Tube in tube test procedure

Although customers require the Screening attenuation as measure of the screening effectiveness, on short elements like connectors or short cable assemblies one can measure only the Transfer impedance up to the GHz range.
With the new "Tube in tube" test procedure the cut-off frequency between Transfer impedance and screening attenuation can be moved to lower frequency ranges.

1 Introduction and Conclusion

Due to the increasing use of all kind of electric or electronic equipment, the electromagnetic pollution increases. To reduce this electromagnetic pollution, all components of a system, especially the connecting cables and the connectors respectively the assemblies shall be screened.

To compare the screening effectiveness of different screen designs, standardised measuring procedures are required, preferably measuring the screening attenuation instead of the Transfer impedance.

Customers and users of RF cables, cable assemblies and connectors ask more often for screening effectiveness values in decibels (dB) instead of Transfer impedance values in mΩ/m respectively mΩ .

This report describes a test method to determine the Screening attenuation of electrical short elements like connectors and cable assemblies instead of the Transfer impedance. The test method, which is easy to use with high sensitivity and high repeatability is named "Tube in tube procedure".

The tube in tube procedure is an extension of the triaxial test method according to IEC 61196-1 and EN 50289-1-6, (see wire 04/2000), taking into account the particularities of connectors and cable assemblies.

The test method is under preparation as an international standard at IEC TC46/WG 5, Screening effectiveness.

2 Physical basics

2.1 Surface Transfer Impedance Z_T

The surface transfer impedance Z_T [Ω] of an electrically short screen is defined as the quotient of the longitudinal voltage induced to the inner circuit by the current fed into the outer circuit or vice versa.
in case of cables, Z_T of an electrically short cable screen is expressed in Milli-ohms per length [mΩ/m] or in decibels in relation to 1Ω.

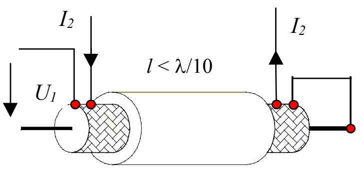

Figure 1- Definition of Z_T

$$Z_T = \frac{U_1}{I_2} \qquad \text{m}\Omega/\text{m} \qquad (1a)$$

$$Z_T \ \text{dB}(\Omega) = +20 \cdot \log_{10}\left(\frac{|Z_T|}{1\Omega}\right) \qquad (1b)$$

In case of single units like connectors or connecting hardware, the Transferimpedance is expressed as the Transfer impedance of the unit.

Bernhard Mund, *bedea* Berkenhoff&Drebes GmbH, Herbornerstrasse 100, D-35614 Asslar, Germany, bmund@bedea.com

2.2 Screening attenuation

At coaxial elements respectively in the common mode of screened balanced elements, the logarithmic ratio of the feeding power P_1 and the periodic maximum values of the power $P_{r,max}$ which may be radiated due to the peaks of voltage U_2 in the outer circuit is termed screening attenuation a_S.

The screening attenuation a_S of electrically long elements, e.g. coaxial cables is defined as the logarithmic ratio of the power fed into the cable and the radiated maximum peak power:

$$a_s = 10 \cdot \log_{10}\left(Env \left| \frac{P_{feed}}{P_{rad,max}} \right| \right) \qquad (2)$$

2.3 Coupling transfer function

The coupling transfer function $T_{n,f}$ gives 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 cable under test.

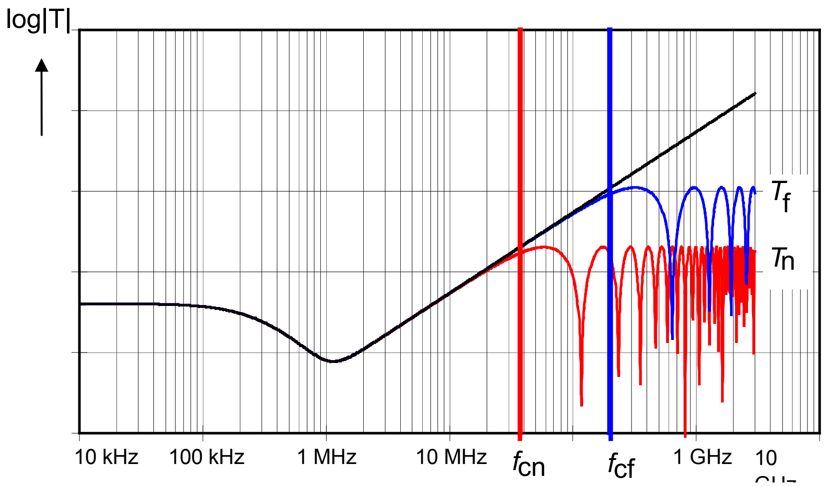

Figure 2 - Calculated coupling transfer function $T_{n,f}$

The measurement of the Transfer impedance, the Screening attenuation and the Coupling attenuation of communication cables is described in IEC 61196 respectively to EN 50289-1-6, triaxial test method.

2.4 Relationship between length and Screening measurements

The relationship between the effective coupling length of the device under test and the electrical wave length is important for the characteristic curve of the screening measurements. In the frequency range of electrically short coupling lengths, the measured screening effectiveness decreases with increasing length. Therefore it is necessary to define the related length. In case of cables, the measured value is related to 1 m by dividing the measured value by the length under test and the value is given in Milli-Ohms per meter [mΩ/m].

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. When measuring connectors or connecting hardware, care should be taken with connecting cables and contact resistances, because they add to the test result.

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:

$$f_c \cdot l \geq \frac{c_0}{\pi \cdot \left| \sqrt{\varepsilon_{r1}} \pm \sqrt{\varepsilon_{r2}} \right|} \qquad (3)$$

where $\varepsilon_{r1,2}$ are the relative dielectric permittivity of the inner and the outer system and l is the cable length respectively the length of the unit under test..
Usual RF connectors have mechanical dimensions in the longitudinal axis in the range of 10 mm to 50 mm. With equation (3), i.e. the definition of electrical long elements, we get cut-off frequencies of about 3 GHz or higher for standard RF-connectors. Above the cut-off frequency they are considered to be electrically long.
The screening attenuation is by definition only valid in the frequency range above the cut-off frequency, where the elements are electrically long. Thus the screening attenuation of a RF connector itself can only be measured at frequencies above 3 GHz.
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.

3 Tube in tube test procedure

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.

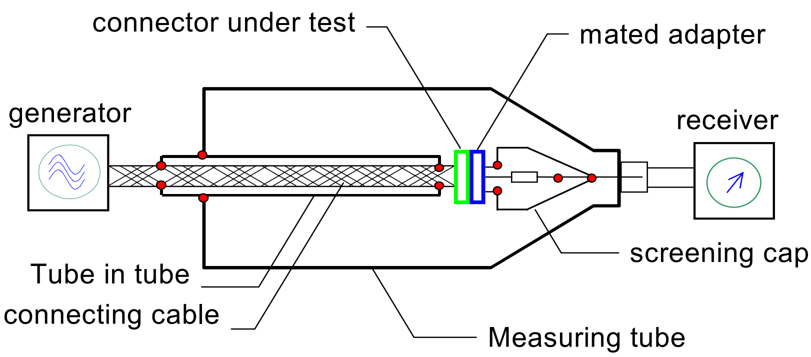

Figure 3 – Principle test set-up for measuring the Screening attenuation of a connector with the tube in tube procedure

3.1 Procedure

The connector respectively the assembly under test is connected to the connecting cable and mounted together with the RF-tight tube into the measuring tube. The connector under test is connected to its mating connector in the test head and is fed via the connecting cable with RF energy by the generator. The mating connector is matched with its characteristic impedance. The head of the measuring tube is connected to the receiver.

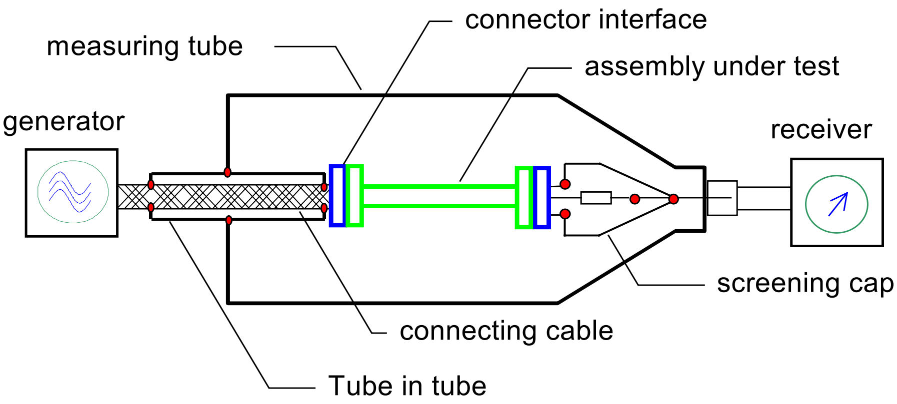

Figure 4 – Principle test set-up for measuring the Screening attenuation of a connector with the Tube in tube procedure

The connector under test forms together with the connecting cable and the tube in tube the inner system, where the electrical short connector is enlarged by the RF-tight Tube in tube. The outer system is formed by the outer conductor of the connector under test, enlarged by the Tube in tube and the measuring tube.

The energy, which couples from the inner system into the outer system travels in both directions. At the short circuit at the near end it will be reflected, so that at the far end the superimposition of both waves can be measured. The logarithmic ratio of the feeding voltage to the measured voltage at the far end is the measure of the Screening attenuation.

With the same test set-up also the Transfer impedance may be measured.

The sensitivity of the system depends on the RF-tightness of the Tube in tube and is > 125 dB up to 3 GHz at the CoMeT system.

3.2 Mated connector

During the measurement, the connector under test is connected to is mating part. It is not possible to separate the influence of the device under test from its mating part or to make a calibration of the mating part alone.

Therefore the type of the mating part should be reported in the test report. Different mating parts or mating parts from different manufacturers may lead to different test results.

A suitable test set-up is manufactured by Rosenberger HF-Technik www.rosenberger.de
and delivered by *bedea* Berkenhoff & Drebes GmbH www.bedea.com as Coupling Measuring Tube CoMeT .

5 Measurements

Figure 5 shows the measurement of the Transfer function of a connector of 10 cm length in the standard tube. The cut-off frequency between Transfer impedance and Screening attenuation is at about 3 GHz.

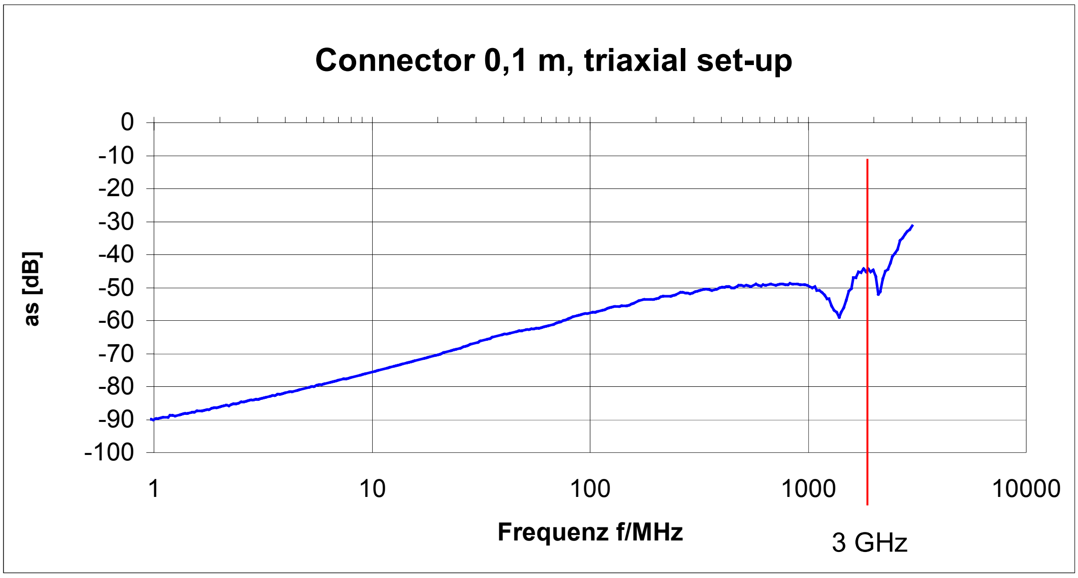

Figure 5 – Transfer function of a connector of 10 cm length

Figure 6 shows the measurement of the same connector with the Tube in tube procedure. The cut-off frequency between the Transfer impedance and the Screening attenuation has moved now from 3 GHz to 150 MHz.

With a Tube in tube of about 3 m, the cut-off frequency is about 50 MHz.

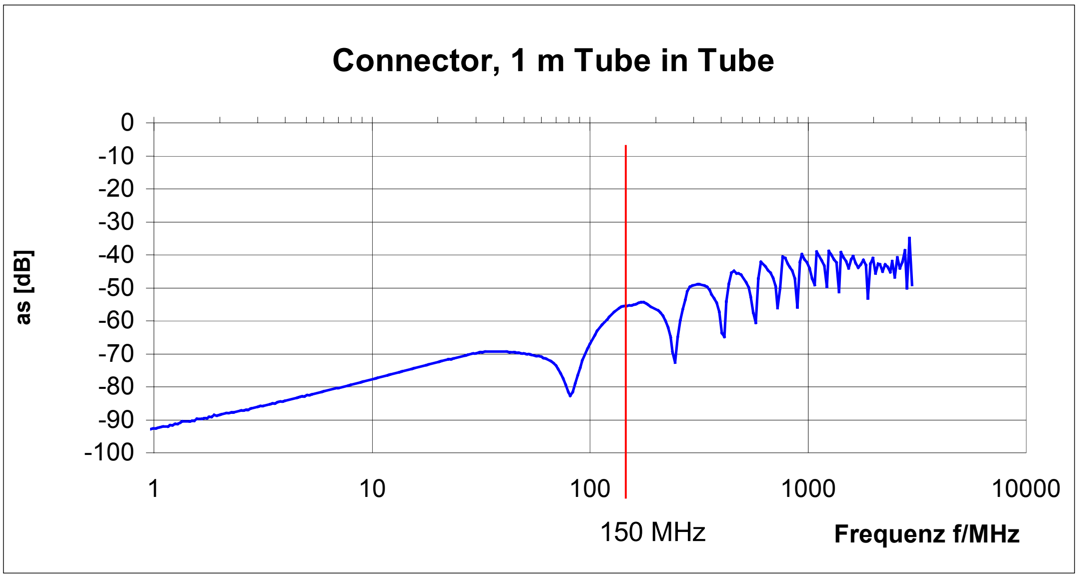

Figure 6 – Transfer function of a connector of 10 cm length

5 Measuring of connecting hardware

A further development of the triaxial test set-up respectively the CoMeT-system is the measuring of multipin connectors and connecting hardware for CATV applications and Data transmission networks. The triaxial test set-up, combined with the tube in tube system is enlarged by a housing or a chamber which is able to take up the sample under test.

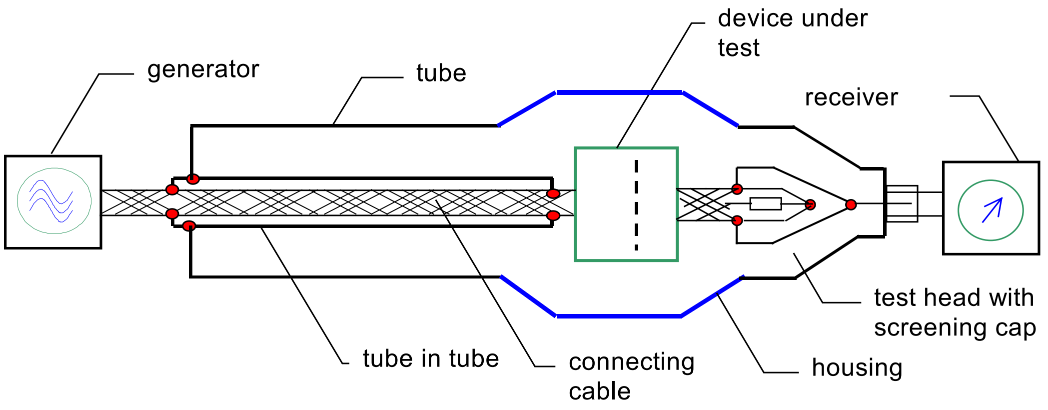

Figure 7– Principle test set-up for measuring the Screening attenuation of connecting hardware with the Tube in tube procedure

By variable length of the Tube in tube, one can measure both, the Transfer impedance as well as the Screening respectively the Coupling attenuation.

Literature

[1] Breitenbach, O./Hähner T.: Kabelschirmung im Übergang von MHz- zu GHz-Frequenzen. ntz Bd. 46(1993) H.8, S. 602-608.

[2] Halme, L./Szentkuti, B.: The background for electromagnetic screening measurements of cylindrical screens. Tech. Rep. PTT(1988) Nr. 3.

[3] L. Halme, R. Kytönen, "Background and introduction to EM screening (shielding) behaviours and measurements of coaxial and symmetrical cables, cable assemblies and connectors", Colloquium on screening effectiveness measurements, Savoy Place London, 6 May 1998, Reference No:1998/452.

[4] O. Breitenbach, T. Hähner, B. Mund, "Screening of cables in the MHz to GHz frequency range extended application of a simple measuring method", Colloquium on screening effectiveness measurements, Savoy Place London, 6 May 1998, Reference No:1998/452.

[5] T. Hähner, B. Mund, "Test methods for screening and balance of communication cables", 13th international Zurich EMC Symposium, February 16-18 1999

[6] T. Hähner, B. Mund, "Measurements of the screening effectiveness of connectors and cable assemblies", EMC 2002, International Wroclaw symposium and exhibition on electromagnetic compatibility, June 25 – 28, 2002, Wroclaw, Poland

[7] IEC 61196-1, Radio-frequency cables Part 1: Generic specification - General Definitions, requirements and test methods.

[8] EN 50289, Communication cables - Specifications for test methods, Part 1-6: Electrical test methods - Electromagnetic performance

Author:

Bernhard Mund received his Dipl.-Ing. degree for Communication- and Microprocessor-technologies from the University of applied sciences, Fachhochschule Gießen-Friedberg in 1984. He joined the manufacturer of communication cables *bedea* Berkenhoff & Drebes GmbH in 1985, where he is responsible for the development and the design of communication cables and the RF- and EMC laboratories.
Bernhard Mund is the Secretary of CENELEC SC 46XA, Coaxial cables and a member of several national and international standardisation committees, e.g. of IEC TC46/WG5, Screening effectiveness.
Contact: bmund@bedea.com