# SCREENING ATTENUATION OF COAXIAL CABLES MEASURED IN GTEM-CELLS

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**Abstract:** This paper describes the determination of the screening attenuation with a GTEM cell. An analytical part gives the link between the voltage at the cell port and the total radiated power. The next section investigates the optimal cable setup in the cell. With a measurement of the common mode current on the cable and a simulation of the radiation resistance the loop antenna characteristics of the cable setup could be verified. It is shown that the use of ferrit cores decrease the difference between the maximum and the minimum screening attenuation. The determination of great screening attenuation could be improved with the use of N-type measurement cables. A comparison between this GTEM cell method and the standard methods shows a good agreement.

**Key words**: screening attenuation, GTEM-cell, total radiated power, coaxial cable, IEC 61000-4-20

## 1. Introduction

The parameter to describe the emission and susceptibility of coaxial cables is given by the screening attenuation:

$$a_S = 10 \cdot \log\left(\frac{P_1}{P_2}\right) \qquad (1)$$

In (1) $P_1$ is the feeding power and $P_2$ is the radiated power (see Fig. 1).

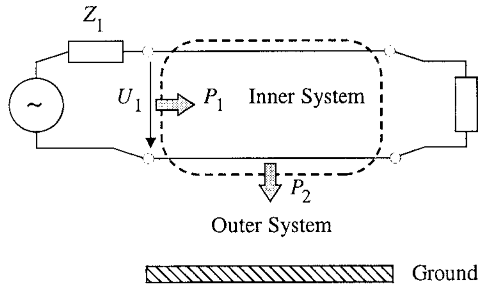


Fig. 1: Equivalent Circuit

In the standards for the absorbing clamp and triaxial method the maximal radiated power $P_2$ is determined via the common mode current that flows on the screen. It is a possibility to obain the worst case radiated power. The question which part of this power is really radiated depends e.g. on the terminating resistors of the primary (inner) and the secondary (outer) circuit (Fig. 1) and the environment. In this paper the radiated power is measured in the GTEM cell.

## 2. GTEM-Cell

The Gigahertz TEM cell (GTEM) is a special 50 Ω TEM waveguide that is used for emission and immunity tests. The cell is terminated with absorbing material and a mesh of resistors that form the characteristic impedance (Fig. 2).

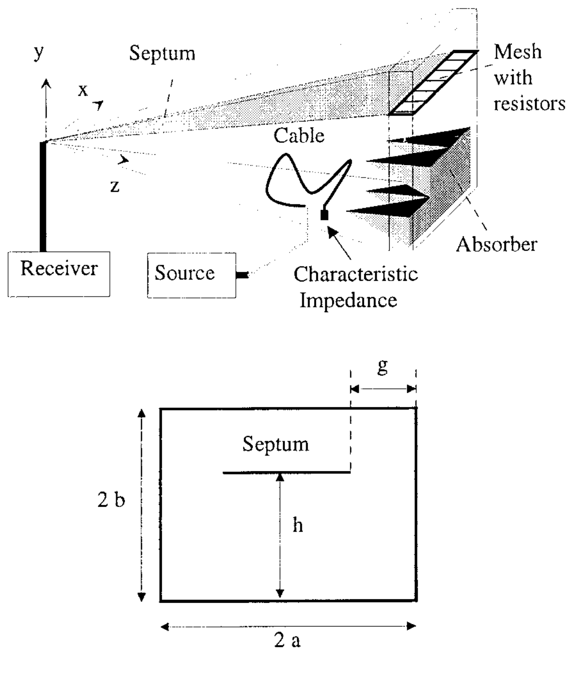


Fig. 2: GTEM-cell

The part of the cable, that is placed in the cell, radiates power. Unfortunately the power that could be measured at the cell port is not the half of the radiated power, because at this port only the TEM-part of the radiation could be measured. In [1] a method is presented to determine the total radiated power $P_2$ with a sequence of 3 orthogonal measurements. The cable set is characterized by an equivalent multipole model. With this model the link between the voltage at the cell port and the total radiated power is [2]:

$$P_2 = \frac{\eta_0}{3\pi} \cdot \frac{k_0^2}{e_{0y}^2 Z_c} \cdot \sqrt{U_{m1}^2 + U_{m2}^2 + U_{m3}^2} \qquad (2)$$

In (2) $\eta_0$ is the field impedance of free space, $k_0 = 2\,\pi/\lambda$ is the wave number, $Z_c$ is the characteristic impedance of the waveguide, $U_m$ is the voltage, where the index m belongs to the 3 cable setups and $e_{0y}$ is the normalized field vector that depends only on the geometry of the cell and the positon of the cable under test (CUT) in the cell. A good approximation for the normalized field vector is:

$$e_{0y} = \frac{4}{a}\sqrt{Z_c}\sum_m^{\infty}\left(\frac{\cosh(My)}{\sinh(Mh)}\cos(Mx)\sin(M\frac{a}{2})J_0(Mg)\right) \qquad (3)$$

For the parameters $a$, $b$, $g$ and $h$ and the coordinate system x, y and z see fig. 2. $J_0$ is the zero order bessel function and M is an abbreviation for m $\pi$ / $a$ with m = [1, 3, 5...].

### 3. Cable Setup

The measurements are done with a RF-Generator SMT02 with a sourcepower of 13 dBm. A Spectrum-Analyser FSP07 steps from 1 MHz up to 1.5 GHz in 1 MHz increments. To obtain a good signal to noise ratio the resolution bandwidth is 30 Hz and the video bandwidth and span are 1 kHz. The preamplifier is on and the used detector is at auto peak. The measurement is controlled with a PC via the GPIB connection. The used GTEM cell type is 1250.

To determine the total radiated power in the GTEM cell the CUT has to be placed in 3 different setups that are orthogonal to one another. With respect to a minimum modification of the cell it would be good to have only one additional hole. With this restrictions two setups are possible: a loop- or monopol antenna. Fig. 3 shows three possible orientations for the loop antenna setup. To hold the cable in the optimal position it is fixed with elastic bands on a polystyrene circle. The test cable is a RG 58 coaxial cable (Alcatel).

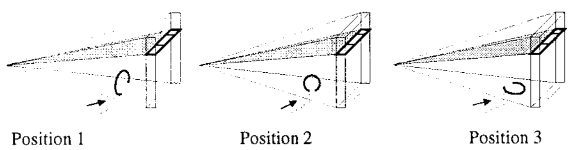


Fig. 3. Three orthogonal cable setups

With the three voltages the total radiated power is calculated with (2). The screening attenuation $a_s$ results with (1). To see the influence of different setup sizes, $a_s$ is determined for 2 different perimeters and lengths.

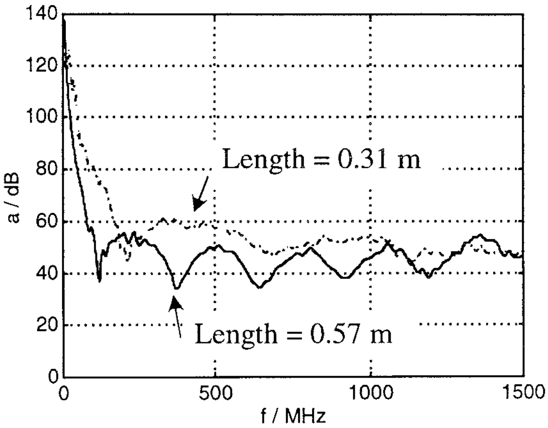


Fig. 4: Screening attenuation: Monopol

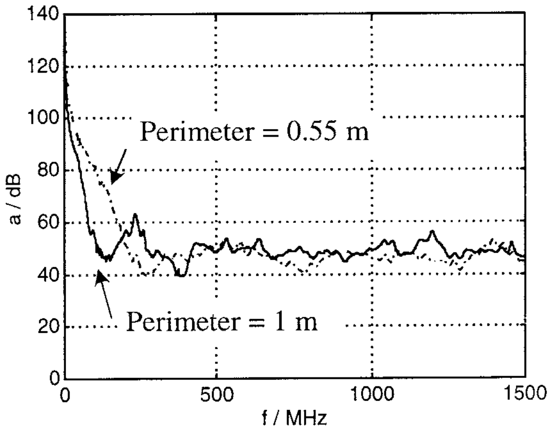


Fig. 5: Screening attenuation: Loop antenna

Each curve in fig. 4 and 5 is the mean of two measurements. For both setups the screening attenuation decrease from 0 Hz up to 100 or 200 MHz. After that it stays more or less constant. Up from the lower corner frequency of approximately 250 MHz radiation effects due to wave propagation takes place. The radiation could be explained with the radiation resistance of an antenna (see next section). To obtain a measure that is more or less independent of a special antenna characteristic the loop antenna shows a more constant screening attenuation over the whole frequency range. The loop antenna has the additional advantage that it could be used for the determination of the coupling attenuation. Therefore a longer cable is needed to consider the unbalanced attenuation. So the loop is advantageous, because on the one port the feeding power could be very near to the source without a great attenuation and on the other port the long cable could follow to have the effect of the unbalanced cable. In this paper the cable perimeter of 1 m is choosen to determine the screening attenuation.

## 4. Antenna characteristic of the cable setup

To investigate the antenna characteristic of the loop antenna the common mode current an the cable screen is measured.

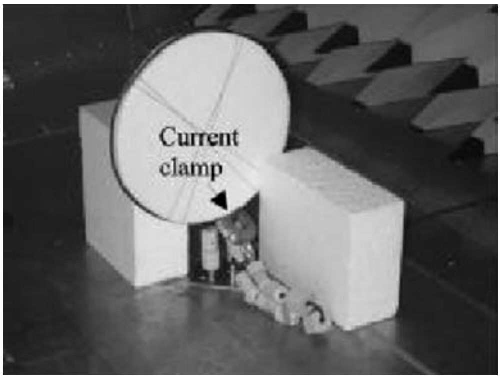


Fig. 6: Current clamp

To avoid further interference in the test lead, ferrit cores on the cable are used (Fig. 6). With this current and the radiation resistance of a loop antenna [3]

$$R_S = 20\left(\frac{2\pi}{\lambda}\right)^4 \left(r_0^2 \pi\right)^2 \tag{4}$$

the total radiated power could be calculated to $P_2 = I^2 R_s$. In (4) $\lambda$ is the wavelength and $r_0$ is the radius of the loop antenna. In fig. 7 the radiation resistance and in fig. 8 the comparison of screening attenuation is presented.

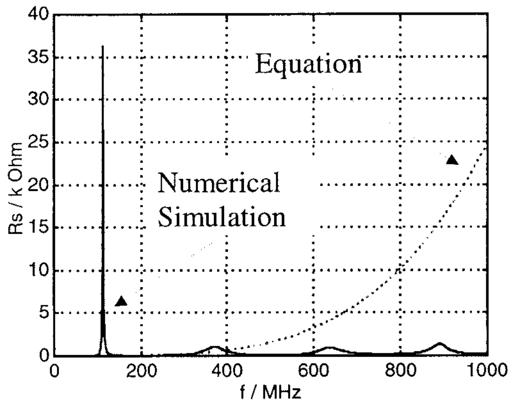


Fig. 7: Radiation resistance of a loop antenna

The condition for (4) is that the loop antenna dimensions are small in comparison to the wave length. With a loop antenna radius of $r_0$ = 0.159 m this condition will be approximately fit up to 90 MHz. This approximation could be confirmed with the radiation resistance and the screening attenuation in fig. 8. To improve the model the radiation resistance is simulated with an electromagnetic field simulation tool CONCEPT. Therefore the loop antenna is simulated with wires and the GTEM cell wall is considered with patches (Fig. 9).

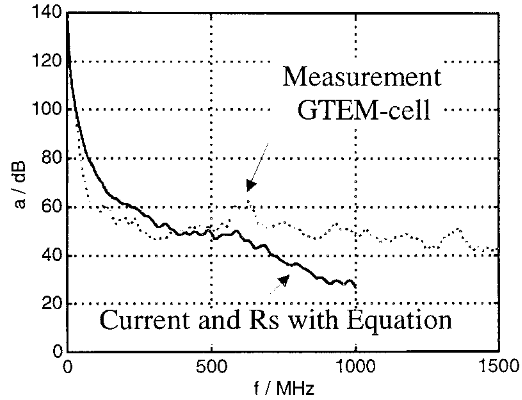


Fig. 8: Screening attenuation with current and (4)

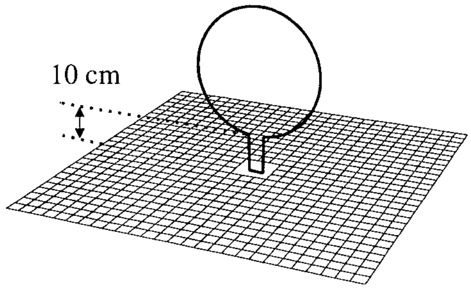


Fig. 9: CONCEPT loop antenna model

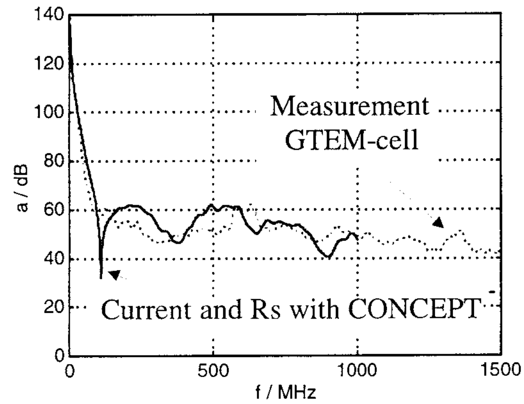


Fig. 10: Screening attenuation with simulation results

In fig. 7 the radiation resistance of the simulation shows resonances and has a flat frequency response in comparison to the dependence of (4). With this radiation resistance and the measured current the calculated and the measured screening attenuation fits very well (fig.10).

## 5. Influence of ferrit cores

In the standard absorbing clamp method ferrit cores are used to avoid unwanted surface wave propagation. Now the influence of ferrit cores should be investigated for the GTEM cell method. Therefore ferrit cores are clamped on the cable (Kitagawa: 2 RFC10 und 2 RFC13) as it is shown in fig. 11. There are two effects of the ferrit cores. In fig. 12 the screening attenuation is plotted without the beginning part. The resonance effects at 147 MHz, 235 MHz and 382 MHz are damped very well, but the whole curve shifted a little bit form the mean value 52.3 dB to 55.2 dB with ferrit cores. As a result one could see that the damping works, but now the screening attenuation is a function of the used ferrit cores.

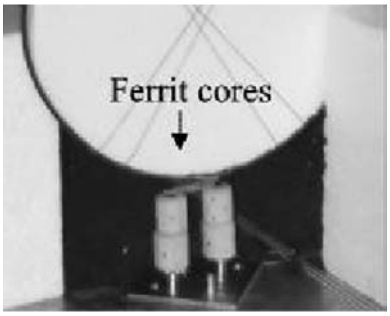


Fig. 11: Ferrit cores

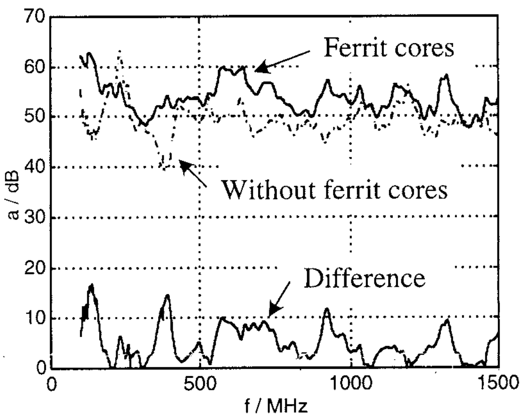


Fig. 12: Screening attenuation ferrit cores

### 6. Influence measurement cable feedthrough

To see the influence of the cable connections a special screened coaxial cable (Sucoflex 104B) is measured for two different feedthroughts. The supporting documents for this cable indicate a screening attenuation of 120 dB and better.

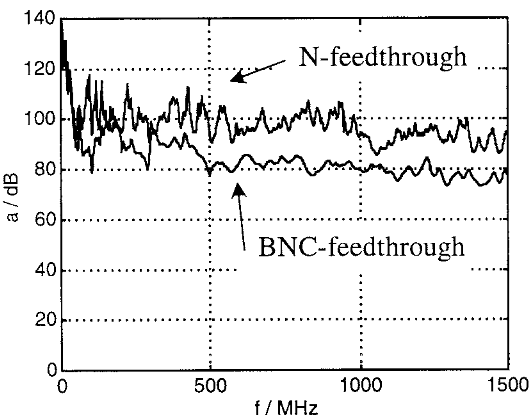


Fig. 13: Screening attenuation different feedthroughs

Fig. 13 shows the measured screening attenuation for 2 different feedthroughts in the GTEM cell. An N-feedthrought improves the screening attenuation approximately 10 dB compared with a BNC-feedthrought. This shows the great influence of the used measurement cable type.

### 7. Comparison with standard methods

In [4] the screening attenuation of a RG 58 cable is determined with the absorbing clamp and the triaxial method. The values vary between 48 and 52 dB for the frequency points f=200 MHz, f=800 MHz und f=3 GHz. In the frequency range up to 1.5 GHz the measured screening attenuation fluctuate approximately ±10 dB. For the comparison a RG 58 cable from Alcatel is measured with and without ferrit cores in the GTEM cell (Fig. 11). The used cable setup is a loop antenna with the perimeter of 1 m. The mean screening attenuation, from the lower corner frequency, without ferrit cores is 52.3 dB and with ferrit corres 55.2 dB. The advantage in the use of ferrit cores is a smaller difference between the maximal and the minimal value. Compared with the standard methods the GTEM cell method shows a good agreement.

### 8. Conclusion

This paper gives an analytical way and method to determine the total radiated power of a cable in a GTEM cell. With this power the screening attenuation $a_s$ could be calculated. A loop antenna is the optimal cable setup with respect to a minimum modification in the cell and the outlook to determine the coupling attenuation with the same setup. With a measurement of the common mode current and a simulation of the radiation resistance the screening attenuation could be verified with a good agreement. Measurements with and without ferrit cores show that the difference between the maximum and the minimum value of the screening attenuation decrease. To determine great screening attenuations N type measurement cables improve the results. A comparison between this GTEM cell method and the standard methods shows a good agreement. Further measurement has to work out the upper boundary of the GTEM-cell method.

### References

[1] Wilson, P., On simulating OATS near-field emission measurements via GTEM cell measurements. IEEE Inter. Symp. on EMC, Aug. 1993

[2] IEC 61000-4-20, Emission and immunity testing in transverse electromagnetic waveguides, 2003

[3] Simonyi, K., Theoretische Elektrotechnik. VEB Deutscher Verlag der Wissenschaften, 1989.

[4] Breitenbach, O., Haehner, T., Mund, B.Screening of cables in the MHz to GHz frequency range extended application of a simple measuring method. IEE Colloquium on Screening Effectiveness Measurements, 7/1-7/15, 1998