

EMC of Cables, Connectors and Components with Triaxial Test set-up

New and revised IEC 62153-4 standards to measure Transfer Impedance
and screening or Coupling Attenuation

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Abstract

New designed cable constructions, e.g. for electro vehicles with characteristic wave impedances in the range of 10Ω required the revision of different standards of the IEC 62153-4-x series which described different test procedures to measure Transfer Impedance and Screening- or Coupling Attenuation on cables, connectors and passive components with the Triaxial Test set-up.

The revised standards IEC 62153-4-3, -4-4 and -4-7 now allow the measurement of screening characteristics of cables, connectors and components under mismatched conditions; impedance matching devices are no longer needed. The changes of the revised standards are also included in the revised "Tube in Tube" test procedure as well as in the draft standard for the newly designed "Triaxial Cell".

In order to measure the Coupling Attenuation of balanced cables, a differential signal is required. This can be generated using a balun which converts the unbalanced signal of a 50Ω network analyzer into a balanced signal. Commercial baluns, however, are only available up to 1.2 GHz.

Alternatively a balanced signal may be obtained with a network analyzer having two generators with a phase shift of 180° . Another alternative is to measure with a multi-port VNA. Both options allow "balunless" measurements of Coupling Attenuation up to and above 3 GHz. Comparative measurements with balun and with multi-port VNA show good correlation.



Figure 1 – Test set-up to measure Transfer Impedance

Keywords: Transfer Impedance; Screening Attenuation; Coupling Attenuation; EMC; Triaxial Cell, Triaxial Test Procedure; Triaxial Test set-up; Screening Effectiveness.

1. Introduction

The term "electromagnetic pollution" describes the constant increase of desired and undesired electromagnetic radiation in our environment. To guarantee the coexistence of radio services with cable networks and also to ensure that complex systems will not disturb each other, measuring of EMC behavior is needed.

Test procedures which measure EMC on cables, connectors and components are described in the IEC 62153-4-x series.

The following report provides an overview about new and revised standards of the IEC 62153-4-x series with Triaxial Test set-up.

The new "balunless" test procedure made to measure Coupling Attenuation on balanced cables and components with multiport network analyzers is described acc. to IEC 62153-4-7 and to IEC 62153-4-9 as well as the use of the Triaxial Cell according to IEC 62153-4-15.

2. Transfer Impedance, IEC 62153-4-3

2.1 General

For an electrically short screen, the Transfer Impedance Z_T is defined as the 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, in Ω/m or in $m\Omega/m$, (see Figure 2).

$$Z_T = \frac{U_1}{I_2 \cdot l}, \text{ and } Z_T \text{ dB}(\Omega) = +20 \log_{10} \left(\frac{|Z_T|}{1\Omega} \right) \quad (1a, 1b)$$

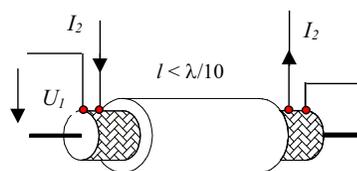


Figure 2 - Definition of Transfer Impedance

The revised version of IEC 62153-4-3Ed.2 includes three different test procedures to measure Transfer Impedance:

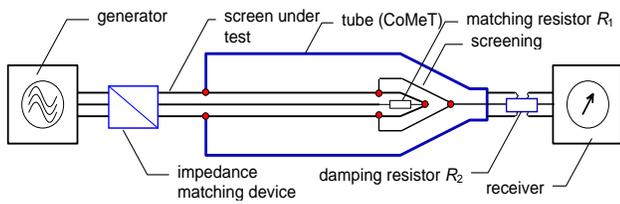


Figure 3a - Test method A - Matched inner circuit with damping resistor in outer circuit

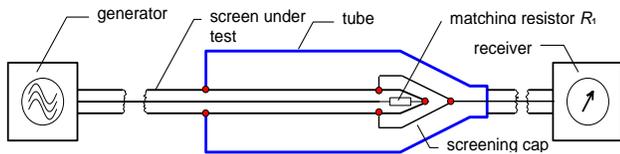


Figure 3b - Test method B - Inner circuit with load resistor and outer circuit without damping resistor

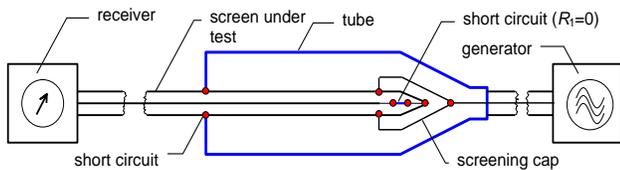


Figure 3c - Test method C - (Mismatched)-Short-Short without damping resistor

Figure 3 - Test procedures acc. to Ed.2 of IEC 62153-4-3 & IEC 62153-4

2.2 Test method A: Matched inner circuit with damping resistor R_2 in outer circuit

By using this method the inner circuit (cable) is terminated on a matched termination ($R_1 = Z_1$) and is considered as the disturbing circuit (i.e. it is fed by the generator). If the impedance of the inner circuit is unknown it shall be measured, e.g. with the open-short method.

The outer circuit is short-circuited on the near end side on the cable shield and connected to the receiver on the far end via a damping or pre-resistor R_2 .

If the impedance of the inner circuit is different from the generator impedance then an impedance matching adapter is used. If no commercial impedance matching device is available, it may be handmade. A description how to build an impedance matching device is given in annex B of IEC 62153-4-3.

In order to obtain the maximum flat bandwidth of the set-up by means of critical damping, the resistor R_2 should be incorporated at the far end of the outer circuit. The value of the resistor is:

$$R_2 = A \times 60 \ln \left(\frac{D}{d} \right) - 50 \text{ where } A = \sqrt{2} \text{ or } A = \sqrt{\frac{\epsilon_{r1}}{\epsilon_{r2}}} \quad (2a, 2b)$$

where

- D is the inner diameter of tube;
- d is the outer diameter of cable screen;
- ϵ_{r1} is the permittivity of inner circuit;
- ϵ_{r2} is the permittivity of outer circuit.

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

This method is principally the same as procedure A, however without the use of the impedance matching adapter and without the damping resistor R_2 . It has a higher dynamic range than procedure A.

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 analyzer with power splitter instead of S-parameter test set.

2.4 Test method C: (Mismatched)-Short-Short without damping resistor and with short circuit

In this method, both the inner and the outer circuits are short circuited on one side, i.e. the damping resistor R_2 and the terminating resistor R_1 are replaced by short circuits. An impedance matching adapter is not used.

According to IEC 62153-4-2, in method C generator and receiver are interchanged. The generator feeds the outer circuit at the near end and the inner circuit (the cable under test) is connected to the receiver at the far end. In this set-up, the influence of the capacitive coupling is suppressed by the short circuits in the primary and secondary circuit. It is also very sensitive and thus suitable to measure very low values of the Transfer Impedance (down to $1 \mu\Omega/m$ and less).

Advantage is simple and easy sample preparation, disadvantage is the lower measurement bandwidth due to inner resonances that appear if sample impedance is different from generator (or receiver) impedance.

2.5 Measuring and evaluation

The S-parameter S_{21} respectively a_{meas} should 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:

$$a_{\text{meas}} = 10 \log_{10} \left| \frac{P_1}{P_2} \right| = -20 \cdot \log_{10} |S_{21}| \quad (3)$$

where:

- P_1 is the power, which is fed into the inner circuit;
- P_2 is the power in the outer circuit.

The conversion from the measured attenuation S_{21} to the Transfer Impedance is given by the following general formula:

$$Z_T = \frac{\left(R_1 + Z_0 \frac{Z_s}{Z_p} \right) (R_2 + Z_0)}{2Z_0 \sqrt{\frac{Z_s}{Z_p}}} \cdot \frac{1}{L_c} \cdot 10^{\left(\frac{a_{\text{meas}} - a_{\text{cal}} - a_{\text{pad}}}{20} \right)} \quad (4)$$

where:

- R_1 is the load resistor of the inner circuit, (CUT),
- R_2 is the damping resistor (series resistor) in the outer circuit,
- Z_0 is the system impedance of generator and receiver
- Z_p is the impedance at the primary side of the impedance matching adapter,
- Z_s is the impedance at the secondary side of the impedance matching adapter.

From the general equation (4) we get for the different procedures:

Procedure A:

$$Z_T = \frac{R_1(Z_0 + R_2)}{Z_0 \cdot L_c} \cdot 10^{-\left\{ \frac{a_{\text{meas}} - a_{\text{cal}} - (a_{\text{pad}} + 10 \log_{10} |Z_0/Z_1|)}{20} \right\}}$$

or

$$Z_T = \frac{R_1(R_2 + Z_0)}{\sqrt{Z_1 Z_0}} \cdot \frac{1}{L_c} \cdot 10^{-\left(\frac{a_{\text{meas}} - a_{\text{cal}} - a_{\text{pad}}}{20} \right)} \quad (5a, 5b)$$

Procedure B:

$$Z_T = \frac{R_1 + Z_0}{2 \cdot L_c} \cdot 10^{-\left\{ \frac{a_{\text{meas}} - a_{\text{cal}}}{20} \right\}} \quad (6)$$

Procedure C:

$$Z_T = \frac{Z_0}{2L_c} \cdot 10^{-\left\{ \frac{a_{\text{meas}} - a_{\text{cal}}}{20} \right\}} \quad (7)$$

where:

- Z_0 is the system impedance (usually 50 Ω),
- Z_1 is the characteristic wave impedance of the inner circuit respectively of the DUT,
- Z_T is the Transfer Impedance,
- 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,
- a_{pad} is the attenuation of a matching pad (if any),
- 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),
- R_2 is the damping resistor in the outer circuit.

3. Screening Attenuation, IEC 62153-4-4

The Screening Attenuation a_s is the measure of the effectiveness of a cable screen. It is the logarithmic ratio of the feeding power P_1 to the max. radiated power P_2 .

$$a_s = 10 \cdot \log |P_1 / P_2| = 20 \cdot \log |U_1 / U_2| \quad (8)$$

Changes compared with Edition 1: The standard IEC 62153-4-4 was extended and matched to the requirements when measuring cables with characteristic wave impedances others than 50 Ω, where impedance matching devices are not commercially available, (e.g. cables for electric vehicles with about 10 Ω characteristic impedance).

According to edition 1, the test was achieved under matched conditions [matching of the device under test with its characteristic impedance, ($R_1 = Z_1$) and matching of the DUT to the output impedance of the network analyzer with an impedance matching device].

Edition 2 of IEC 62153-4-4 allows now the test with matching conditions as well as with mismatch between generator and DUT. An impedance matching device is no longer required.

Only the device under test shall be matched with its characteristic wave impedance at the far end. Before measuring with mismatch, the characteristic wave impedance of the DUT shall be determined,

e.g. with the “open/short” procedure according to Annex A of IEC 62153-4-4.

The Test set-up of edition 2 of IEC 62153-4-4 is given in figure 2b.

The Screening Attenuation a_s , which is comparable with the results of the absorbing clamp procedure, shall be calculated with the arbitrary determined normalized value $Z_S = 150 \Omega$.

$$a_s = 10 \log_{10} \left| \frac{P_1}{P_{r,\text{max}}} \right| = 10 \log_{10} \left| \frac{P_1}{P_{2,\text{max}}} \cdot \frac{2 \cdot Z_S}{Z_1} \right| \quad (9)$$

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

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,

$$r \text{ is the reflexion coefficient} = \left| \frac{Z_0 - Z_1}{Z_0 + Z_1} \right| \quad (11)$$

Z_0 is the system impedance respectively the output impedance of the generator, (usually 50 Ω),

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

The term $10 \log_{10} |1 - r^2|$ represents the reflexion loss between generator and DUT due to the mismatch. A mismatch between 50 Ω generator impedance and 10 Ω characteristic wave impedance of the DUT gives a correction value of about 2,5 dB.

4. Balanced cables, connectors and components

4.1 General

When measuring the screening effectiveness of screened balanced cables, connectors or components, one has to decide, what characteristic is of interest: Transfer Impedance, Screening Attenuation or Coupling Attenuation.

When measuring Transfer Impedance and Screening Attenuation of screened balanced cables, connectors or components they are treated as “quasi-coaxial” systems. All connectors of all pairs of the DUT shall be connected together on both ends. Other possible configurations may be agreed with the customer/user.

The Transfer Impedance of balanced cables, connectors and components can be measured under matched conditions as well as under mismatched conditions according to IEC 62153-4-3 and -4-4.

The Coupling Attenuation a_c is the sum of the unbalance a_U of the pair and the Screening Attenuation a_s of the screen. The measuring of Coupling Attenuation of balanced cables is specified in the following standards:

IEC 62153-4-5, Coupling or Screening Attenuation – absorbing clamp method and IEC 62153-4-9, Coupling Attenuation of screened balanced cables, triaxial method.

The measuring of Coupling Attenuation can be achieved with absorbing clamps or with the Triaxial Test Procedure. Measuring with absorbing clamps shows some drawbacks against the measurement with the Triaxial Test Procedure.

Absorbing clamp measurements should be done in a screened room to avoid environmental disturbances. Whereas, when measuring with the triaxial set-up, environmental influences are excluded by the triaxial test set-up itself.

Another drawback of the clamps is the limited frequency range. With the clamp MDS 21 one can measure from 30 MHz up to 1 GHz and with the MDS 22 from 500 MHz to 2.5 GHz. Measurements above 2,5 GHz are not possible with clamps.

Therefore the Triaxial Test Procedure is preferred. IEC 62153-4-9 describes the Triaxial Test Procedure with open test head, (see figure 5).

4.2 Coupling Attenuation, Triaxial Test Procedure

To measure the Coupling Attenuation as well as to measure the unbalance attenuation a differential signal is required.

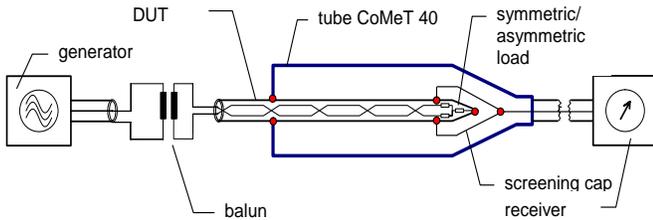


Figure 4 – Measuring of Coupling Attenuation with balun, (principle)

A differential signal can for example be generated using a balun which converts the unbalanced signal of a 50 ohm network analyser into a balanced signal. Commercial baluns however are available up to about 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. Both options allow “balunless” measurements of Coupling Attenuation up to and above 3 GHz, [1].

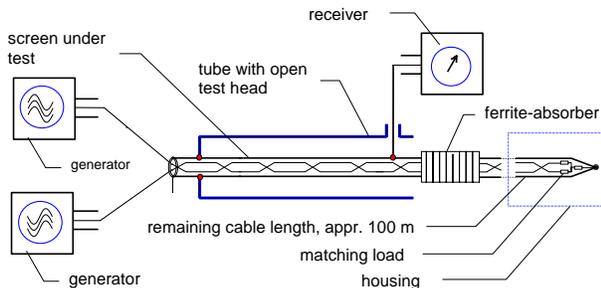


Figure 5 – Measuring of Coupling Attenuation according to IEC 62153-4-9 with multi-port VNA, (principle)

According to IEC 62153-4-9 the tube length is at least 2m (to correctly determine the influence of the Screening Attenuation) and the length of the specimen amounts 100m (to correctly determine the influence of the unbalance attenuation which increases with length). The measuring tube is equipped with an open test head.

The measurements between feeding through a balun and feeding by a multi-port VNA with mixed mode S-parameters show good agreement and confirm that the Coupling Attenuation can be measured to at least 3 GHz when using a multi-port VNA, see figures 6a to 6c.

IEC TC 46/WG 5 is preparing the revision of IEC 61153-4-9 to include “balunless” test methods with multi-port VNA. The reduction of the length under test to 3m is also under discussion. Another option of discussion is the separate measurement of Screening Attenuation and unbalance attenuation instead of Coupling Attenuation at frequencies above 1 GHz.

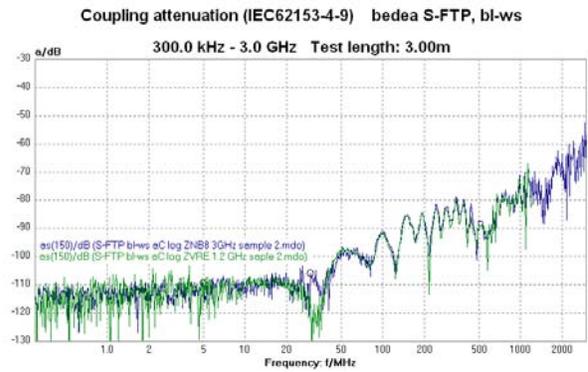


Figure 6a - pair blue-white

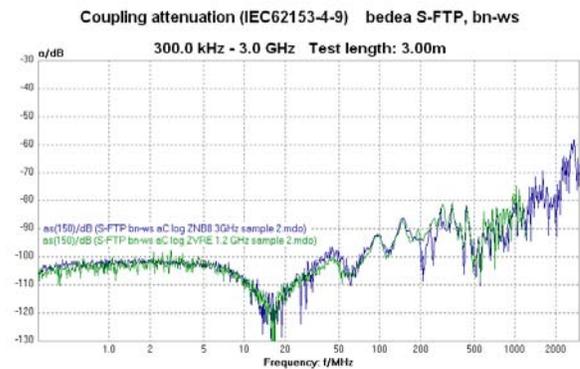


Figure 6b - pair brown-white

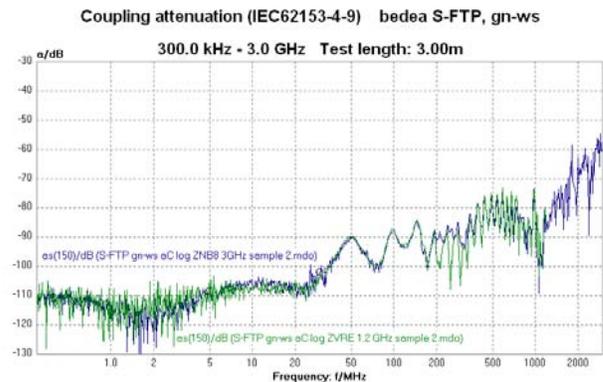


Figure 6c - pair green-white

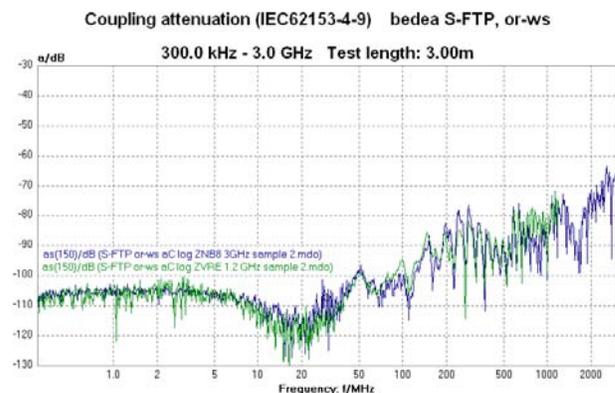


Figure 6d - pair orange-white

Due to simplicity in the comparative measurements presented above the length of the sample was restricted to 3m and the measuring tube operated with a standard test head (see fig. 4).

5. Tube in Tube Test Procedure

5.1 Coupling transfer function

The coupling transfer function $T_{n,f}$ shows the relation between the Screening Attenuation a_S and the Transfer Impedance Z_T of a screened element like a coaxial cable or a coaxial connector (n = near end, f = far end). In the lower frequency range where the 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. In case of cables, the cut-off frequencies $f_{cn,f}$ may be moved towards higher or lower frequencies by variable length of the component under test, [3], [6].

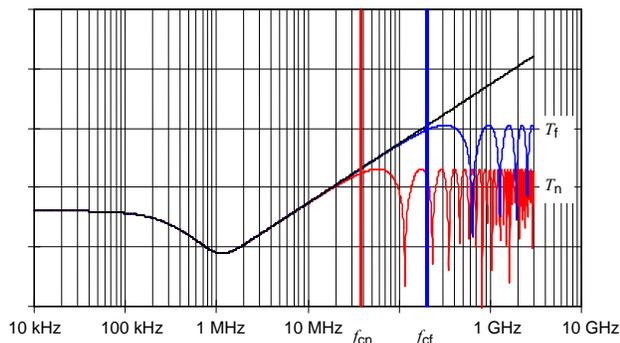


Figure 7 – Coupling transfer function

In case of fixed elements like connectors or connecting hardware, the measured value is the value of the unit and will not be related to length.

With electrically long lengths respectively in the range of wave propagation, the Screening Attenuation formed by the maximum envelope curve is the measure of the screening effectiveness. Therefore the Screening Attenuation is defined only at high frequencies, above the cut-off frequencies.

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:

$$f_c \cdot l \geq \frac{c_0}{\pi \cdot \sqrt{\epsilon_{r1} \pm \sqrt{\epsilon_{r2}}}} \quad (12)$$

where $\epsilon_{r1,2}$ are the relative dielectric permittivity of the inner and the outer system and l is the cable length under test.

Usual RF connectors have mechanical dimensions in the longitudinal axis in the range of 10 mm to 50 mm. With equation (12), i.e. the definition of electrical long elements, we get cut-off frequencies of about 3 GHz or higher for standard RF-connectors.

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.

But customers and users of RF connectors and assemblies like to have the Screening Attenuation also in the MHz range, because it

is more illustrative than the Transfer Impedance and can be used for direct calculation of emission and radiation.

The problem can be solved by using the Tube in Tube Procedure. By extending the electrical short RF-connector by a RF-tight closed metallic tube, one is building a cable assembly which is electrically long. Thus the cut-off frequency respectively the lower frequency limit to measure the Screening Attenuation is extended towards lower frequencies.

The Tube in Tube Procedure allows the measurement of the connector (and its mated adapter) together with its connecting cables. If one connects the extension tube to the connecting cable close to the connector, one is measuring the Screening Attenuation of the combination of the connector (and its mated adapter) and the transition between the cable and the connector under test. This measurement reproduces the practical application of a connector, the measurement of the naked connector without connecting cable is worthless.

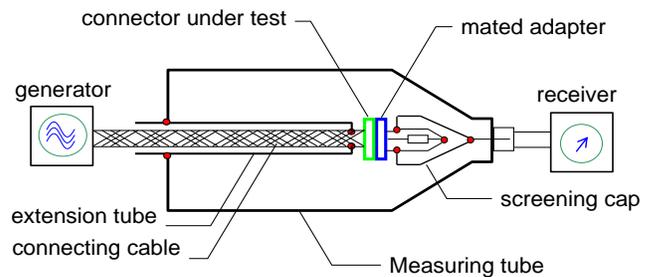


Figure 8 – Tube in Tube Procedure

The standard IEC 62153-4-7, test method for measuring the Transfer Impedance and the Screening or the Coupling Attenuation – Tube in Tube method is under revision at IEC TC 46/WG 5, (46/459/CD). The changes of IEC 62153-4-3 and IEC 62153-4-4 as described above will be included in edition 2 of the Tube in Tube standard.

The Transfer Impedance of connectors, assemblies and components with Tube in Tube Method can be measured now with three different procedures, A, B, C, as described under clause 2. Screening Attenuation of connectors, assemblies and components can now also be measured with mismatch, see clause 3.

6. Triaxial Cell, IEC 62153-4-15

6.1 General

The Triaxial Cell was designed to test larger connectors and assemblies, e.g. assemblies for electric vehicles.

The principles of the Triaxial Test Procedures according to the IEC 62153-4-3 and -4-4 can be transferred to rectangular housings. Tubes and rectangular housings can be operated in combination in one test set-up. The cell may be used also with Tube in Tube Procedure according to IEC 62153-4-7. Furthermore, the cell may be used to measure balanced components with multiport VNA.

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 as follows:

$$f_{MNP} = \frac{c_0}{2} \sqrt{\left(\frac{M}{a}\right)^2 + \left(\frac{N}{b}\right)^2 + \left(\frac{P}{c}\right)^2} \quad (13)$$

where:

M, N, P number of modes (even, 2 of 3 > 0)
 a, b, c dimensions of cavity [mm]
 c_0 velocity of light in free space

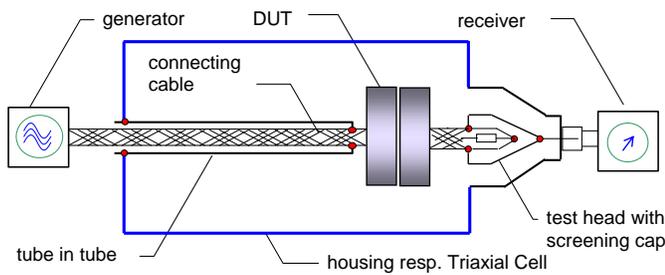


Figure 9- Triaxial Cell, principle

For dimensions of the Triaxial Cells of mm, 750/250/250 mm and 1000/150/150mm the first resonance frequencies are given in table 1. Since the device under test is placed inside the cavity, the resonance frequencies during the test may differ from the calculated frequencies.

Table 1 - Resonance frequencies of Triaxial Cells

| 750-er Cell | | | | 1000/150/150-er Cell | | | |
|-------------|-----|-----|-------|----------------------|-----|-----|-------|
| a | b | c | f/GHz | a | b | c | f/GHz |
| 750 | 250 | 250 | 0,87 | 1000 | 150 | 150 | 1,41 |

Comparative measurements of Transfer Impedance and Screening Attenuation of cables with tubes and with Triaxial Cells showed the same results up to the first resonance frequencies.



Figure 10 – Different designs of Triaxial Cells

Above the first resonance frequencies of the cells, deviations of the max. values of the curves within 3 dB were measured. The behaviour of the cells above the first resonance frequencies and the location of the device under test in the cell are under further study.

The changes of IEC 62153-4-3 and IEC 62153-4-4 as described above will be included also in the test procedure with Triaxial Cell.

Transfer Impedance in the Triaxial Cell can be measured with three different procedures, A, B, C, as described under clause 2. Screening Attenuation of connectors, assemblies and components can now also be measured with mismatch, see clause 3. Coupling Attenuation can be measured in the Triaxial Cell “balunless” with multi-port VNA as described above.

6.2 Passive Components with Triaxial Cell

Another field of application for the Triaxial Cell can be measuring passive components for CATV networks like wall outlets, splitters and tap-offs.

According to IEC 60728-2 respectively of EN 50083-2 in Europe, the coupling unit-method is used from 5 MHz to 30 MHz, the absorbing clamp-method is used from 30 MHz to 100 MHz, and in the frequency range from 950 MHz to 3000 MHz and above the substitution method is required.

For evaluation or qualification of a passive device according to EN 60728-2/EN 50083-2, e.g. in the range from 5 MHz to 1.200 MHz three different costly test procedures with three different expensive test equipment are needed.

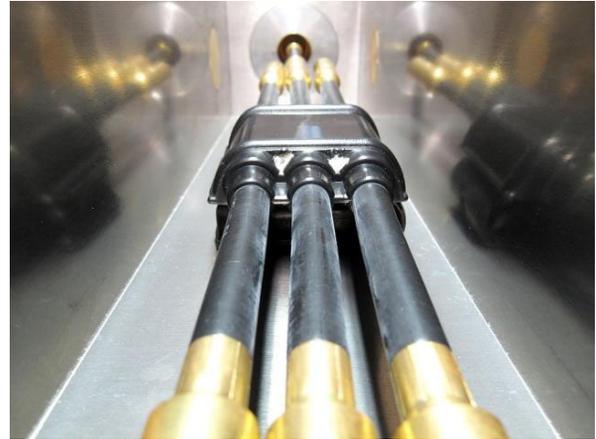


Fig. 11: CATV tap-off in Triaxial Cell

With the Triaxial Test Procedure which was extended by the Triaxial Cell, now one can measure Transfer Impedance and Screening Attenuation of cables, connectors and passive equipment from DC up to 3 GHz.

Herewith effort and costs for evaluation or qualification of EMC behavior of passive components can be reduced considerably.

The introduction of the Triaxial Test Procedure for passive CATV components into the relevant standards is under discussion at respective IEC and CENELEC committees.

7. Measuring of EMC gaskets and feedthroughs, IEC 62153-4-10

Feedthrough configurations with poor ground connections can contribute significantly to the overall EMI level of communication equipment. Electromagnetic gaskets like contact springs or conducting polymers can dramatically reduce conducted and radiated emissions, respectively. A cross-sectional sketch of the typical configuration of a feed-through is shown in Fig. 8. The connector body is soldered onto the circuit board and thus electrically connected to the ground potential or equipotential of the electronic circuitry [4].

The test set-up consists of two RF-tight coaxial systems which are separated by a metallic wall. The feed throughs or EMC gasket under test is mounted into this wall. The contacts to the device under test are achieved by special designed test pins. Together with the test pins, both coaxial systems have a characteristic impedance of 50 ohm up to the device under test.

RF-energy is fed into the system by a network analyzer at one end. On the opposite end of the system, the coupled energy is

measured by the network analyzer. The frequency range of the system reaches from a few kHz up to and above 4 GHz.

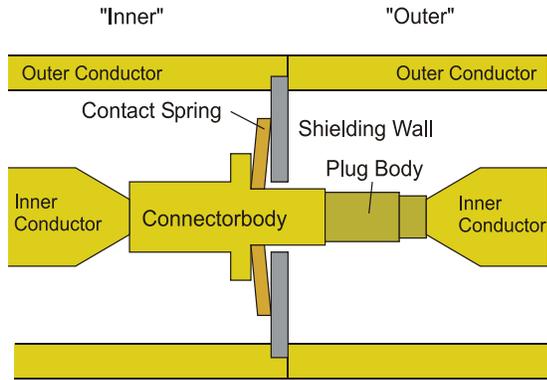


Fig. 12: Cross-sectional sketch of a typical feedthrough configuration

In the equivalent circuit, the influence of the feedthrough or the gasket can be depicted as a shunt resistance Y respectively as the Transfer Impedance Z_T . In an ideal case, that means, in case of optimal screening, the magnitude of the Transfer Impedance is zero and no coupling occurs from one circuit into the other.

In case of real feedthroughs and gaskets, a voltage U_2 is applied to the shunt resistance, which can be measured by the NWA.

The logarithmic ratio of the input voltage U_1 to the measured Voltage U_2 can be expressed as the Screening Attenuation of the system or the Transfer Impedance.

Advantage of the system is the closed test set-up which will not be disturbed from outside or radiate disturbing energy to the surrounding. With the closed set-up, a dynamic range of more than 125 dB may be reached without extra screened enclosure.

Further advantage is the fast and simple preparation of the sample under test and the easy interpretation of the test results.

8. Relation between Transfer Impedance and Screening Attenuation, 62153-4-16

The Triaxial Test set-up allows the measurement of Transfer Impedance and Screening Attenuation in one test set-up and in one step, e.g. according to test method B in figure 3.

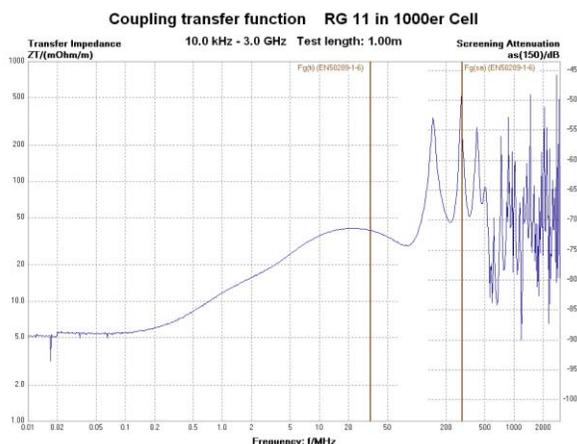


Figure 13 – Coupling transfer function

Figure 13 shows the cut-off frequencies of the Transfer Impedance Z_T and of the Screening Attenuation a_S according to EN 50289-1-6. For a cable of 1 m length and a relative dielectric constant of the inner system ϵ_r of 2,28 we obtain an undefined range or a “grey zone” in the frequency range from about 30 MHz to about 300 MHz, although this frequency range is of specific interest for different services.

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.

A good compromise for measuring Transfer Impedance and Screening Attenuation in one test set-up could be a length of 1 m. The behavior of the device under test at length other than 1m could be calculated respectively estimated from the 1m test results.

A proposal to close the gap respectively the grey zone between Transfer Impedance and Screening Attenuation by interpolation of both quantities, (ITML/2013/03), was made by Thomas Hähner and will be discussed further by IEC TC 46/WG 5.

9. Overview over test procedures with Triaxial Test set-up

The standards to measure the screening effectiveness of communication cables, connectors and components are prepared by IEC TC 46/WG 5. Table 2 gives an overview over the test procedures with Triaxial Test set-up.

Table 2 – Triaxial Procedures acc. to IEC 62153-4 series

| Metallic Communication Cable test methods - Electromagnetic compatibility (EMC) | |
|---------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TR 62153-4-1 Ed.2 | Introduction to electromagnetic (EMC) screening measurements, (46/465e/DTS). |
| 62153-4-3Ed.2 | Transfer Impedance - Triaxial method, (46/471/FDIS). |
| 62153-4-4Ed.2 | Shielded Screening Attenuation, test method for measuring of the Screening Attenuation a_S up to and above 3 GHz, (46/439/CD). |
| 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, (46/459/CD). |
| 62153-4-9 | Electromagnetic Compatibility (EMC) – Coupling Attenuation, triaxial method, (revision at draft stage). |
| 62153-4-10 | Shielded Screening Attenuation test method for measuring the Screening Effectiveness of Feedthroughs and Electromagnetic gaskets |
| 62153-4-15 | Test method for measuring Transfer Impedance and Screening Attenuation - or Coupling Attenuation with Triaxial Cell, (46/454/CD). |
| 62153-4-16 (uc) | Technical report on the relationship between Transfer Impedance and Screening Attenuation, (at draft stage). |

IEC TR 62153-4-1, Introduction to electromagnetic (EMC) screening measurements gives a complete overview over EM shielded measurements of cables, connectors and components. Physical background is described for each of the different test procedure.

10. Conclusions

The Triaxial Test Procedures for measuring Transfer Impedance and Screening- or Coupling Attenuation offer a simple and easy test method for cables, connectors and passive components for a wide range of frequency from DC up to several GHz.

The family of standards of the Triaxial Procedures of the IEC 62153-4 series to measure screening effectiveness with the Triaxial Test set-up are revised under or under revision and matched or will be matched to new applications. They represent the state of the art in screening measurement of cables, connectors and components.

New test procedures or test set-ups like the Triaxial Cell are introduced and in use or under consideration, see item 8. New technologies, e.g. with multi-port VNAs are meanwhile available now to the industry and allow fast and easy measurement of the Coupling Attenuation of EM shielded balanced cables where differential feeding signals are needed.

Advantages of the triaxial test set-up compared with other test procedures are the wide frequency, the closed test fixture and the simple and easy sample preparing among different others.

Further development of the Triaxial Test Procedures could be the extension to measure EMC of active components. First tests are promising.

11. Acknowledgments

Special thanks to Thomas Hähner and to Thomas Schmid and the members of IEC TC 46/WG 5 who have prepared the existing and the revised documents of the IEC 62153 series.

12. References

- [1] Thomas Hähner, Bernhard Mund, "Balunless" Measurement of Coupling Attenuation of Balanced Cables & Components, Wire & Cable Technology international 07-2013.
- [2] Bernhard Mund, Thomas Schmid: Measuring EMC of HV cables and components with Triaxial Cell, Wire & Cable Technology international 01/03-2012).
- [3] Bernhard Mund: Measuring the EMC on RF-connectors and connecting hardware, Tube in Tube test procedure, IWCS (International wire and cable symposium) 2004.
- [4] Lauri Halme, Bernhard Mund et. al, Measurement of the Shielding or Screening Effectiveness of Feed-throughs and Electromagnetic Gaskets up to and above 4 GHz, IWCS (International wire and cable symposium) 2007.
- [5] Lauri Halme, Rauno Kytönen: "Background and introduction to EM screening (shielding) behaviours and measurements of coaxial and symmetrical cables, cable assemblies and connectors", IEE Colloquium on screening effectiveness measurements, Savoy Place London, 6 May 1998.
- [6] Lauri Halme, Balint Szentkuti, The background for electromagnetic screening measurements of cylindrical screens. Tech. Rep. PTT(1988) No. 3.

13. Authors



Dr Lauri Halme, Diploma Engineer (M.Sc. E.E.) 1962, Licentiate (D.Sc. E.E.) 1972, both in Electrical Engineering from the Helsinki University of Technology (HUT).

Dr Lauri Halme was employed by Telecom Finland 1962 -1997 as Executive Director of the Telecommunications Laboratories and Research Center among others. Since 1964 he has been Assistant and Specialist Lecturer on transmission lines and electromagnetic screening at the Helsinki University of Technology (HUT). After leaving Telecom Finland in 1997, he continues as Lecturer and Specialist at Aalto University, Helsinki.

Dr Lauri Halme has contributed to international standardisation committee IEC TC 46 and its different SCs and WGs for more than four decades, (since 1968).

Beside different other standardisation activities, Lauri Halme is Chairman of IEC TC 46, Communication cables, Chairman of IEC SC 46A, Coaxial cables, Convenor of the working group IEC TC 46/WG 5, Screening effectiveness, Chairman of CENELEC TC 46X, Communication cables as well as Technical Manager of IEC TC 100 / Technical Area TA 5, Cable networks.



After having successfully completed his apprenticeship as Radio- and TV Technician, **Bernhard Mund** studied Communication- and Microprocessor-Technologies at FH Giessen-Friedberg.

In 1985 he joined bedea Berkenhoff & Drebes GmbH, Asslar, Germany, manufacturer of e.g. special cables. Formerly being R&D Manager for communication cables, he is now responsible for the RF- and EMC department.

Having had experience with the absorbing clamp procedure and the injection wire procedure, Bernhard Mund started the development of the test fixture of the Triaxial Test Procedures in 1990 in cooperation with Otto Breitenbach and Thomas Hähner.

Besides his work for bedea Bernhard Mund is active as Chairmen of the German standardisation committee UK 412.3, Koaxialkabel as well as Secretary of international committees IEC SC 46A, Coaxial Cables and of CENELEC SC 46XA, Coaxial Cables.

Further standardisation activities among others are the membership of IEC TC 46/WG 5, Screening Effectiveness and of IEC TC 46/WG 9, Cable Assemblies.

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