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A MODEL FOR SHIELDING EFFECTIVENESS EVALUATION

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***Abstract* – This paper deals with a new Spice Model for determining shielding effectiveness in the case of-conductive materials - function of macroscopic parameters ε, μ, σ, radiation frequency and material thickness. Although the model used in this deduction is based on the well known Schelkunoff's isomorphism.**

Keywords: *modeling, shielding effectiveness, materials, environment.*

1. INTRODUCTION

Nowadays, as the electromagnetic pollution degree has reached alarming levels, a vast research effort is dedicated to the field of electromagnetic compatibility. As a multidisciplinary direction, electromagnetic compatibility includes several subject areas of which shielding occupies a central position since it offers solutions to the limitation of harmful radiated perturbations.

Reducing radiated perturbations can be achieved by using electromagnetic shields. Today's research effort aimed at:

1.Elucidation of phenomena involving production, propagation, refraction, reflection, absorption and multiple reflection of perturbing electromagnetic radiation;

2.Study of undesired radiant disturbances on the electromagnetic environment as we well as on the natural environment, including humans;

3.Investigation of the possible methods of controlling unwanted influences of radiant disturbances;

4.Establishing effective legal norms devised to preserve environment quality;

5.Identify ways of choosing more adequate materials for electromagnetic shielding.

Within this context, the principal directions of interest in the field of shielding materials are:

-Designing of new materials with reflecting and/or absorbing properties of electromagnetic radiation;

-Improving the methods of determining shielding properties of materials.

At present, there are many analytical and computing models to solve, at least theoretically, the problem of electromagnetic shielding, meaning the determination of the influence of a shield (conductor/semiconductor, with/without magnetic properties) on electromagnetic radiation [1]. Mainly, two have been used more often: Kaden model for symmetrical structures and Schelkunoff model for the infinite plane shield [2].

2. SHIELDING MODELING USING TRANSMISSION LINES

Shielding effectiveness *SE* is defined as the ratio between intensities of electric/ magnetic/ electromagnetic fields without shield, E_i, H_i respectively with shield E_t, H_t at normal incidence [3].

Schelkunoff model is considered the most accurate from the viewpoint of the initial conditions and algorithm. Based on it many testing methods have been issued, for different materials, some of them generating civilian (ASTM) or military (MIL) standards.

Last years researches on this model have revealed some divergences between theory and experimental results. Maybe that's why in 2006 ASTM ES7-83 standard for measuring shielding effectiveness with TEM coaxial cell has been disapproved.

2.1. Spice Model

The proposed model starts from the signal attenuation due to the shield, effect which occurs when an e.m.f. is induced in the electroconductive shield depending on material conductivity (induce eddy currents) and its magnetic permeability. The proposed shield model after SPICE simulation is represented in figure 1.

A first simulation was achieved in the case of a copper screen, to verify the method with known results. The specifications of the material (copper) are:

Conductivity $\sigma = 5{,}8.10^{7}\,\Omega^{-1}\mathrm{m}^{-1}$

Permeability $\mu = 1{,}257.10^{-6}\,\mathrm{H/m}$

Permittivity $\varepsilon = \dfrac{1}{36\cdot\pi\cdot10^{9}}\,\mathrm{F/m}$

The shielding effectiveness in Schelkunoff's isomorphism is given by: $SE_{dB} = 20\log\dfrac{V_{IN}}{V_2}$ (voltage without shield/voltage after shielding)

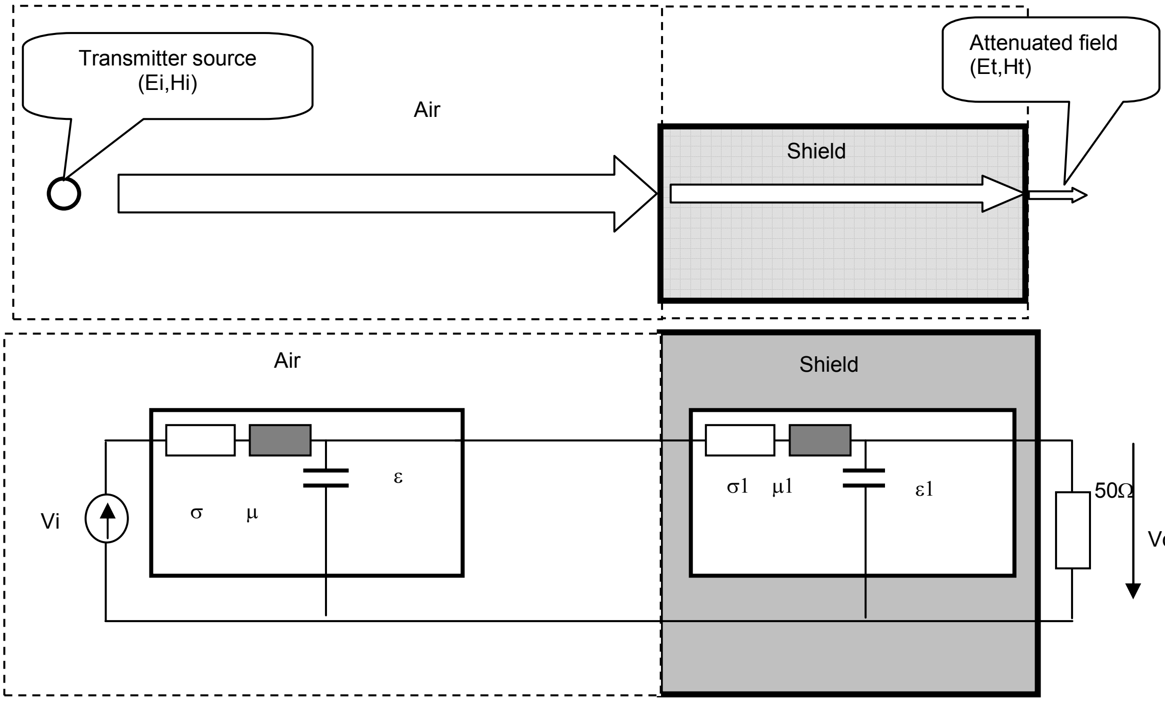

Fig.1: Shield modeling

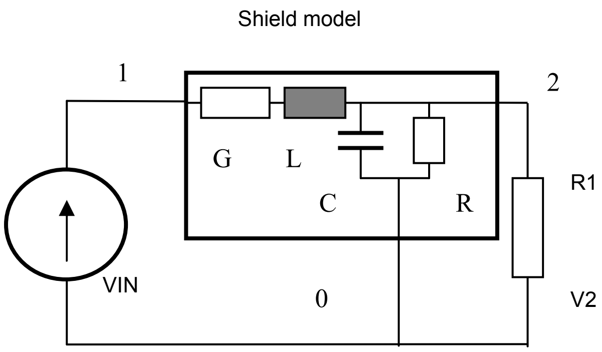

Figure 2: Transmission line model used in modeling a shielding material

The simulated electrical diagram is shown in figure 2. Figure 3 below presents the shielding effectiveness versus frequency ranging from 1Hz to 1000GHz are for four shield thicknesses.

We note a good likeness between the graphs obtained by simulation and those obtained by White [2]. Nevertheless, the shielding effectiveness after simulation is lower than the measured one. Also, the frequencies above which simulations have shown an effectiveness increase are higher than those in the case of measured variations. Measurement conditions require that the electromagnetic radiation source be placed at a certain distance from the shield.

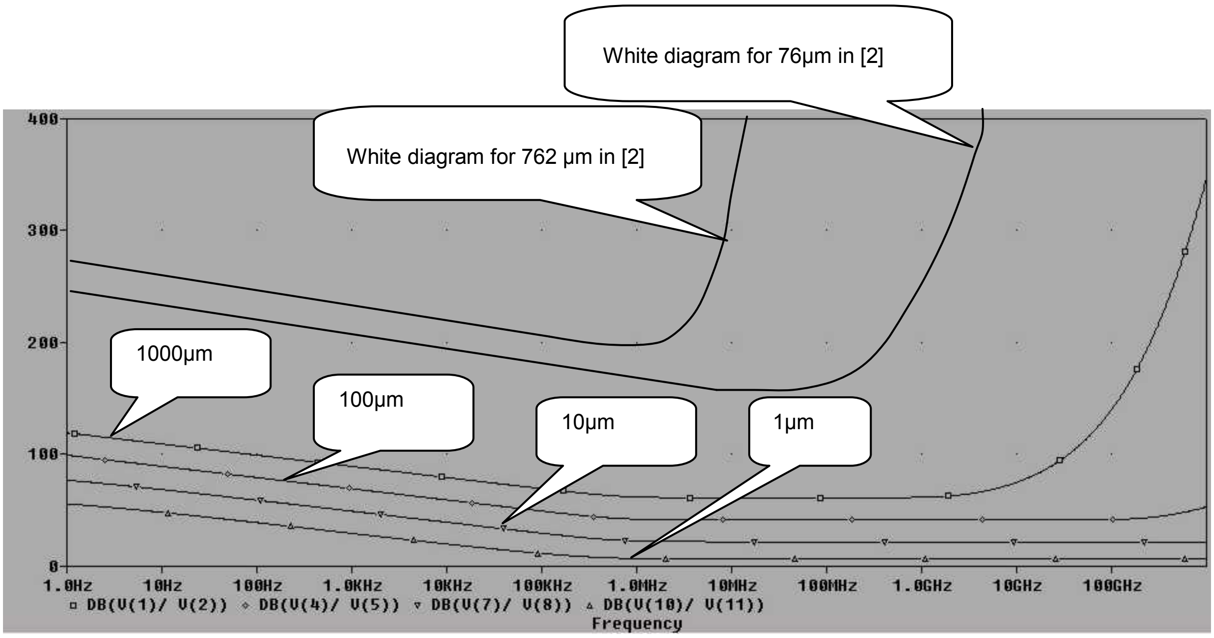

Figure 3: Shielding effectiveness of a copper shield, the highest effectiveness corresponds to the thickest shield

If the shield model is applied to conductive media in which electromagnetic waves can propagate, a transmission line model for air is obtained, having a very low electrical conductivity. The shielding effectiveness for air simulated with the shield model is given in figure 4.

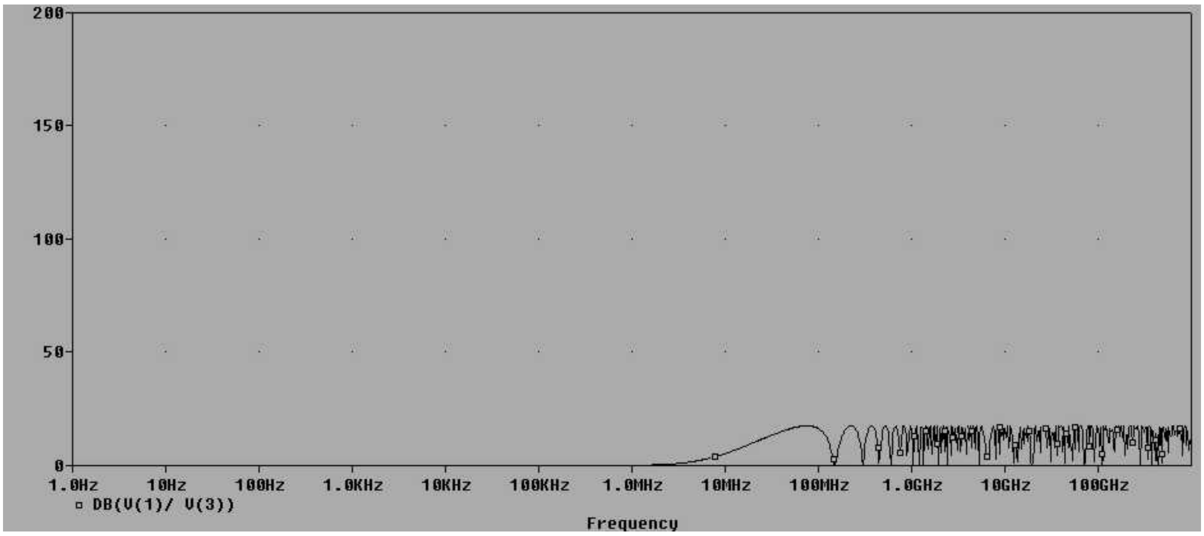

Figure 4: Air shielding effectiveness

It can be seen that the attenuation introduced by 100m of air is around zero up to 10kHz and below 20dB throughout the entire frequency range. If the air space is increased by a factor of 10, the variations of attenuation will be observed starting with a 10 times lower frequency value. The simulations achieved by considering a distance from source to shield of 1 m and 1000m respectively, have shown identical values for the shielding effectiveness.

The simulations performed for a different shielding material – nickel(Ni) with the specifications $\sigma_r = 0{,}23$, $\mu_r = 100$ are shown in figure 5

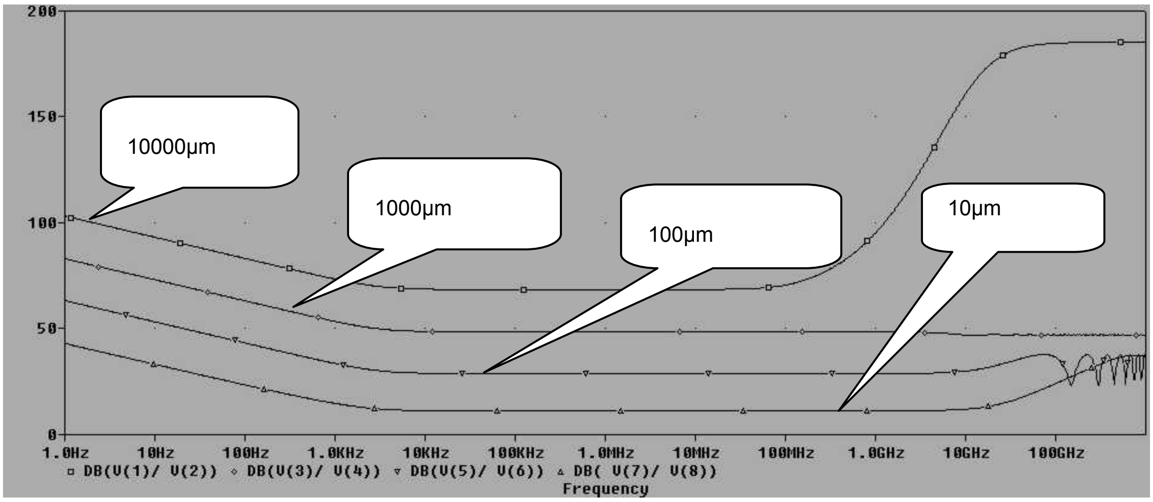

Figure 5: Shielding effectiveness for a nickel shield

We note a reduction of shielding effectiveness throughout the entire frequency range, which is in accordance with the graphs obtained by measurement.

3. SHIELDING EFFECTS ON ETHERNET TRANSMISSION LINES

The characteristics of category 5 UTP cables are specified by EIA/TIA 568A and ASTM D 4566 standards. These standards state maximum capacitances of 5,6nF/100m (200pF/100m), inductances in the µH range whereas the resistance is that of copper. The cable wave impedance is 100Ω+/-15% with a load resistance of identical magnitude to ensure a load-matched transmission. In accordance with the EIA/TIA 568A standard the attenuation is below 22dB/100m throughout the entire frequency range which was confirmed after a SPICE simulation. The simulation shows a signal delay along the transmission line of less than 20ns/100m which is in accordance with the maximum admissible limit of 5.7ns/m required by the EIA/TIA 568 standard.

In order to assess shielding effectiveness in the case of an Ethernet transmission, a model of the Ethernet transmission through an UTP cable, perturbed by a wireless transmission was created. Figure 6 and Figure 7 presents the utilized model and the simulated situation while figure 8 shows the shielding effectiveness graph.

This attenuation is sufficient in accordance with the EIA/TIA 568A standard which requires an attenuation of perturbations (ACR Attenuation to Cross Talk Radio) of minimum 50dB throughout the entire frequency range.

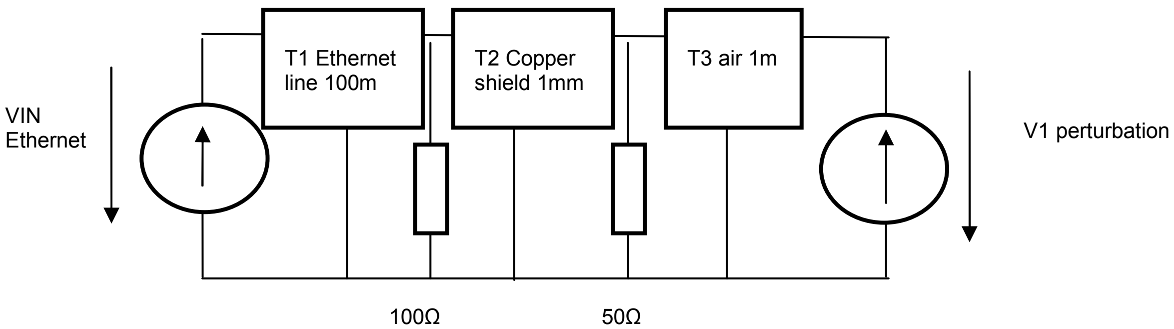

Figure 6: Model and simulation of real configuration for a perturbed Ethernet transmission

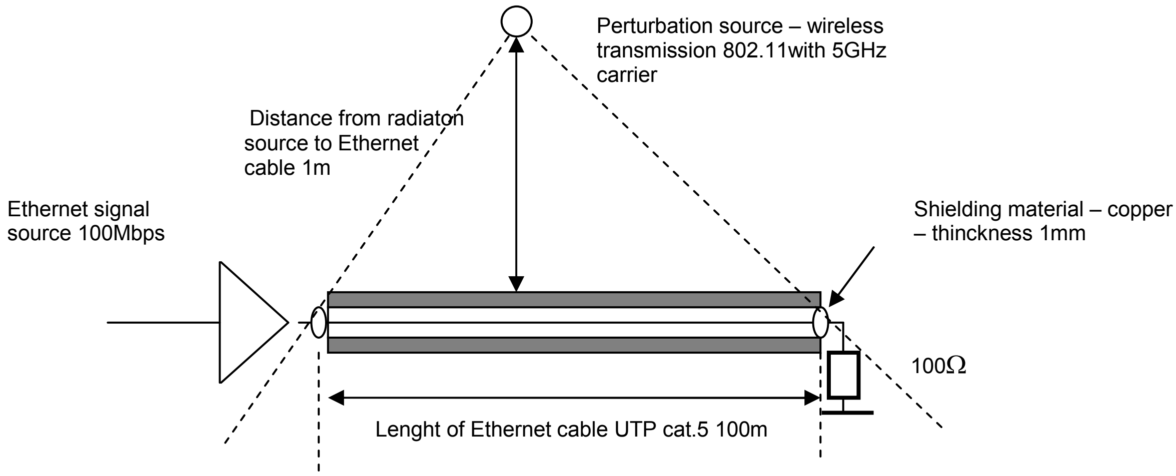

Figure 7: Real configuration for a perturbed Ethernet transmission

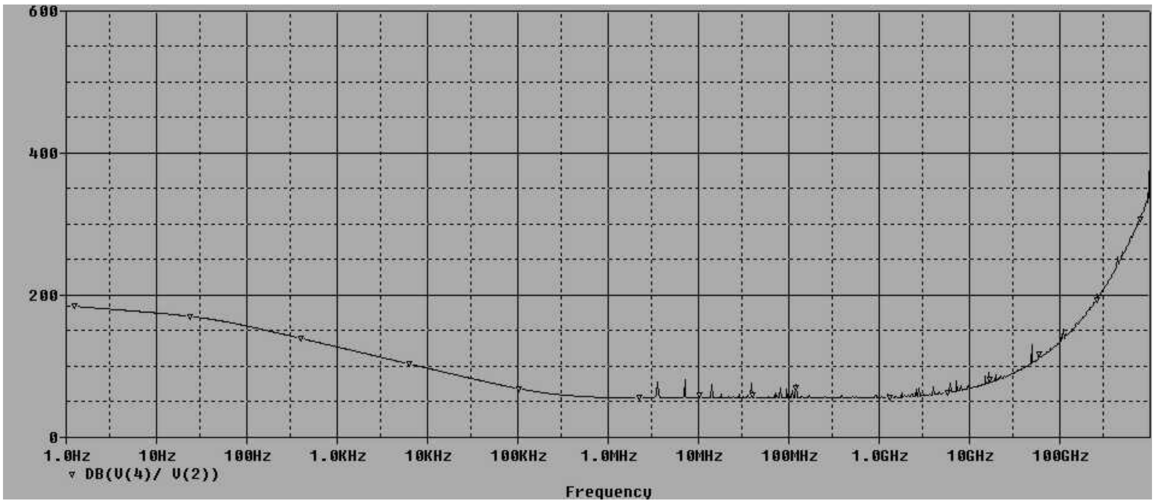

Figure 8: Attenuation introduced by a 1mm copper shield

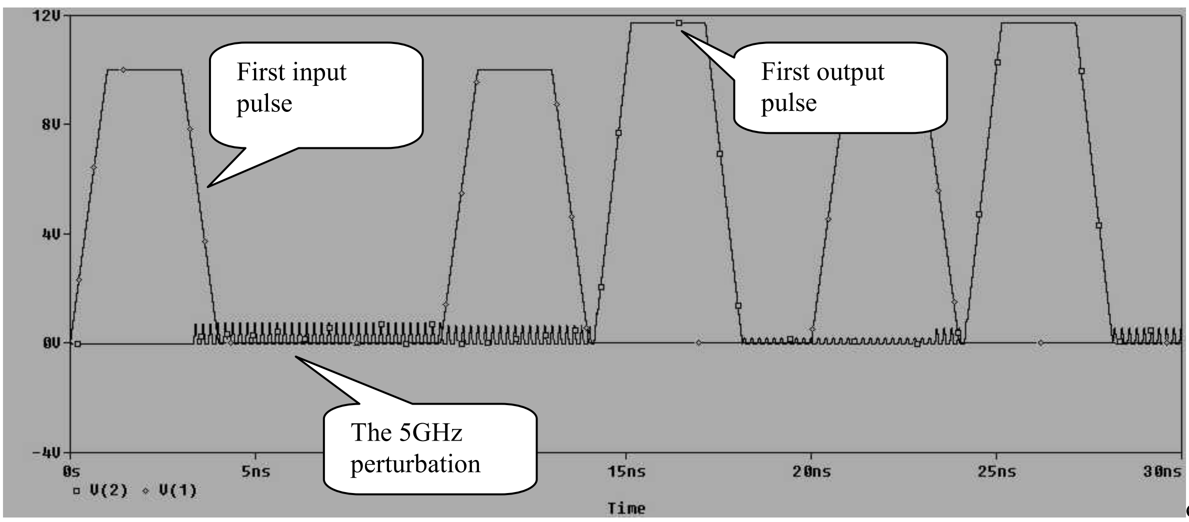

Figure 9: The 5GHz perturbation of the 100MHz Ethernet signal

For a time-domain analysis, in addition to the frequency-domain analysis a zero forward voltage diode was utilized in order to ensure that the perturbing radiation is aimed at the UTP line. The thickness of the shield was also reduced to 100μm. The perturbing source has a signal amplitude of 1000V. The time variation is shown in figure 9.
It can be observed that the shield ensures a significantly large attenuation and the perturbation does not affect the useful signal.

4. CONCLUSIONS

The results obtained by simulation were compared with the results obtained with a program developed by EDSA [4], the example being the effectiveness calculated for an iron shield of 1,7mm. For iron σ_R=0,17, μ_R=1000. The EDSA program calculates a shielding effectiveness of 260dB, which is higher than the 200dB effectiveness obtained with the shield model.
Shielding effectiveness measurements on various materials inside the TEM cell published in [5] show values close to the values obtained by simulations in the low-frequency range (below 1MHz). Due to the already mentioned differences, the proposed model can be used, in this stage, only for shielding efficiency evaluation. In order to obtain results that can be used in practice, the model needs to be improved. A possible cause of its low accuracy could be the line model provided by SPICE which is unable to operate with high R/L values.

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