Background, content and future of the EMC measurement standard prEN 50289-1-6, Open / shielded test methods,

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The following report gives an overview of common used and standardised measurement procedures of the screening effectiveness of communication cables. Furthermore a view to future EMC measurements of communication cables as well as of connectors is given.

1 INTRODUCTION

1.1 General

Due to increasing use of all kind of electric or electronic equipment, electromagnetic pollution increases. To reduce this electromagnetic pollution, all components of a system, especially the connecting cables shall be screened.
To have a measure of the screening effectiveness and to compare different screen constructions with each other, international standardised measuring procedures are required.
The following report gives an overview of common used and standardised measurement procedures of the screening effectiveness of communication cables which are summarised in **prEN 50289-1-6.** Furthermore a view to future EMC measurements of communication cables as well as of connectors is given.

1.2 CLC TC46X/WG3

Following a decision of the CENELEC TC46X, Communication Cables, the Working Group CLC TC46X/WG3, Screening Effectiveness, was established in 1996. The task of this Working Group has been to develop standards to measure the screening behaviour of communication cables; especially for balanced data cables. The first meeting of this working group has been held on 10th of January 1997 in Hoersholm, Denmark.
At the moment a draft standard prEN 50289-1-6 is published, which includes 4 different measurement procedures to measure screening effectiveness of communication cables.

The CLC TC46X/WG3 is the mirror committee to the IEC TC 46/WG5, Screening Effectiveness. Since some Experts are members of both Working Groups a good co-operation between this both groups is given and double work is avoided.

2 PHYSICAL BASICS

2.1 General coupling equation

For the measurement of coupling it is expedient to use the concept of operational attenuation with the square root of power waves, like in the definition of scattering parameters [1,2]. The general coupling transfer function is then defined as:

$$T_{\substack{n\\f}} = \frac{\underline{U}_{\substack{2n\\f}} \Big/ \sqrt{Z_2}}{\underline{U}_1 \Big/ \sqrt{Z_1}} = \frac{\sqrt{\underline{P}_{\substack{2n\\f}}}}{\sqrt{\underline{P}_0}} \qquad (1)$$

The electromagnetic influence between the cable and the surrounding is in principle the crosstalk between two lines and is caused by capacitive and magnetic coupling. At the near end the magnetic and capacitive coupling add where at the far end they subtract [2,3]. The coupling over the whole cable length is obtained by integrating the infinitesimal coupling distribution along the cable with the correct phase. The phase effect, when summing up the infinitesimal couplings along the line is expressed by the summing function S [2]. When the cable attenuation is neglected *S* could be expressed by the following equation.

$$S_{\substack{n\\f}}(lf) = \frac{\sin\left(\beta_2 \pm \beta_1\right)\cdot l/2}{\left(\beta_2 \pm \beta_1\right)\cdot l/2}\exp\left(-\,j\left(\beta_2 + \beta_1\right)\cdot l/2\right) \qquad (2)$$

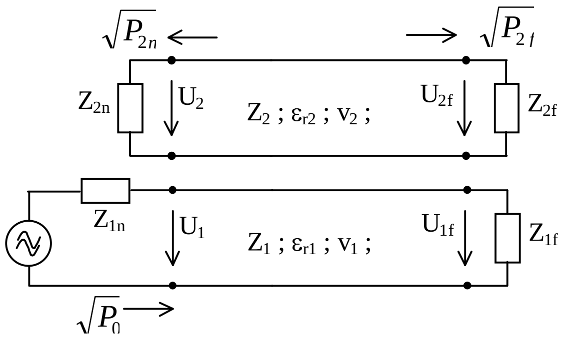


Fig. 1: Equivalent circuit

For high frequencies the asymptotic value becomes:

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

And for low frequencies the summing function becomes:

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

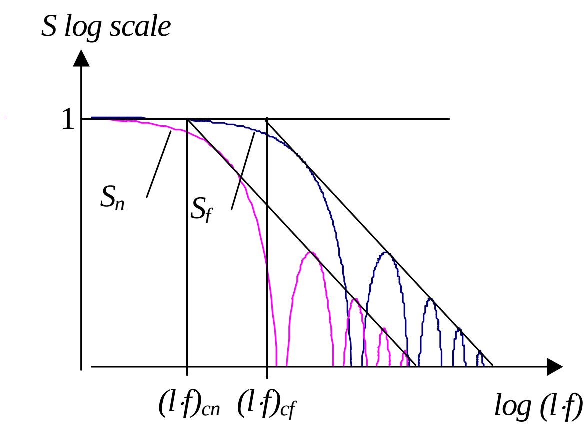


Fig. 2: Summing function S

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

$$f_{\substack{c,n\\f}} \cdot l \geq \frac{c}{\pi \cdot \left|\sqrt{\varepsilon_{r1}} \pm \sqrt{\varepsilon_{r2}}\right|} \qquad (5)$$

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

2.2 Coupling transfer function

The primary screening quantities of a screen are the surface transfer impedance Z_T and the capacitive coupling impedance Z_F or the effective transfer impedance Z_{TE} . For homogeneous screens they are constant along the cable length. The integration along the cable could then be easily solved. The coupling between the cable and the surrounding could then be expressed by the coupling transfer function. For matched lines it is [1,2]:

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

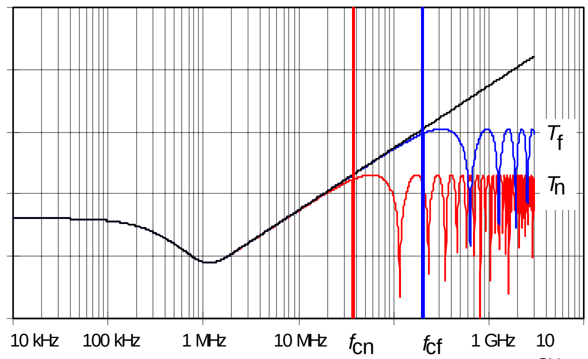


Fig. 3: Calculated coupling transfer function (l = 1 m; ε_{r1} = 2,3; ε_{r2} = 1; Z_F=0)

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

Below the cut off frequencies the surface transferimpedance Z_T is the measure of the screening effectiveness. The value of the transferimpedance Z_T increases with the sample length.

Above the cut off frequencies in the range of wave propagation, resp. in the range where the samples are electrical long, the screening attenuation a_S is the measure of the screening effectiveness. The screening attenuation is a length independent quantity.

Balanced cables which are driven in the differential mode will, due to irregularities in the cable symmetry, radiate a part of the input power.

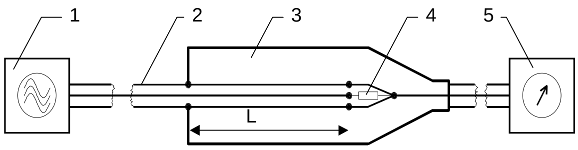
For unscreened balanced cables this radiation is depicted by the unbalance attenuation a_U. For screened balanced cables the disturbing power from the pair is additionally attenuated by the outer screen. The unbalance causes a current in the screen which is then coupled by the transfer impedance and capacitive coupling impedance into the outer circuit. Consequently the total effectiveness against electromagnetic disturbances of shielded balanced cable 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 into the coupling attenuation a_C.

$$a_c = a_u + a_s \qquad (7)$$

3 MEASUREMENT PROCEDURES

3.1 Triaxial set-up to measure the surface transfer impedance

The triaxial procedure to measure the transfer-impedance is one of the classical methods to measure the transferimpedance. It is described in IEC 61196-1 and prEN 50289-1-6. The difference between the IEC and EN method is the interchange of generator and receiver. In the EN method the power is fed into the cable. The benefits of feeding the inner system, which is terminated by its characteristic impedance, are the matching of the generator and reflection free wave propagation over the cable length. The triaxial test set-up consists of a tube of brass or aluminium with an inner diameter of about 40 mm. The length is 0,5 m to 1 m.

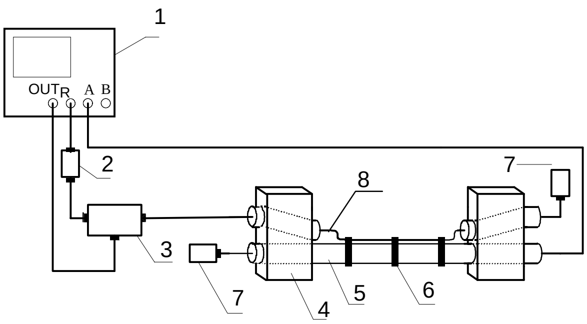


1 generator	4 termination load
2 cable under test	5 measuring receiver
3 measuring tube	L coupling length

Fig. 4: Principle of the triaxial set-up

3.2 Line injection set-up to measure the surface transfer impedance

A further method for the investigation of cable screens is the line injection of the Swiss PTT which is detailed described in IEC 96-1 Amendment 2/1993.



1 Networkanalyzer	5 cable under test
2 attenuator 20 dB	6 adhesive tape
3 power splitter	7 termination load
4 matching pads	8 injection wire

Fig. 5: Principle of line injection set-up, far end measurement

The injection wire, which is connected to the RF-generator injects RF-energy into the screen of the cable under test. The energy which is coupled into the cable under test is measured by the measuring receiver.

The transferimpedance Z_T can then be calculated by the logarithmic ratio A_T of the feeding voltage U_1 to the coupled voltage U_2 to:

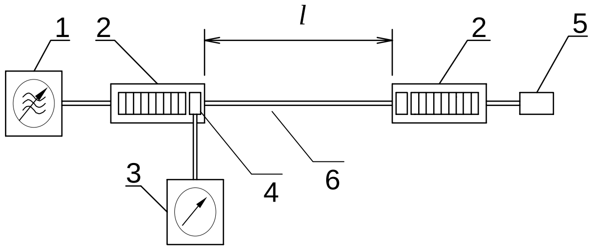
$$Z_T = \frac{2}{l} \cdot \sqrt{Z_1 \cdot Z_2} \cdot 10^{-\frac{A_T}{20}} \tag{8}$$

where $A_T = U_2/U_1$

The upper frequency limit to which the transfer-impedance Z_T can be measured depends on the length of the test section of the cable sample and of the differences in the velocities of propagation in the cable and the outer system. Theoretical the upper frequency limit is more than 3 GHz (see eq. 5). In practice this requires a well matched feeding system.

3.3 Absorbing clamp set-up to measure the screening attenuation

For the investigation of cable screens of coaxial cables in the higher frequency ranges, the screening attenuation a_s was introduced (in the 70ths by Spatz and others). The screening attenuation is measured with absorbing clamps with the measuring set-up according to IEC 61196-1 clause 12.4. An absorbing clamp consists of a current transformer and a number of ferrite rings which are arranged in one housing.



1 Generator	4 Current transformer
2 Absorber	5 Termination load
3 Receiver	6 Cable under test

Fig. 6: Principle test set-up with absorbing clamps, near end measurement

The screening attenuation a_s is the logarithmic ratio of the maximum radiated power P_{2max} to the feeding power P_1 of the cable:

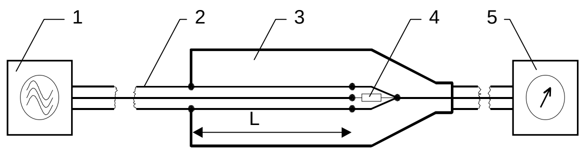
$$a_S = 10 \log (P_1/P_{2max}) \tag{9}$$

The generator feeds the cable with RF-Power. With the current transformer of one clamp the maximum power is measured while the other clamp matches the outer system and absorbs disturbances from outside the measuring length. The maximum power P_{2max} in the outer system results from the near and far end measurement. With the now available absorbing clamps the screening attenuation can be measured up to 2,5 GHz.

3.4 Shielded screening attenuation set-up to measure the screening attenuation

A new development to measure the screening attenuation is the “Shielded screening attenuation” test method. Although the principle were already described in the 60ths, it was Breitenbach who brought this idea back to the international standardisation in 1990 [4,5]. That measuring procedure is in principle an extension of the well known old IEC triaxial method. The new set-up allows the measuring of the transferimpedance Z_T and, in the frequency range of electrical long cable samples, the measuring of the screening attenuation a_S in one test set up. The procedure is standardised in IEC 61196-1, Amendment 1 and also in prEN 50289-1-6.

Contrary to the triaxial method of IEC 61196-1 the generator and the receiver are interchanged and the measuring tube is extended to a length of 2m to 3m. The advantage of the feeding into the matched cable under test (inner system) is, beside the screened test set-up, the matching of the generator and with that the propagation of the RF-energy in the CUT without reflection.



1 generator	4 termination load
2 cable under test	5 measuring receiver
3 measuring tube	L coupling length

Fig. 7: schematically arrangement for measuring the screening attenuation a_S and the transfer-impedance Z_T with the Shielded Screening Measuring set-up

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

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

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

3.5 Absorbing clamp set-up to measure the coupling attenuation of balanced cables

That set-up is in principle the same as the absorbing clamp set-up to measure the screening attenuation. It has been specially adapted in order to measure the coupling attenuation of symmetric cables, which is the combined result of unbalance attenuation and screening attenuation [6].

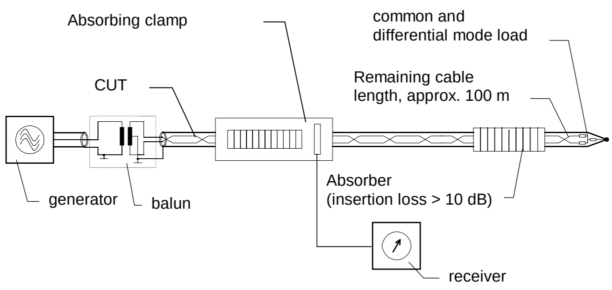


Fig. 8: Test set-up for the coupling attenuation absorbing clamp method

4 FUTURE

4.1 Coupling attenuation, injection clamp method

That injection clamp method is based on the same principle as the absorbing clamp method [7]. The difference is, that the power is fed to the surrounding of the cable (outer circuit), via the injection clamp. Also the outer circuit is matched to 150 Ω. The main benefits are, that the injection clamp make it possible to measure down to 100 KHz, instead of 30 MHz as in the absorbing clamp method. In addition the injection clamp has a about 15 dB less operational attenuation as the absorbing clamp. Thus a about 15 dB higher dynamic range is achieved.
This procedure is an approved new work item proposal in IEC, (IEC 46/86/NP).

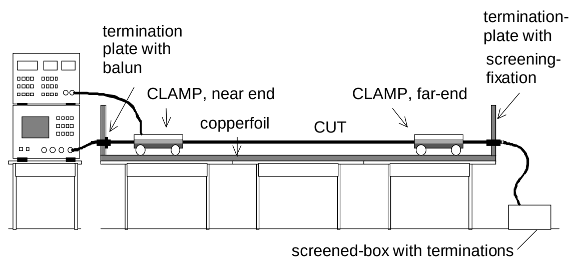


Fig. 9: injection clamp set-up

4.2 Coupling attenuation, Open tube method

As the clamp method could be used to measure the screening and coupling attenuation also the triaxial set-up to measure the screening attenuation can be extended to measure the coupling attenuation. Advantages are the wide frequency range, the high dynamic range and shielded surrounding of the sample under test [8,9,10].
The procedure is given to IEC TC 46 as a New work item proposal, NWP.
The set-up consist of:

- ∇ A metallic non ferromagnetic tube with a length sufficient to produce a superimposition of waves in narrow frequency bands which enable the envelope curve to be drawn.
- ∇ A signal generator with the same characteristic

impedance as the cable under test.

∇ A balun for impedance matching of unbalanced generator output signal to the characteristic impedance of balanced cables.

∇ A receiver with a calibrated step attenuator or network analyser.

∇ Ferrite rings with an attenuation $a_{\text{Ferrit}} > 10$ dB in the measured frequency range.

∇ Metallic boxes to shield the balun and the remaining cable length including the matching resistors

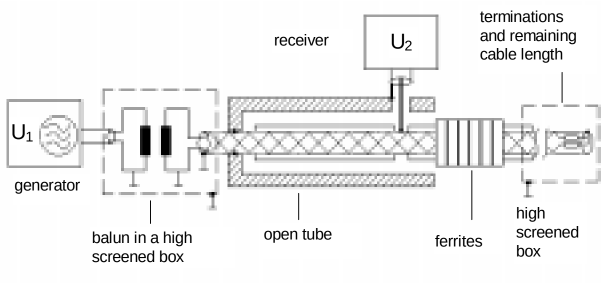


Fig. 10: Triaxial set-up to measure the coupling attenuation

4.3 Measurement of Connectors

An other procedure, which is under discussion is the screening effectiveness of coaxial, balanced and multipin connectors. The mechanical length of the connectors is usually short. Therefore in the frequency range of their application the summing function S=1. Thus only the transferimpedance may be measured. Since the capacitive coupling, specially for multipin connectors, can not be neglected, connectors can not be measured in a set-up with a short circuit at one end. Based on the open tube method, a possible test set-up is:

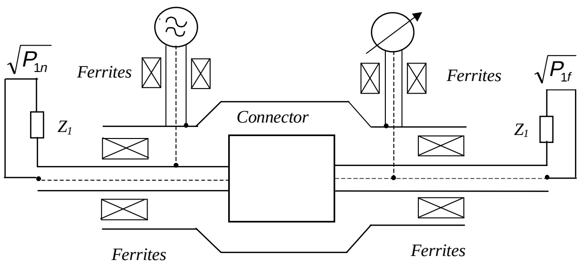


Fig. 11: Principle set-up to measure the transfer impedance of connectors

5 LITERATURE

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