SIMULATION OF ELECTROMAGNETIC SHIELDING IN COMSOL MULTIPHYSICS ENVIRONMENT

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Summary The paper presents results of energy radiation from point source, which is situated in a metal case with quadrangular opening. The opening is shielded with transparent metal grid to prevent leakage of electromagnetic field. The leakage of electromagnetic field without the grid and the leakage of electromagnetic field with the grid are simulated. The shielding effectiveness is evaluated as a proportion of electric or magnetic field intensity at the place of an observer without the metal grid and with the metal grid.

1. INTRODUCTION

Electromagnetic compatibility is achieved by reducing the interference below the level that disrupts the proper operation of the electronic system or subsystem. This compatibility is generally accomplished by means of electronic filters, and component or equipment shielding. Electromagnetic Interference emitter/susceptor system is shown in Figure 1. The emitter represents a system or subsystem that generates electromagnetic field and the susceptor represents a system or subsystem that is susceptible to electromagnetic waves. In the real world, a system or subsystem can be simultaneously an emitter and a susceptor.

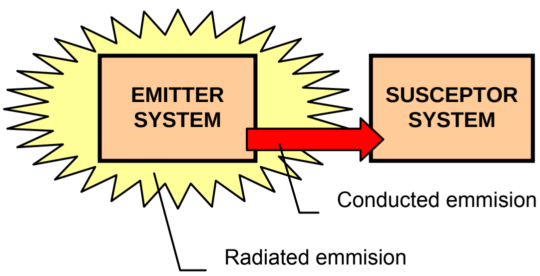

Fig. 1. An example of an electromagnetic interference

Electromagnetic waves consist of two oscillating fields at right angles (fig. 2). One of these fields is the electric field (E-Fields) while the other is the magnetic field (H-Fields). E-Fields are generated by and most easily interact with high impedance voltage driven circuitry, such as a straight wire or dipole. H-Fields are generated by and most readily interact with low impedance current driven circuitry such as wire loops.

The losses in field strength from a shielding barrier (fig. 3) are a function of the barrier material (permeability, conductivity and thickness), frequency and distance from the EMI source to the shield. The basic differential equations that express classical electromagnetic field phenomena and its interaction with conductive materials were developed well over a hundred years ago by J.C. Maxwell. The analytic solutions of these differential equations are generally complex, even for simple models. This has discouraged their use in shielding analysis.

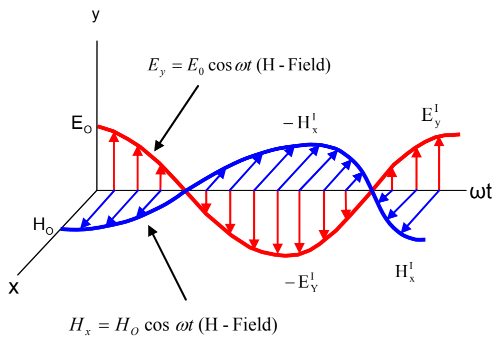

Fig. 2. Electromagnetic plane polarized waveform

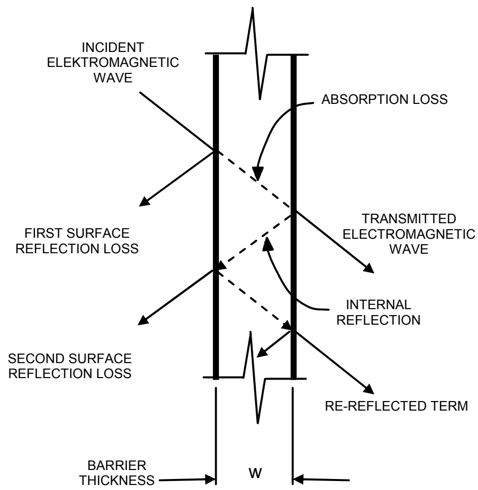

Fig. 3. Losses due to a solid conductive barrier

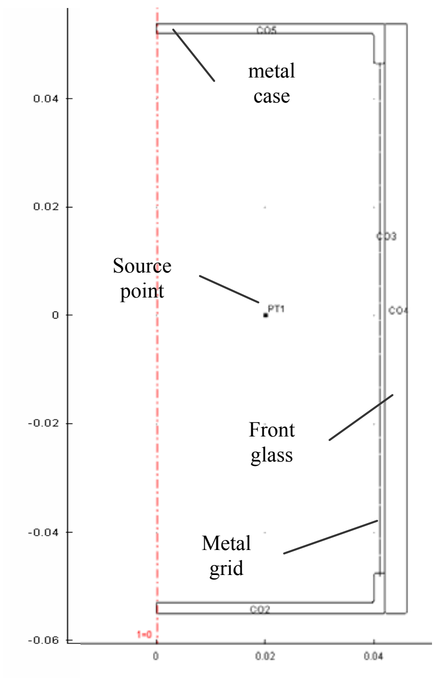

Fig.4 Geometry model of the case.

2. THEORETICAL MODELS

Any barrier placed between an emitter and a susceptor that diminishes the strength of the interference can be thought of as an Electromagnetic interference shield. How well the shield attenuates an electromagnetic field is referred to as its shielding effectiveness (SE) [3]. Therefore, shielding effectiveness is a measure of the ability of that material to control radiated electromagnetic energy. The standard unit of measurement for shielding effectiveness is the decibel (dB). The decibel is expressed as the ratio of two values of electromagnetic field strength where the field strengths are compared before and after the shield is in place. It is defined as:

E-Field:

$$\mathrm{SE_{dB}} = 20 * \log_{10}\left(\frac{\mathrm{E_1}}{\mathrm{E_2}}\right), \qquad (1)$$

H-Field:

$$\mathrm{SE_{dB}} = 20 * \log_{10}\left(\frac{\mathrm{H_1}}{\mathrm{H_2}}\right), \qquad (2)$$

3. GEOMETRY AND PHYSICAL MODEL OF A SOLVED PROBLEM

Two geometry models of shielding are created in 2D. The first is a metal case in Fig.4 (components CO2 and CO5) with a cut-out in front side, where metal grid (component CO3) and front glass cover (component CO4) are placed. Similar geometry model is created for the second metal case, but without the metal grid.

Source of electromagnetic radiation, element PT1, is in the same position and has got the same qualities at both cases.

Field radiated from the mentioned source is represented by transversal waves (TE) which are described in 2D by the equation [2]:

$$\nabla \times (\mu_r^{-1} \nabla \times \mathbf{E}) - k_0^2 \varepsilon_{rc} \mathbf{E} = \mathbf{0}, \qquad (3)$$

where:

E is the electric field intensity vector,

μ_r is the relative permeability of an environment,

ε_{rc} is the complex permittivity of an environment.

The wave number k_0 of free environment is defined as:

$$k_0 = \omega\sqrt{\varepsilon_0 \mu_0} = \frac{\omega}{c_0}, \qquad (4)$$

where:

$$\varepsilon_{rc} = \varepsilon - j\frac{\sigma}{\omega}, \qquad (5)$$

c_0 is the light velocity in a vacuum,

μ_0 is the permeability of a vacuum,

ε_0 is the permittivity of a vacuum.

The complex permittivity of an environment is given as:

The radiation source is modelled as a magnetic dipole supplied by the current I0 = 1A with the frequency given by parameter a = (1, 2, 3, 4, 5, 6, 7, 8, 9). The parametric solver counts with frequency value:

$$f = 10^a, \qquad (6)$$

In this event, TE wave has got only one component of electric field in φ direction. The magnetic field lies in r,z - plain of model.

Harmonic electric and magnetic fields can be described in form:

$$\mathbf{E}(r,z,t) = E_\varphi(r,z)\mathbf{e}_\varphi e^{j\omega t}, \qquad (7)$$

$$\mathbf{H}(r,z,t) = (H_r(r,z)\mathbf{e}_r + H_z(r,z)\mathbf{e}_z)e^{j\omega t}, \qquad (8)$$

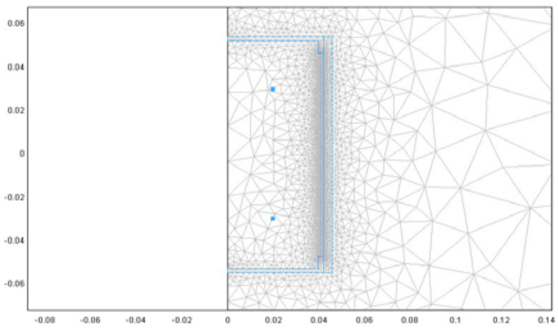

Fig.5 Processing mesh for the case with the metal grid.

- The geometry model without the metal grid:

Number of boundary elements	218
Number of elements	2574
Minimum element quality	0.5586

Fig.5 and Fig.6 show the generated meshes of finite element method task solution. Small size of stitches of the metal grid causes greater number of elements at model with metal grid than at model without metal grid.

Tab.1. Boundary conditions of the physical model

Subdomain (Components):	Interior and exterior case (air)	CO2, CO3, CO5 (Iron)	CO4 (Glass (quartz))
Relative permeability (mur)	1	4000 (Iron)	1
Relative permittivity (epsilonr)	1	1 (Iron)	4.2
Conductivity (sigma)	0	1.12e7 (Iron)	1e-14
Refractive index (n)	1	1	2.05

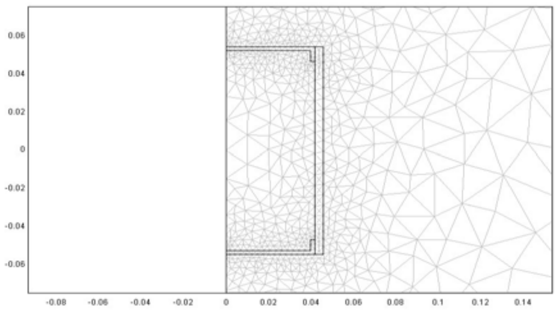

Fig.6 Processing mesh for the case without the metal grid.

4. SETTINGS OF BOUNDARY CONDITIONS, SETTINGS OF PROPERTIES FOR SINGLE DOMAINS

The physical boundary conditions have been assigned to geometry model at described application mode. The geometry boundaries like contours, surfaces, planes or points have got concrete physical values according to Tab.1.

The mesh of finite elements was finally optimally generated at the fourth grade of nine-grade fineness scale of settings with following results:

- The geometry model with the metal grid:

Number of boundary elements:	2665
Number of elements:	83169
Minimum element quality:	0.4955

5. ACHIEVED SIMULATION RESULTS AND GRAPHIC PROCESSING

FEMLAB includes a set of solvers for PDE-based problems.

Simulation of electromagnetic field radiation was performed separately for geometry models in Fig.5 and Fig.6. The solver UMFPACK (FEMLAB`s default linear system solver) for linear stationary PDE problems, depending on parameter (6), was applied at both events.

6. POSTPROCESSING RESULTS

FEMLAB provides many tools for postprocessing and visualizing model quantities. It creates a wide variety of plots:

- Surface plots,
- Slice plots,
- Isosurface plots,
- Contour plots,
- Streamline plots,
- Principal stress/strain plots,
- Combinations of these plots,

Fig.7 presents contour plot of electric field (frequency 1GHz) radiated from the geometry model of case. In the figure, essential difference of radiated electric field intensity is shown. The diagrams allow determining of electric field intensity in various directions. For example Fig.8 shows line of electric field intensity along perpendicular to front side of case in 1m distance. Comparison of electric field intensity value in the same distance out of front side of case with metal grid and without metal grid determines shielding effectiveness according to relation (1). The SEdB value of radiated electric field with frequency interval from 10 kHz to 1 GHz is on Fig.9.

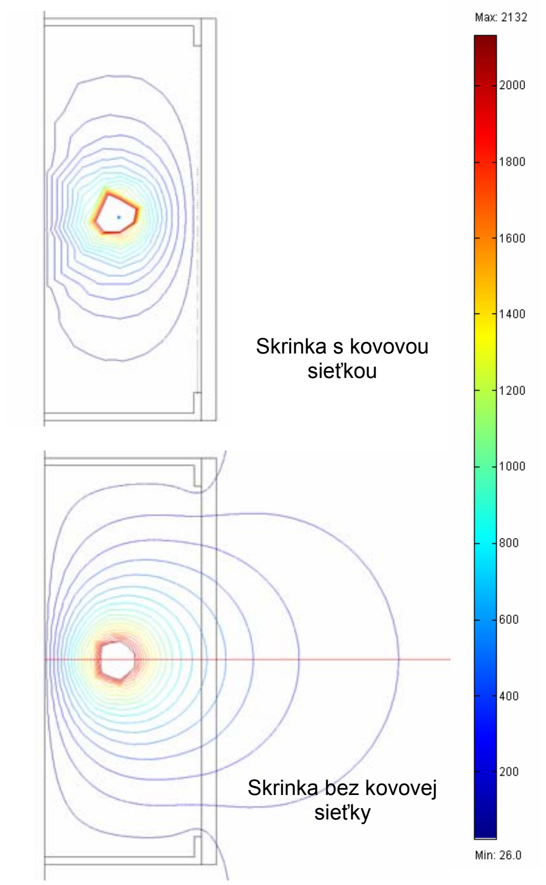

Fig. 7. Contour plots of radiated electric field from the case with metal grid and without metal grid.

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[3] *Henry Ott: Noise Reduction Techniques in Electronic Systems, 2nd Edition, ISBN: 0-471-85068-3, Hardcover, April 1988*

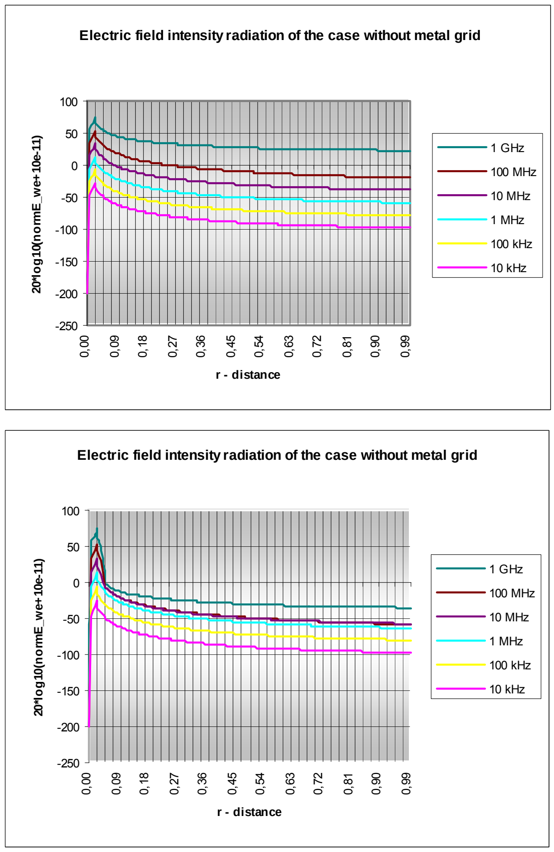

Fig.8. Electric field intensity radiation of display model with metal grid and without it.

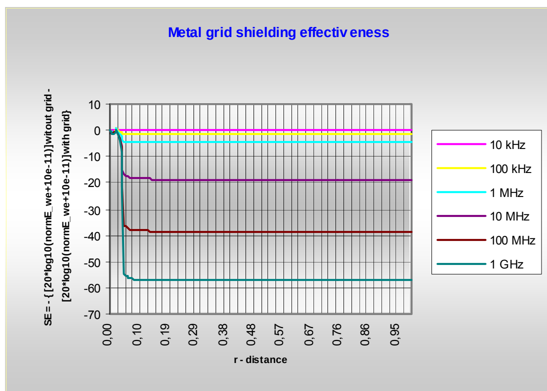

Fig. 9. Metal grid shielding effectiveness