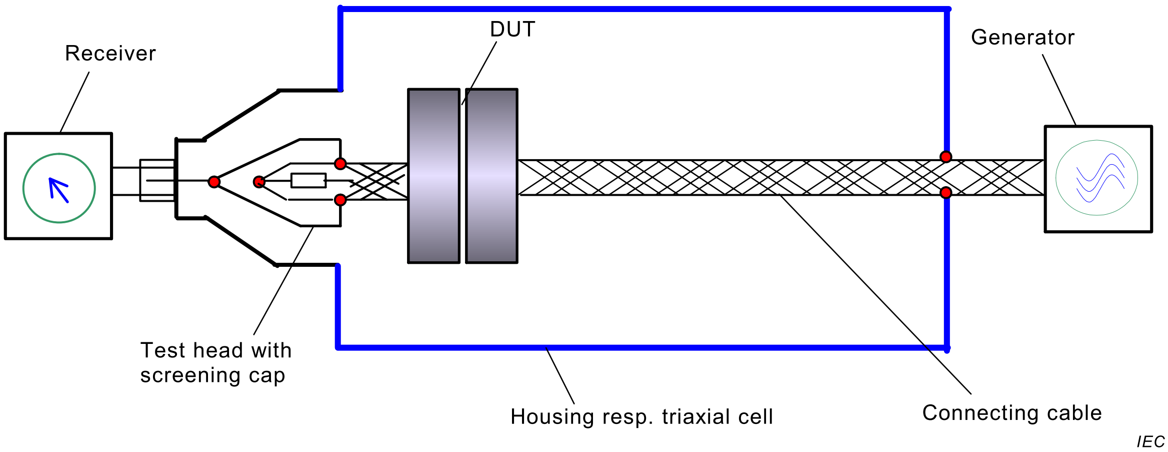

Figure 2 – Principle depiction of the triaxial cell to measure transfer impedance and screening attenuation

In principle, the triaxial cell can be used in accordance with all triaxial procedures of Table 1, where originally a cylindrical tube is used. The screening effectiveness of connectors, assemblies or other components can be measured in principle in the tube as well as in the triaxial cell. Test results of measurements with tube and with triaxial cell correspond well.

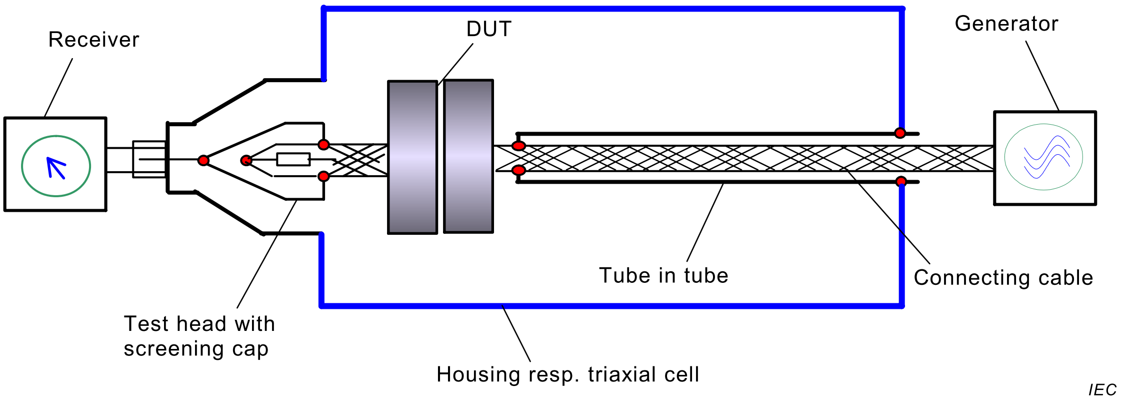

Figure 3 – Principle depiction of the triaxial cell to measure transfer impedance and screening attenuation of assemblies with tube in tube according to IEC 62153-4-7

The triaxial cell 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 housing 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 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 connecting cable (or the tube in tube, if applicable) and a solid metallic housing or cell having the DUT in its axis.

5.2 Transfer impedance

The test determines the screening effectiveness of a shielded device 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 galvanic and 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 for the measurement of the transfer impedance 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 could be found in Clause 9 of IEC/TS 62153-4-1:2013 as well as in IEC 62153-4-3.

5.3 Screening attenuation

The disturbing or primary circuit is the matched cable, assembly or component 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 62153-4-1:2013 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:

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

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

$$a_\mathrm{c} = 10 \cdot \lg\left(\mathrm{Env}\left|\frac{P_1}{P_{\mathrm{r,max}}}\right|\right) \tag{9}$$

where

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

The relationship of the radiated power P_r (related to the normalised impedance of the environment Z_S=150Ω), to the measured power P_2 received on the input impedance of the receiver R is:

$$\frac{P_{r,\max}}{P_{2,\max}} = \frac{R}{2Z_s} \tag{10}$$

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 (two generators with 180° phase shift and one receiver). The procedure to measure coupling attenuation with a multiport network analyser is under consideration.

5.5 Tube in tube method

If required, measurements according to IEC 62153-4-7 can also be achieved in the triaxial cell. The measurements shall be performed in accordance with IEC 62153-4-7 but using the triaxial cell instead of the tube fixture (see Figure 2 and Figure 3).

6 Test procedures

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 Triaxial cell

The triaxial cell consists of a rectangular housing in analogy to the principles of the triaxial test procedures according to IEC 62153-4-3 and IEC 62153-4-4. The material of the housing shall be of non-ferromagnetic metallic material. The length of the housing should be preferably 1 m.

Reflexions of the transmitted signal may occur (in the outer circuit), due to the deviation of the characteristic impedances. The plane of the short circuit at the near end (generator side) should be therefore preferably direct at the wall of the housing.

At the receiver side, the transition of the housing to the coaxial system impedance (50 Ω-system) should be also direct at the wall of the housing.

6.3 Cut off frequencies, higher order modes

The housing, respectively the triaxial cell, is in principle a cavity resonator which shows different resonance frequencies, depending on its dimensions.

For a rectangular cavity resonator, the resonance frequencies can be calculated according to equation (11). For this calculation, one of the parameters M,N may be set to zero. Conductive parts inside the cavity resonator or a poor centering of the DUT in the triaxial cell may lead to deviating resonance frequencies or to mute them.

$$f_{MNP} = \frac{c_0}{2}\sqrt{\left(\frac{M}{a}\right)^2 + \left(\frac{N}{b}\right)^2} \tag{11}$$

where

M,N are the number of modes (even, 2 of 3 > 0);

a,b,c are the dimensions of cavity;

c_0 is the velocity of light in free space.

Measurements of screening attenuation can be achieved up to the first cut off frequency, (M, N = 1).

The behaviour of the triaxial cell above the first cut off frequency is under consideration.

6.4 Test equipment

The measurements can be performed using a vector network analyser (VNA) or alternatively a discrete signal generator and a selective measuring receiver.

The measuring equipment consists of the following:

a) a vector network analyser (with S-parameter test set) or alternatively
   - a signal generator with the same characteristic impedance as the coaxial system of the cable under test or with an impedance adapter and complemented with a power amplifier if necessary for very high screening attenuation, and
   - a receiver with optional low noise amplifier for very high screening attenuation.

b) Impedance matching circuit if necessary:
   - primary side: nominal impedance of generator,
   - secondary side: nominal impedance of the inner circuit,
   - loss: >10 dB,

c) balun for impedance matching of unbalanced generator output signal to the characteristic impedance of balanced cables for measuring the coupling attenuation. Requirements for the balun are given in IEC 62153-4-9:2008, subclause 6.2. Alternatively a VNA with mixed mode option may be used, see IEC/TR 61156-1-2,

Optional equipment is:

d) 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.

6.5 Calibration procedure

The calibration shall be established at the same frequency points at which the measurement of the transfer impedance 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.

$$a_{\text{cal}} = 10 \cdot \lg\left(\frac{P_1}{P_2}\right) = -20 \cdot \lg\left(S_{21}\right) \qquad (12)$$

where

a_{cal} Is the attenuation obtained at the calibration procedure

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 or balun is used, the attenuation shall be measured over the above- mentioned frequency range and the data shall be saved.

6.6 Test leads and connecting cables to DUT

Test leads and connecting cables to the DUT shall be well screened.

In case of measuring transfer impedance, the transfer impedance Z_{con} of the connecting cables inside the test set-up can be measured separate either in the triaxial tube or in the triaxial cell, expressed in mΩ/m, according to IEC 62153-4-3. The length of the connecting cables in the set-up shall be measured, the transfer impedance Z_{con} calculated and be subtracted from the measured transfer impedance of the DUT.

In case of screening attenuation or coupling attenuation, the screening attenuation or the coupling attenuation of the connecting cables can be measured separate either in the triaxial tube or in the triaxial cell, expressed in dB, according to IEC 62153-4-4 or IEC 62153-4-9.

The measured screening attenuation or coupling attenuation of the connecting cables inside the set-up shall be at least 10 dB better than the measured value of the DUT.

7 Sample preparation

7.1 Coaxial connector or assembly or quasi-coaxial component

The connector or the assembly or the component under test shall be connected to its mating part according to the specification of the manufacturer.

A well screened coaxial connecting cable shall be mounted to the connector, the assembly or the component under test and/or its mating part(s). One end of the connecting cable shall be connected to the test head of the test set-up and matched with the nominal characteristic impedance of the DUT.

The screen of the other end of the connecting cable shall be connected to the wall of the housing (the short circuit at the generator side).

In case of tube in tube procedure, the other end of the connecting cable shall be passed through the rf-tight tube in tube and connected to the generator. On the side of the device under test, the screen, the feeding cable shall be connected to the extension tube with low contact resistance. On the generator side, the screen of the connecting cable shall not be connected to the extension tube. The extension tube shall be connected to the wall of the housing (the short circuit at the generator side).

7.2 Balanced or multipin connector or component

The device under test shall be connected to its mating part according to the specification of the manufacturer.

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

For the measurement of transfer impedance or screening attenuation, screened balanced or multiconductor cables or multipin conductors or components 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, also those of individually screened pairs or quads, shall be connected together at both ends. All screens shall be connected over the whole circumference (see Figure 4 and Figure 5).

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.

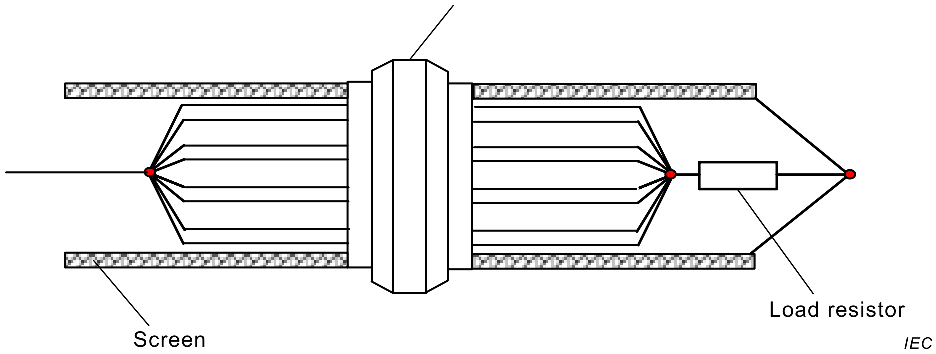

Figure 4 – Preparation of balanced or multipin connectors for transfer impedance and screening attenuation

When measuring the coupling attenuation, the connecting cable shall be fed by a balun or by VNA with multimode option (under consideration). The pair under test shall be matched by a symmetrical/asymmetrical load. The pairs which are not under test shall be left open.

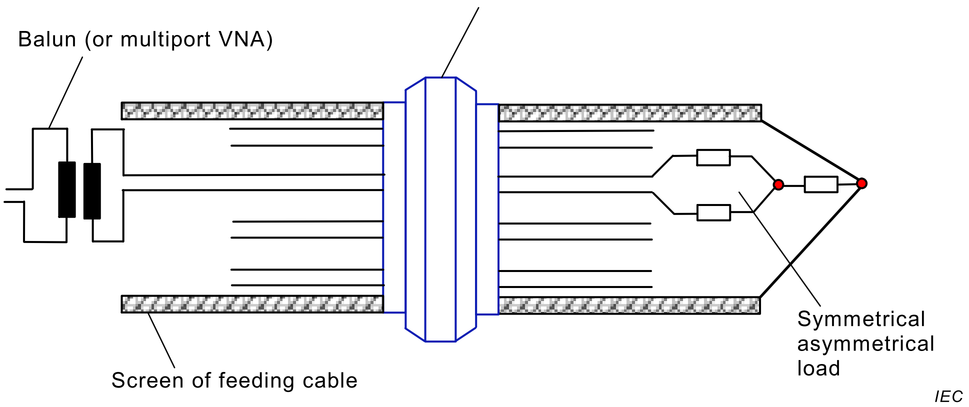

Figure 5 – Preparation of balanced or multipin connectors for coupling attenuation measurement

7.3 Cable assemblies

The connectors of the assembly under test shall be connected with its mating parts on both ends respectively on one end in case of single ended assemblies, according to the specification of the manufacturer.

The mating connectors shall be connected with well screened coaxial feeding cables.

In case of multi-pin conductor assemblies, all conductors of the assembly under test shall be short circuited on both ends in the mating connector. If the assembly under test is connected in its intended use direct to a specific unit and no mating connecter is available, the manufacturer of the assembly shall provide an appropriate mating connector or an appropriate adaptation. The mating connector or the adaption shall be well screened, at least 10 dB better than the device under test. Care shall be taken, that the connection of the connecting cable to the mating connector or the adaption is well screened.

7.4 Other screened devices

The screening effectiveness of other shielded or screened devices, e.g. screened cable conduits, may also be measured. They shall be prepared and treated as quasi-coaxial systems.

8 Transfer impedance (short – matched)

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. Other procedures according to 62153-4-3 may be applied accordingly if required.

The load resistor 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.

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.

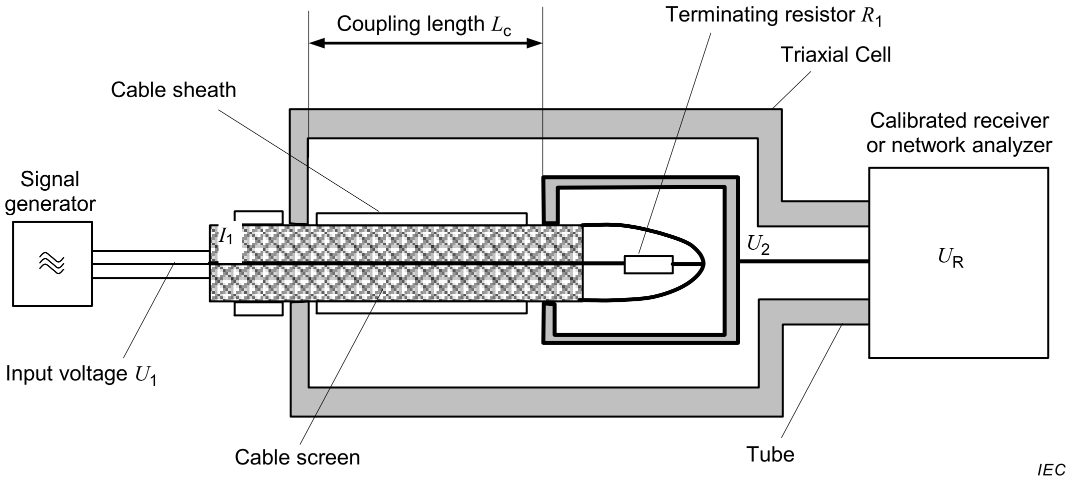

Figure 6 – Test set-up (principle) for transfer impedance measurement according to test method B of IEC 62153-4-3

8.3 Measuring procedure

The length of the connecting cables inside the cell 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 cell to connect the DUT, the result is the transfer impedance of the connecting cables, Z_{con}.

The DUT shall be connected to the generator and the outer circuit (cell) 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:

$$a_{meas} = 10 \cdot \lg\left(\frac{P_1}{P_2}\right) = -20 \cdot \lg(S_{21}) \quad (13)$$

where

P_1 is the power fed to inner circuit;

P_2 is the power in the outer circuit.

8.4 Evaluation of test results

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

$$Z_T = \frac{R_1 + Z_0}{2} \cdot 10^{-\left(\frac{a_{meas} - a_{cal}}{20}\right)} - Z_{con} \quad (14)$$

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;

L_c is the coupling length;

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.

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

8.5 Test report

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

9 Screening attenuation

9.1 General

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

9.2 Impedance matching

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 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 of IEC 62153-4-4).

9.3 Measuring with matched conditions

9.3.1 Procedure

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 (Figure 6).

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

9.3.2 Evaluation of test results

The screening attenuation a_S shall be calculated with the arbitrary determined normalised value Z_S = 150 Ω1.

$$a_s = 10 \cdot \lg \left| \frac{P_1}{P_{r,max}} \right| = 10 \cdot \lg \left| \frac{P_1}{P_{2,max}} \cdot \frac{2 \cdot Z_s}{R} \right| \tag{15}$$

$$= Env\left\{ -20 \cdot \lg \left| S_{21} \right| + 10 \cdot \lg \left| \frac{300 \Omega}{Z_1} \right| \right\} - a_{att} \tag{16}$$

where

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;

Z_1 is the characteristic impedance of the device under test, in Ω;

1 Z_S is the normalised value of the characteristic impedance of the environment of a typical cable installation. It is in no relation to the impedance of the outer circuit of the test set-up.

R Is the input impedance of the receiver;

α_{att} is the attenuation of the impedance matching adapter – if used and if not taken into account otherwise, e.g. during the calibration procedure of the network analyzer.

This conversion – equations 15 and 16 – from the measured forward transfer scattering parameter S_{21} to screening attenuation is only valid if the characteristic impedance of the outer circuit Z_2 is higher than the input impedance of the receiver R (see IEC/TS 62153-4-1: 2013 chapter 9). In the case where the receiver input impedance R is higher than the characteristic impedance of the outer circuit Z_2 a correction factor may be applied (see Annex G).

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

9.4 Measuring with mismatch

9.4.1 General

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.

9.4.2 Evaluaton 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[2].

$$a_s = 10 \cdot \lg \left| \frac{P_1}{P_{r,max}} \right| = 10 \cdot \lg \left| \frac{P_1}{P_{2,max}} \cdot \frac{2 \cdot Z_s}{R} \right| \quad (17)$$

$$= Env \cdot \left\{ -20 \cdot \lg |S_{21}| + 10 \cdot \lg |1 - r^2| + 10 \cdot \lg \left| \frac{300\Omega}{Z_1} \right| \right\}$$

where

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

R is the receiver input impedance

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 between the generator impedance and the nominal characteristic impedance of the cable under test: $r = \left| \left(\frac{Z_0 - Z_1}{Z_0 + Z_1} \right) \right|$;

2 Z_S is the normalised value of the characteristic impedance of the environment of a typical cable installation. It is in no relation to the impedance of the outer circuit of the test set-up.

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

Z_1 is the characteristic impedance of the device under test in Ω.

This conversion – equations 17 and 18 – from the measured forward transfer scattering parameter S_{21} to screening attenuation is only valid if the characteristic impedance of the outer circuit Z_2 is higher than the input impedance of the receiver R (see IEC/TS 62153-4-1 2013 chapter 9). In the case where the receiver input impedance R is higher than the characteristic impedance of the outer circuit Z_2 a correction factor may be applied (see Annex G).

9.5 Test report

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

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

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 5. The sample is then centered in the cell.

The DUT shall be connected via a balun to port 1 (i.e. it is exited in differential mode) and the test head of the set-up shall be connected to port 2 of the vector network analyser. The forward transfer scattering parameter S_{21} shall be measured. Alternatively, the DUT may be fed by a multiport VNA (under consideration).

Only the maximum peak values of the measured forward transfer scattering parameter S_{21} shall be 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, and the attenuation of the balun shall be taken into account when calibrating the triaxial apparatus.

The maximum peak values of the measured forward transfer scattering parameter S_{21} are 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.

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:

$$a_c = 10 \cdot \lg\left|\frac{P_1}{P_{r,max}}\right| = 10 \cdot \lg\left|\frac{P_1}{P_{2,max}} \cdot \frac{2 \cdot Z_s}{R}\right| \tag{18}$$

$$= Env\left\{-20 \cdot \lg|S_{21}| + 10 \cdot \lg\left|\frac{300\Omega}{Z_1}\right|\right\} - a_z \tag{19}$$

$$= a_{\text{m,min}} - a_{\text{z}} + 10 \cdot \lg \left| \frac{300\Omega}{Z_1} \right| \qquad (20)$$

where

a_{c}	is the coupling attenuation related to the radiating impedance of 150 Ω in dB;
$a_{\text{m,min}}$	is the attenuation recorded as minimum envelope curve of the measured values in dB;
a_{z}	is the additional attenuation of an eventually inserted adapter, if not otherwise eliminated e.g. by the calibration, 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 test head;
Z_1	is the (differential mode) characteristic impedance of the device 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.

11 Coupling transfer function

Under consideration (see also Annex D).

Annex A
(informative)

Principle of the triaxial test procedure

With the triaxial test-set up, one can measure both the transfer impedance at the lower frequency range and the screening attenuation at higher frequencies.

The test set-up consists of a network analyser (or alternatively a discrete signal generator and a selective measuring receiver) and a tube with terminations to the cable screen and the network analyser or receiver. The material of the tube shall be well conductive and non-ferromagnetic, for example brass or aluminium.

The cable under test (CUT), which is centred in the middle of the tube, forms together with the tube a triaxial system (see Figure A.1). The inner system is the CUT itself and the outer system is formed by the screen under test and the tube.

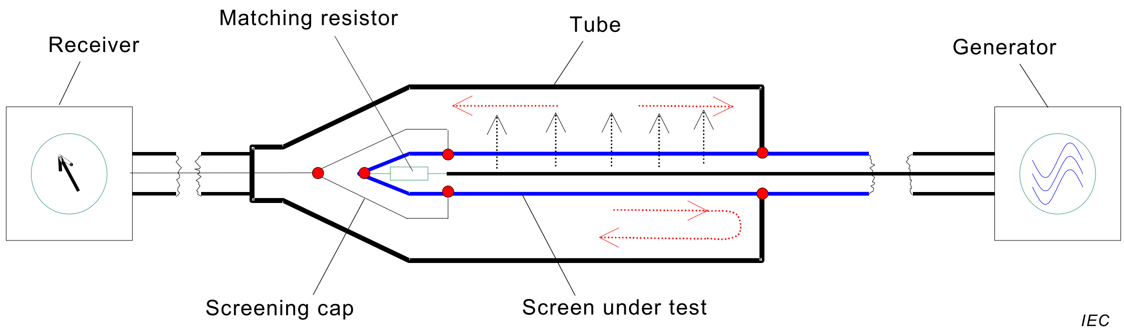

Figure A.1 – Principle test set-up to measure transfer impedance and screening attenuation

The CUT is terminated with its characteristic impedance at the far end (see Figure A.1).

The screen under test is short circuited with the tube at the near end of the generator. Due to this short circuit, the influence of capacitive parts is excluded.

A generator with the voltage U_1 feeds the inner system. The voltage U_2 is measured with a measuring receiver with an input impedance equal to the characteristic impedance of the tube (50 Ω), see Figure A.2.

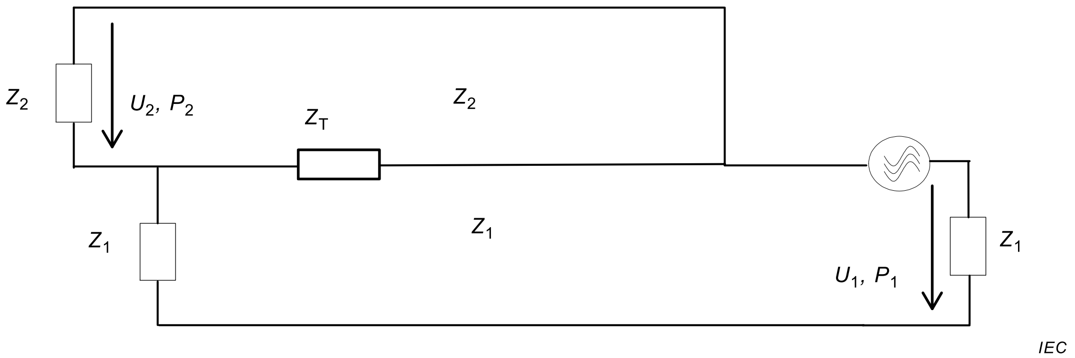

Figure A.2 – Equivalent circuit of the principle test set-up in Figure A.1

The energy, which couples through the weak screen, travels into both directions of the tube, respectively the outer system. At the short circuit at the near end side of the generator, the wave is totally reflected, so that the receiver measures the complete energy that couples through the screen.

At the low frequency range, the transfer impedance Z_T may be calculated from the voltage ratio U_2/U_1:

$$Z_T \cdot l \approx Z_1 \cdot \left|\frac{U_2}{U_1}\right| \text{ if } Z_T << Z_1 \tag{A.1}$$

At high frequencies, the logarithmic ratio of the input power P_1 to the measured power P_2 on the receiver gives the screening attenuation a_S.

$$a_S = 10 \cdot \lg\left(\left|\frac{P_1}{P_2}\right|_{\max}\right) = 20 \cdot \lg\left(\left|\frac{U_1}{U_2}\right|_{\max}\right) + 10 \cdot \lg\left|\frac{Z_R}{Z_G}\right| \tag{A.2}$$

In order to compare the screening attenuation with other test procedures in accordance with IEC 62153-4-4, the measured ratio of power P_1 to P_2 is related to the standardized characteristic impedance of the outer system of 150 Ω:

$$a_s = 10 \cdot \lg\left(\left|\frac{P_1}{P_r}\right|_{\max}\right) = 20 \cdot \lg\left(\left|\frac{U_1}{U_2}\right|_{\max}\right) + 10 \cdot \lg\left|\frac{Z_R}{Z_G}\right| + 10 \cdot \lg\left|\frac{2 \cdot Z_S}{Z_R}\right| \tag{A.3}$$

$$a_s = 10 \cdot \lg\left(\left|\frac{P_1}{P_r}\right|_{\max}\right) = 20 \cdot \lg\left(\left|\frac{U_1}{U_2}\right|_{\max}\right) + 10 \cdot \lg\left|\frac{2 \cdot Z_S}{Z_G}\right| \tag{A.4}$$

where

P_1 is the power fed to the DUT (inner system);

P_2 is the power measured at the receiver (outer system);

P_r is radiated power related to the normalised impedance of the environment Z_S = 150 Ω;

U_1 Is the input voltage of the DUT;

U_2 Is the voltage measured at the receiver;

Z_R Is the input impedance of the receiver;

Z_G Is the output impedance of the generator;

Z_S is the arbitrary determined normalized impedance of the environment of a typical cable installation Z_S = 150 Ω.

Annex B
(informative)

Triaxial cell

Larger connectors and cable assemblies do not fit into the commercial available test rigs of the triaxial test procedure which have been designed originally to measure transfer impedance and screening attenuation on communication cables, connectors and assemblies.

The “triaxial cell” was designed to test larger devices and assemblies, especially for the HV cables and components for electromotive vehicles. The principles of the triaxial test procedures can be transferred to rectangular housings.

Tubes and rectangular housings can be operated in combination in one test rig. The screening effectiveness of larger connectors or devices can be measured in the tube as well as in the triaxial cell. Test results of tube and cell measurements correspond well.

The triaxial cell consists of a rectangular housing in analogy to the principles of the triaxial test procedure according to IEC 62153-4-3 and IEC 62153-4-4. The material of the housing shall be of non-ferromagnetic metallic material, see Figure B.1 and Figure B.2.

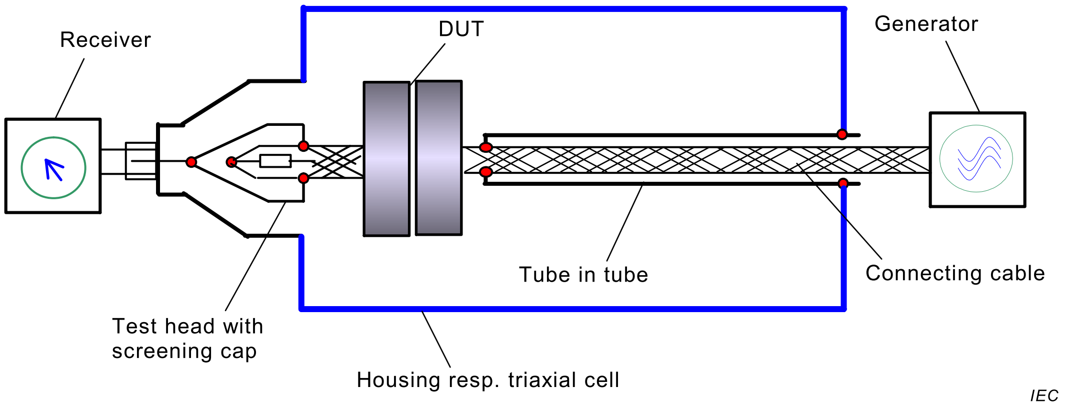

Figure B.1 – Principle depiction of the triaxial cell to measure transfer impedance and screening attenuation at HV-assemblies with tube in tube according to IEC 62153-4-7

Reflexions of the transmitted signal may occur (in the outer circuit), due to the deviation of the characteristic impedances. The plane of the short circuit at the near end (generator side) should be therefore preferably direct at the wall of the housing of the cavity without any additional tube.

At the receiver side, the transition of the housing to the coaxial 50 Ω system should be also direct at the wall of the housing.

IEC

Figure B.2 – Example of different designs of triaxial cells

Annex C
(informative)

Cut off frequencies, higher order modes

The housing respectively the triaxial cell is in principle a cavity resonator which shows different resonance frequencies, depending on its dimensions.

For a rectangular cavity resonator, the resonance frequencies can be calculated according to equation (C.1). For this calculation, one of the parameters M,N,P may be set to zero. Conductive parts inside the cavity resonator may lead to deviating resonance frequencies or to mute them.

$$f_{MNP} = \frac{c_0}{2}\sqrt{\left(\frac{M}{a}\right)^2 + \left(\frac{N}{b}\right)^2 + \left(\frac{P}{c}\right)^2} \tag{C.1}$$

where

M,N,P are the number of modes (even, 2 of 3 >0);

a,b,c are the dimensions of cavity;

c_0 is the velocity of light in free space.

For the dimensions of the triaxial cells of 136/136/99 mm, 750/250/250 mm and 1 000/300/300 mm resonance frequencies are given in Table C.1 up to 3 GHz. Since the device under test is placed inside the cavity, the resonance frequencies during the test may deviate from the calculated frequencies.

Measurements of transfer impedance and screening attenuation of a cable RG 11 with single braid construction with tube and with triaxial cell with a length of 1 m show the same results up to the first resonance frequency of about 720 MHz.

Table C.1 – Resonance frequencies of different triaxial cells

136-er cell				**750-er cell**				**1 000/150-er cell**				**1 000/300-er cell**			
a	b	c		a	b	c		a	b	c		a	b	c	
136	136	99		750	250	250		1000	150	150		1000	300	300	
m	n	p	f/GHz	m	n	p	f/GHz	m	n	p	f/GHz	m	n	p	f/GHz
1	1	1	2,17	1	1	1	0,87	1	1	1	1,41	1	1	1	0,72
1	2	0	2,47	1	2	0	1,22	1	2	0	2,00	1	2	0	1,01
0	2	1	2,68	0	2	1	1,34	0	2	1	2,24	0	2	1	1,12
1	2	1	2,89	1	2	1	1,36	1	2	1	2,24	1	2	1	1,13
2	2	0	3,12	2	2	0	1,26	2	2	0	2,00	2	2	0	1,04
0	1	2	3,22	0	1	2	1,34	0	1	2	2,24	0	1	2	1,12
1	1	2	3,41	1	1	2	1,36	1	1	2	2,24	1	1	2	1,13
2	2	1	3,47	2	2	1	1,40	2	2	1	2,24	2	2	1	1,16
0	2	2	3,75	0	2	2	1,70	0	2	2	2,83	0	2	2	1,41
1	2	2	3,91	1	2	2	1,71	1	2	2	2,83	1	2	2	1,42
2	3	0	3,98	2	3	0	1,84	2	3	0	3,00	2	3	0	1,53

Figures C.1 and C.2 show measurements of transfer impedance and screening attenuation of a cable RG 11 with single braid construction with tube and with triaxial cell of a length of 1 m.

Up to the calculated first resonance frequency of about 720 MHz, no deviation of the measured curves can be observed.

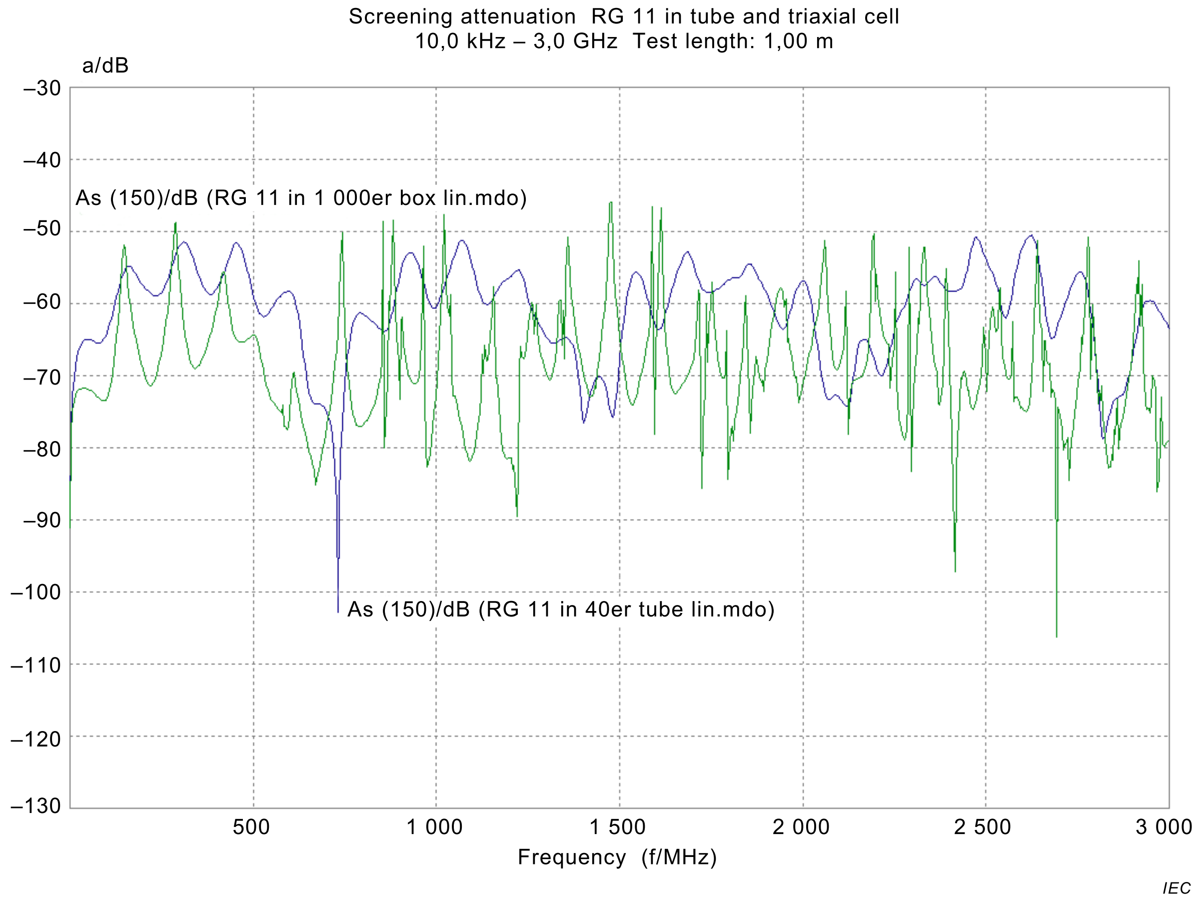

Figure C.1 – Comparison of the measurements with tube and with triaxial cell of a RG 11 cable with single braid construction, linear scale

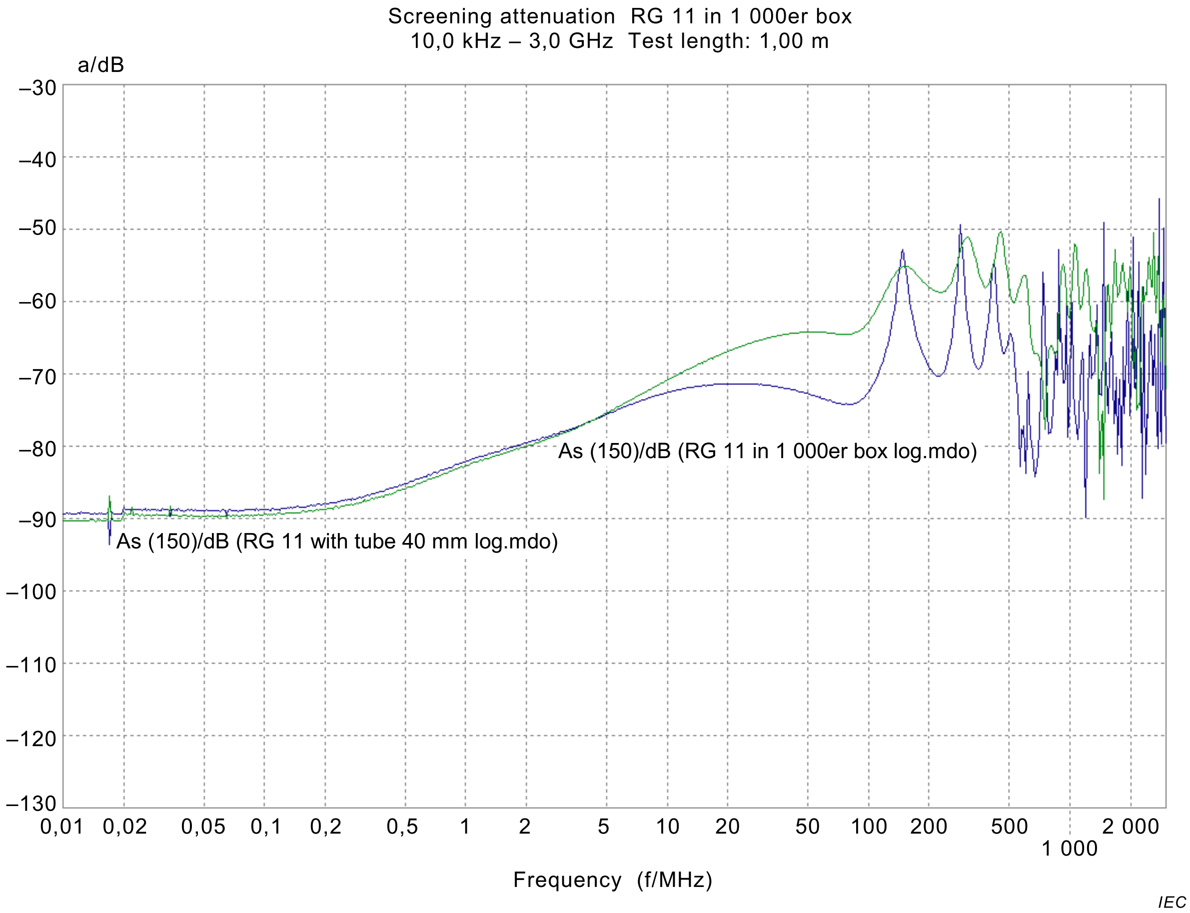

Figure C.2 – Comparison of the measurements with tube and with triaxial cell of a cable RG 11 with single braid construction, log scale

Above the first resonance frequency of the cell of about 720 MHz, deviations of the maximum values of the curves within 3 dB can be found. Measurements of samples with complex geometries are under further study.

Measuring of screening effectiveness of connectors and cable assemblies with the triaxial cell is under study and will be included as additional test procedure in the revised version of IEC 62153-4-7.

Annex D
(informative)

Coupling transfer function

Depending on the length of the device under test and the frequency, the screening effectiveness is divided into the transfer impedance and the screening attenuation. The coupling transfer function in Figure D.1 shows the transfer impedance Z_T and the screening attenuation a_s of a cable screen vs. frequency.

With the triaxial procedure, the transfer impedance Z_T and the screening attenuation a_s can be measured in one test set-up.

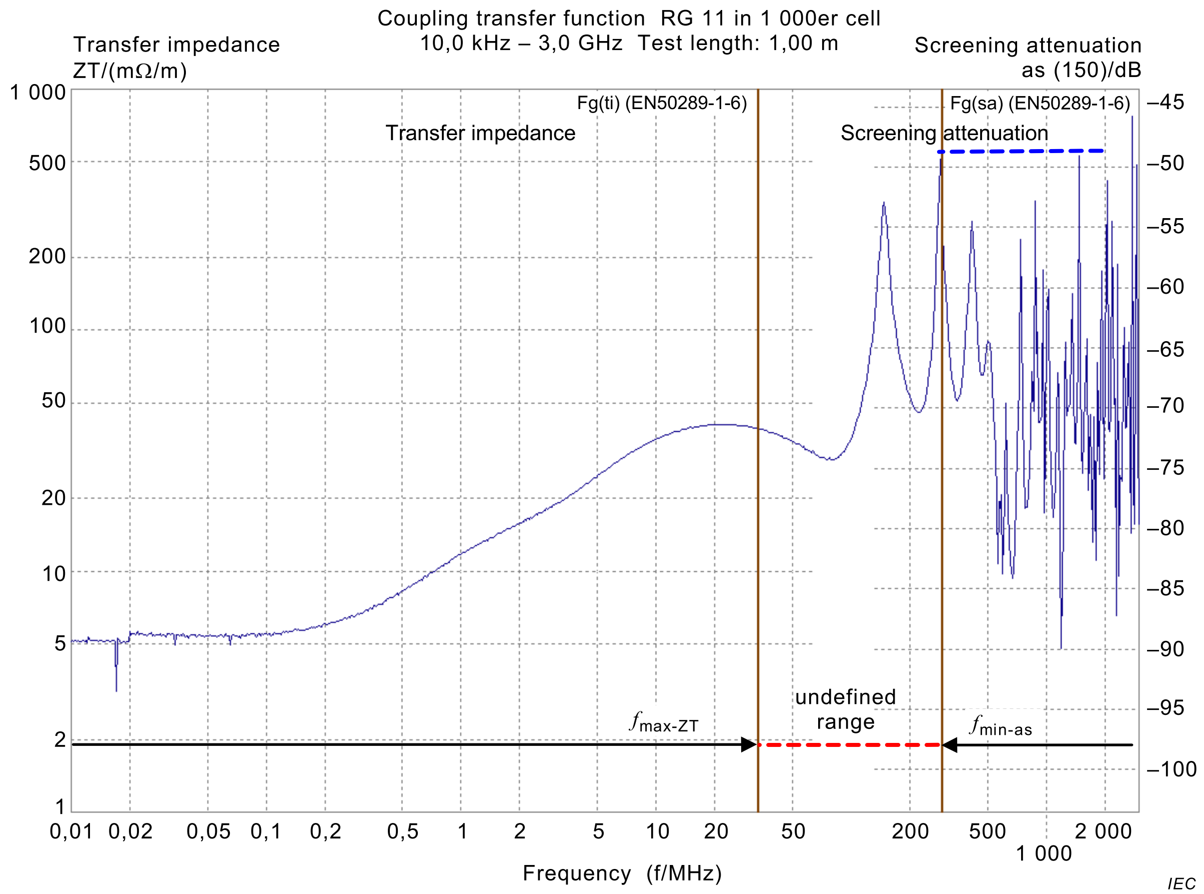

Figure D.1 – Measured coupling transfer function of a braided screen vs. frequency with the triaxial cell

In the DC range, respectively at very low frequencies, the transfer impedance of a braided screen is equal to the DC resistance. In the range of about 1 MHz to 10 MHz, the value of the transfer impedance drops down to lower values (at optimized braids) and increases then with about 20 dB per decade towards higher frequencies.

The coupling transfer function $T_{n,f}$ gives the relation between the screening attenuation a_s and the transfer impedance Z_T of a cable screen. In the lower frequency range, where the cable samples are electrically short, the transfer impedance Z_T can be measured up to the cut off frequencies $f_{cn,f}$. Above these cut off frequencies $f_{cn,f}$ in the range of wave propagation, the screening attenuation a_s is the measure of screening effectiveness. The cut off frequencies $f_{cn,f}$ may be moved towards higher or lower frequencies by variable length of the cable under test.

The upper cut off frequency $f_{\text{max-ZT}}$ for measuring the transfer impedance depends on the used test method (see IEC 62153-4-3) and may roughly be approximated by:

$$f_{\text{max-ZT}} \leq \frac{50 \cdot 10^6}{\sqrt{\varepsilon_{r1}} \cdot L_c} \tag{D.1}$$

The lower cut off frequency $f_{\text{min-as}}$ for measuring the screening attenuation according to IEC 62153-4-4 is given by:

$$f_{\text{min-as}} \geq \frac{c_0}{2 \cdot \left| \sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}} \right| \cdot L_c} \tag{D.2}$$

where

c_0 is the velocity of light in free space;

ε_{r1} is the relative dielectric constant of the inner system;

ε_{r2} is the relative dielectric constant of the outer system;

L_c is the coupling length.

Figure D.1 shows the cut-off frequencies of the transfer impedance Z_T and of the screening attenuation a_s. For a cable of 1 m length and a relative dielectric permittivity of the inner system ε_r of 2,28, one obtains an undefined range or a “grey zone” in the frequency range from about 30 MHz to about 300 MHz.

In principle, the undefined range could be covered by varying the length of the device under test. But varying the length of the device under test is not always desired or impossible in case of DUTs with fixed length, e.g. in case of cable assemblies.

Hence it should be discussed how the coupling transfer function could be the measure for the screening effectiveness, including transfer impedance and screening attenuation.

IEC 62153-4-7 is being revised. During this revision, it should be discussed to introduce the coupling transfer function as shown in Figure D.1. The length of the test set-up could be fixed to 1 m. The value of the minimum of the screening attenuation at $f_{\text{min-as}}$ could be extended to $f_{\text{max-ZT}}$ and is from here the measure of the screening attenuation. With this extension, the screening effectiveness, consisting of transfer impedance and screening attenuation, is explicitly described over the complete frequency range.

Furthermore, with the new procedure of IEC 62153-4-3:2013, the cut off frequency $f_{\text{max-ZT}}$ of the transfer impedance can be moved towards higher frequencies and the undefined range can be reduced.

To compare different devices and for qualification purposes, the proposed application of the coupling transfer function is useful in any case.

Annex E
(informative)

Attenuation versus scattering parameter S_{21}

Sometimes confusion arises between attenuation and the forward transfer scattering parameter S_{21}. By definition attenuation is the logarithmic ratio of the power at the input of a DUT to the power at the output of the DUT. Whereas the forward transfer scattering parameter S_{21} relates the output signal to the input signal.

For passive components the image attenuation (depending on the device also named wave attenuation or two port attenuation or operational (Betriebs) attenuation under matched conditions) is positive (as the output signal is smaller than the input signal) whereas the scattering parameter S_{21} is negative. Therefore in the equations to convert the measured scattering parameter S_{21} to the screening or coupling attenuation a minus sign is used in front of the S_{21} term (see 9.3.2 and 9.4.2)

Further details are described in IEC TR 62152.

Figures E.1 and E.2 show the S_{21} measurement of a 3dB attenuator. The measurements have been done with two different network analyzers and the results show negative values as expected.

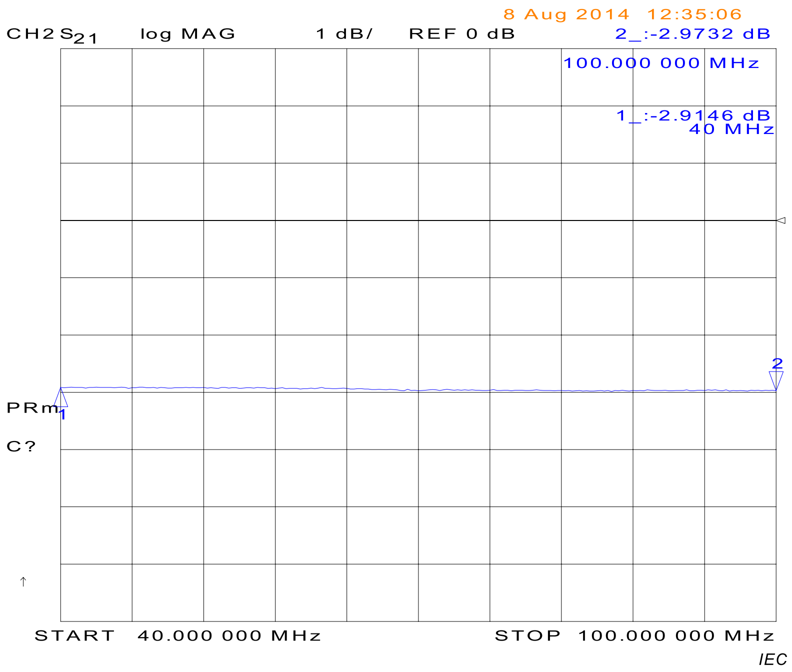

Figure E.1 – Measurement with HP8753D of S_{21} of a 3dB attenuator

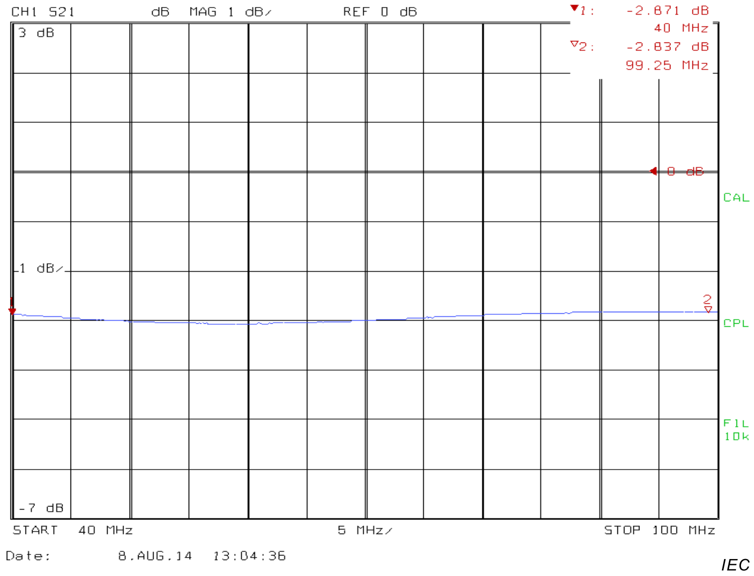

Figure E.2 – Measurement with ZVRE of S_{21} of a 3dB attenuator

Annex F
(informative)

Application of a moveable shorting plane

F.1 Effect of the measurement length on the measurement cut-off frequency

The distance of the shorting plane of the outer system of the triaxial test set-up and the screening cap of the test head ("measurement length") defines the cut-off frequency for the measurement bandwidth of the transfer impedance Z_T. If a higher cut-off frequency for Z_T is required a shorter distance between shorting plane and test head is needed. A detailed description of this context can be found in Clause 9 of IEC 62153-4-1:2013 as well as in IEC 62153-4-3.

F.2 Details of the movable shorting plane

The introduction of a movable shorting plane to the triaxial set-up in combination with the tub-in-tube method is shown in Figure F.1. It gives full flexibility in choosing the shorting plane distance and therefore the cutoff frequency of the screening measurement.

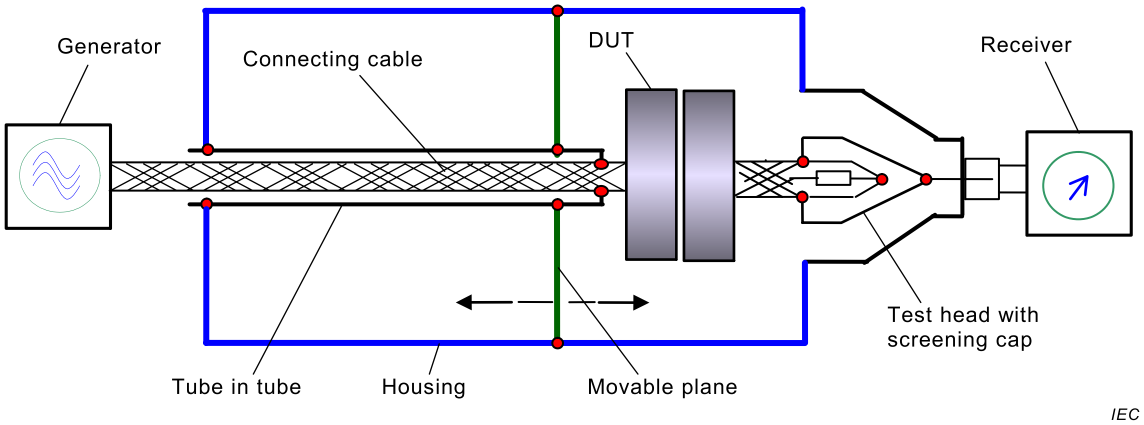

Figure F.1 – Crosssection of triaxial cell with movable shorting plane

The main requirements for such a plane are a sufficient conductivity of the plane material as well as a sufficiently low contact resistance between the tube-in-tube and the plane just as the contact resistance between the plane and the outer housing of the triaxial cell. The application of suitable spring contacts wich are also used in other EMC applications helps to ensure these contact requirements. Figures F.2, F.3 and F.4 give design examples of such a plane to housing contact solution and plane to tube contact solution, respectively.

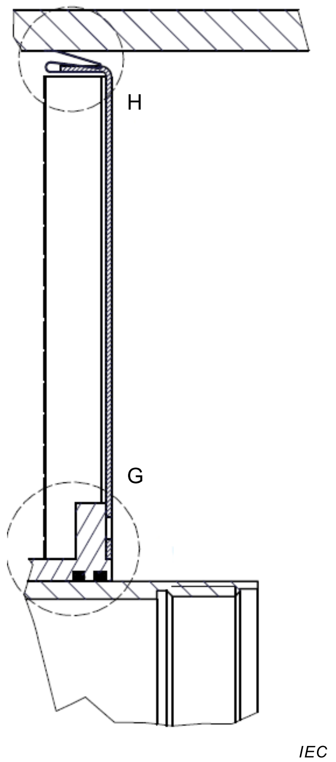

Figure F.2 – Crosscut of plane shortening housing and tube-in-tube

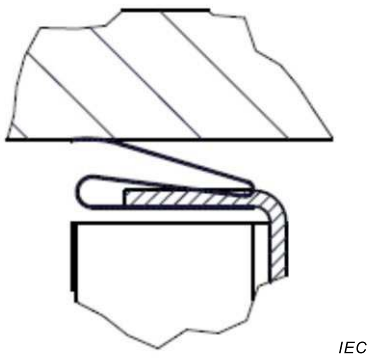

Figure F.3 – Detail H of figure F.2: contact between plane and housing

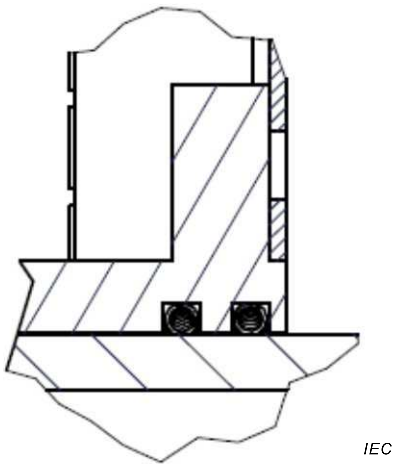

Figure F.4 – Detail G of figure F.2: contact between plane and tube-in-tube

F.3 Measurement results

Figure F.5 shows a compilation of transfer impedance measurements made on one test sample with different shorting plane distances applied. The closer the plane gets to the test sample the higher the cutoff frequency is located in the diagram. Since the test sample is of a very short elongation it therefore provides a locally concentrated coupling area. This results in measurement curves with steadily increasing maximum values with a rippled character. The ripples are generated by a quarter wave cancelation of the reflected wave at the shorting plane. The envelope curve in red indicates the theoretical transferimpedance character of a single coupling area as the connector under test is.

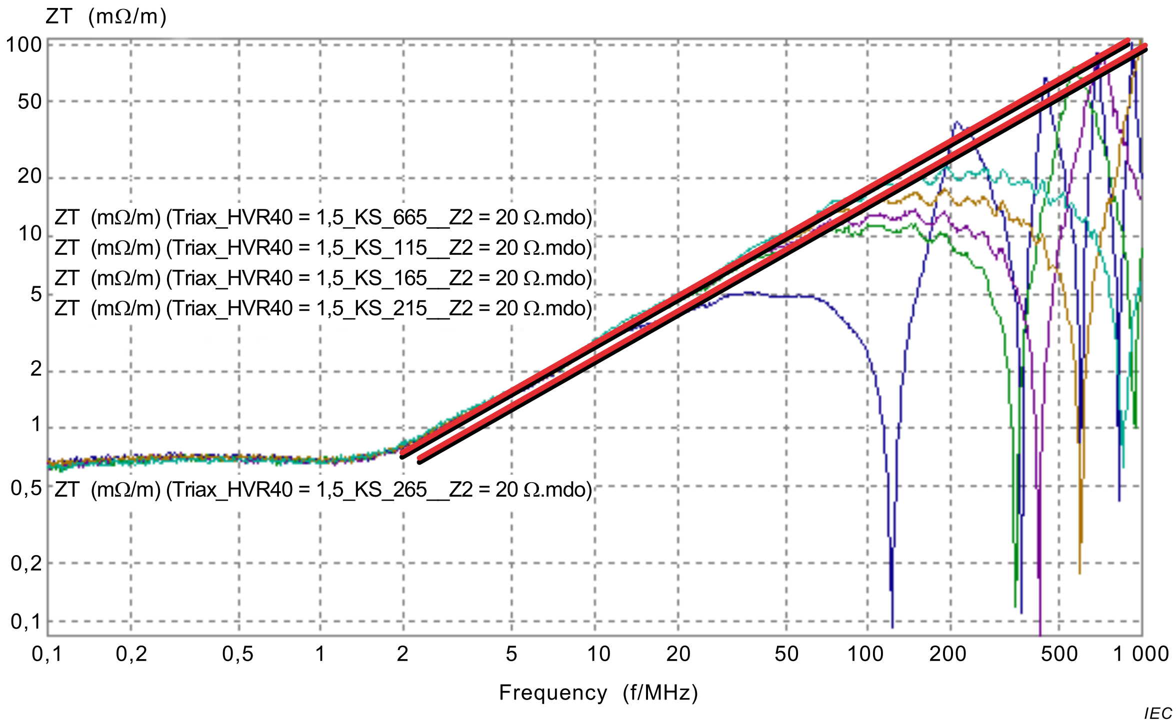

Figure F.5 – Compilation of transfer impedance test results with different shorting plane distances

Annex G
(informative)

Correction in case the receiver input impedance R is higher than the characteristic impedance of the outer circuit Z_2

If the characteristic impedance of the outer circuit Z is lower than the input impedance of the receiver, then the envelope curve (maximum values) of the measured forward transfer scattering parameter S_{21} will depend on the input impedance of the receiver (see IEC TS 62153-4-1:2013 Clause 9 and Figure G.1). In this case a correction factor shall be used to correct the test results.

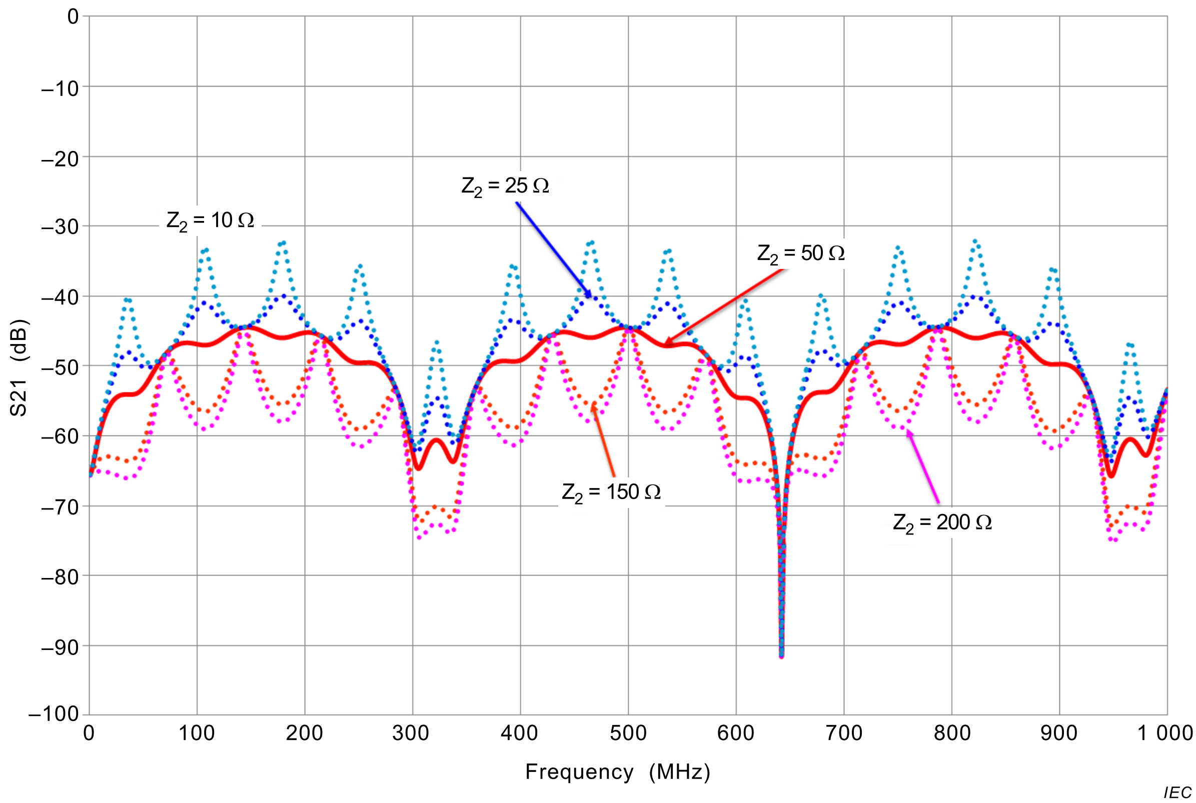

Figure G.1 – Example of forward transfer scattering parameter S_{21} for different impedances in the outer circuit where the receiver input impedance is 50Ω

The characteristic impedance of Z_2 of the outer circuit can either be measured with a time domain reflectometer TDR or, if the DUT has a uniform cylindrical shape, be calculated according to equation G.1.

$$Z_2 = \frac{60\Omega}{\sqrt{\varepsilon_{r1}}} \cdot \ln\left(1{,}27 \cdot \frac{D}{d}\right) \qquad \text{(G.1)}$$

where

ε_{r2} is the dielectric permittivity in the outer circuit

d is the diameter of the device under test

D is the width of the cell.

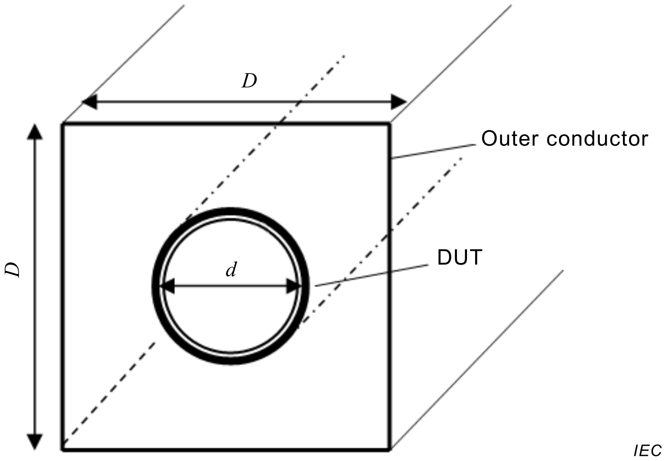

Figure G.2 – DUT with uniform cylindrical shape in the centre of the cell

For a DUT with uniform cylindrical shape resulting in an impedance of the outer circuit lower than the receiver input impedance a correction factor is obtained by Equation G.2. This correction factor shall be added to the measured forward transfer scattering parameter S_{21}.(negative dB value, see Annex E)

$$a_{\text{corr}} = -20 \cdot \lg\left(\frac{R}{Z_2}\right) \tag{G.2}$$

Where

a_{corr} is the correction factor

R is the input impedance of the receiver

Z_2 is the characteristic impedance of the outer circuit

For non uniform DUT the correction is not straight forward as additional reflections superpose the results. This case is under further study.

Bibliography

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