Simulation of metallic enclosures with apertures on Electrical Shielding Effectiveness

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Abstract

Electromagnetic shielding of metallic enclosures with an aperture is simulated by means of COMSOL in this paper. The effect of the polarization type, the thickness of material and material type on electrical shielding effectiveness has been investigated to give suggestions to enclosure designers to get better performance against to EMI. It is obtained that locating rectangular aperture in vertical position with respect to the direction of source results in better electrical shielding performance. Performance of an enclosure whose thickness is about a skin depth is 6dB worse than the enclosure whose thickness is in the order of five times skin depth. As expected, higher conducting materials need to be preferred rather than poor one. Silver, aluminum, cupper and chrome are in the order of better to worst.

1. Introduction

Shielding generally shows a metallic coating and covers all or part of the electronic device. This process is done for two purposes: First is to prevent the radiation coming out of the electronic device or the entrance of an external radiation into the device. Second is to prevent interference. Shielding is aimed at reducing the sensitivity of electronic devices sensitive to external signals, such as high-power radars or receivers and transmitters of wireless communication devices. Therefore, the conceptually the shielding can be defined as an obstacle against the passage of electromagnetic fields [1].

During the design of most electronics systems, metallic shielding enclosures are generally used to reduce radiation from external electromagnetic fields and exudation effects from interior devices. The general definition of the electrical shielding effectiveness (ESE) according to the IEEE Standard 299 (IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures) [2] is generally used to determine the efficiency of a shield. Electrical shielding effectiveness (ESE) can be identified in Eq. (1). E_a and E_p are the electric field strengths with absence and presence of an enclosure, respectively

$$ESE = 20\log\frac{E_a}{E_p} \quad \text{[dB]} \qquad (1)$$

Robinson et. all [3] claimed an analytical formulation based on a transmission line model, where the rectangular enclosure and the aperture are modelled by a short-circuit rectangular waveguide and a coplanar strip transmission line, respectively. There are also a number of numeric methods to calculate ESE of enclosures with complex apertures: Finite difference time domain (FDTD) [4], Transmission line matrix (TLM) [5] and Moment of method (MoM) [6]; however, they lead to high memory usage and high CPU time on the computer. For example, MoM technique requires tens of seconds for running per each frequency point on computers having high speed (3-4GHz) and high capacity. Therefore, it takes 3 to 4 hours to produce data containing nearly one thousand frequency points. Also different transformation codes on numerical methods take more time to get data.

In this study, COMSOL Multiphysics® which is the commercial simulation that used Finite Element Time Domain (FETD) or Time Domain Finite Element Method (TDFEM) combines the advantages of a time-domain technique with the versatile spatial discretization options of the finite element method has been used [7]. Aperture size [8] and some parameters of shielding [9, 10] have already investigated before. Unlike these studies, three different parameters have been investigated: The effect of polarization type, the thickness of enclosure material and the material type of enclosure on ESE have been analyzed and investigated in detail to get more useful suggestions to designers in conclusion.

Aim of this paper is, by using this simulation model to analyze parameters that effect ESE in detail and to give suggest device producers to get better performance against to EMI.

Paper is organized as follows: Section 2 gives simulation set up and it includes the analysis of simulation results of ESE versus frequency and section 3 contains conclusion of results which have been investigated in Section 3 and future work.

2. Simulation and Test Set Up

A metallic enclosure having size of 160 x 160 x 800mm with a single aperture size of 300 x 18.75mm was preferred on Fig. 1. The receiver probe was at the center of enclosure which was 80mm distance to aperture. The incident angle was zero ($\theta = 0°$) due to the normal incident plane wave and the angle of polarization was 90° ($\alpha = 0°$). The COMSOL settings used in all simulations: The technique is FETD in time-domain. The version is COMSOL 4.4, the number of mesh cells is between 934 700 and 953 600, the mesh shape is tetrahedral; the maximum mesh length is λ_{min} /15. The computing time is between 26 and 31mins for simulations. It should be noted that all simulations are carried out on a personal computer using an

Intel Core i7 2.60GHz processor with 16GB RAM and 256GB SSD.

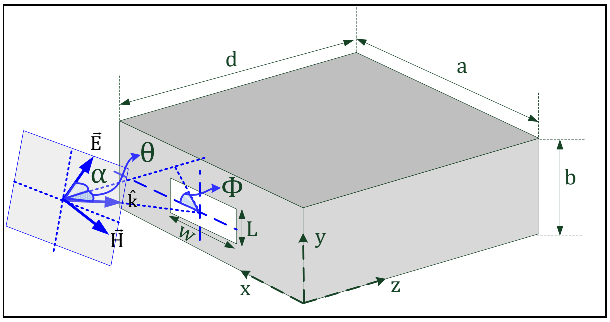

Fig. 1. The location of plane wave and its parameters: Perpendicular polarization of TE mode means the angle of polarization (α = 90°) (the angle between electric field and travelling wave direction z-axis), the incident angle θ = 0° (the angle between traveling wave k and z-axis) and other incident angle (Φ = 90°) (the angle from positive x-axis on x-y plane up to 360°).

2.1 Effect of polarization type

A metallic enclosure having size of 160 x 160 x 800mm with a single aperture size of 37.5 x 150mm was preferred and the material of enclosure was aluminum with 2mm thickness. The receiver probe was at the center of enclosure which was 80mm distance to aperture. The effect of polarization type on ESE has been calculated as seen on Fig. 2. For vertical, circular, elliptic and parallel polarizations ESE is 54.18, 52.06, 45.38 and 40.54dB, respectively. ESE is the highest with vertical polarization and is the lowest with parallel polarization due to the effect of aperture shape as discussed in Section 3.1. The amplitude of incident electric field with vertical polarization overlaps with aperture height (h = 37.5mm) and the amplitude of incident electric field with parallel polarization overlaps with aperture length (h = 150mm) in this case. As a result, ESE changes with polarization of plane wave and the direction of electric field according to the aperture shape. In this situation it is aperture width because the aperture shape of enclosure is rectangular.

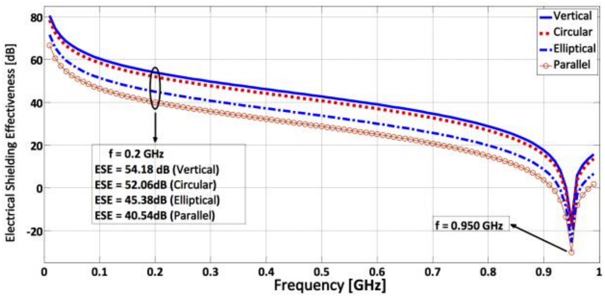

Fig. 2. The effect of polarization type on ESE versus frequency

2.2 Effect of thickness of enclosure material

A metallic enclosure having size of 160 x 160 x 800mm with a single aperture size of 300 x 18.75mm was preferred and the material of enclosure was aluminum with different thickness. The receiver probe was at the centre of enclosure which was 80mm distance to aperture. The effect of thickness of enclosure material has been calculated as seen on Fig. 3. In this case other shielding parameters are fixed and only thickness of enclosure material t has been changed as 5mm, 3mm, 1mm, 1μmm, 1nmm. ESE is highest value 48.844dB with 5mm thickness of material. So, ESE has decreased with increased thickness of material. The reason of this result can be explain with skin depth. The distance the wave must travel in a lossy medium to reduce its value to e-1 = 0.368 = %36.8 is defined as the skin depth δ and for good conductors can be identified with Eq. 2 [11].

$$\delta \cong \sqrt{\frac{2}{\omega\mu\varepsilon}} \qquad [\text{m}] \qquad (2)$$

Here, ω is angular frequency, ε is dielectric constant and μ is electrical permeability. As a result ESE decreases with decreased thickness of enclosure material.

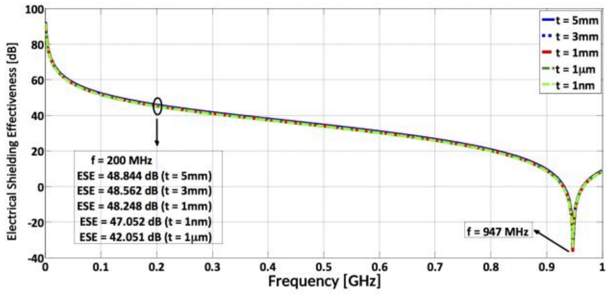

Fig. 3. The effect of thickness of enclosure on ESE versus frequency

2.3 Effect of material type

A metallic enclosure having size of 160 x 160 x 800mm with a single aperture size of 300 x 18.75mm was preferred and the material of enclosure was different material with 2mm thickness. The receiver probe was at the centre of enclosure which was 80mm distance to aperture. Effect of material type has been calculated in Fig. 4. For, silver, copper, aluminum and chrome ESE decreases, respectively due to the decreased conductivity σ_s of these materials. This can be explained with Eq. 3 [11].

$$\vec{J} = \sigma_s \vec{E} \qquad [\text{A/m}^2] \qquad (3)$$

Here, $\boldsymbol{J}$ is the convection current density, σ_s is a parameter that characterizes the free-electron conductive properties of a conductor, $\boldsymbol{E}$ is the electrical field intensity. While the σ_s decrease, electrical field intensity increases. So, ESE becomes worse with increased amplitude of electric field.

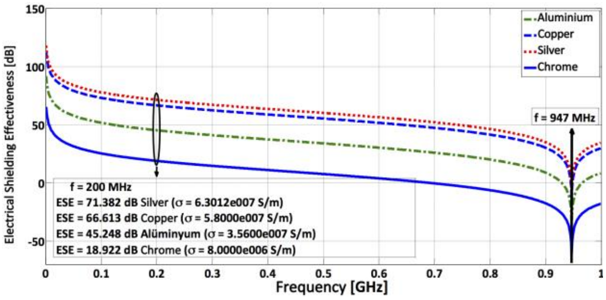

Fig. 4. The effect of material on ESE versus frequency

3. Conclusions

In computer enclosures there are many parameters to be effected by airing, I/0 connections and other purposes. This paper provides insight about effect of some shielding parameter on ESE.

In this paper by using COMSOL simulation model the effect of some parameters on ESE has been investigated to give suggestions enclosure designers to get better performance against to EMI. These shielding parameters are: the effect of the polarization type, the thickness of material and material type.

While some of the usual assumptions were confirmed, some important new observations were also made. We give observations as the following:

1. ESE changes with polarization of plane wave and the direction of electric field with respect to aperture (width) dimensioning. It can be offered that locating rectangular aperture in vertical position with respect to to direction of source is preferred to obtain higher ESE performance.
2. We may also conclude that thicker enclosure itself is not enough it is about the skin depth. Performance of an enclosure whose thickness is about a skin depth is 6dB worse than the enclosure whose thickness is in the order of five times skin depth. That's why thickness of an enclosure must be a couple of skin depth (~ $5x\delta$) need to be chosen as an enclosure depth.
3. As expected, higher conducting materials need to be preferred rather than poor one, and silver, aluminum, copper and chrome are in the order of better to worst.

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