Wall Thickness Effect on Shielding Effectiveness of Metallic Enclosure with Apertures

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Abstract

This paper presents a brief study of wall thickness effects on the shielding properties of metallic enclosures with apertures. An approximate model is proposed in Electric Field Integral Equation (EFIE) solution by method of moments (MoM) to calculate the coupled waves inside the cavity. As shown, considering wall thickness in our calculation leads to more accurate results. We also characterize the thickness effects on shielding properties of an enclosure with an array of slots. The model is compared with the measurements performed in an anechoic chamber and also with the results from a commercially available code (FEKO).

1. Introduction

Metallic shielding is one of the major techniques to protect modern electronic equipments from electromagnetic waves interferences. The ability of a shielding enclosure is usually characterized by its shielding effectiveness (SE), defined as the ratio of the field strength in the presence and the absence of the enclosure at an observation point.

Various analytical and numerical techniques have been proposed to evaluate SE of metallic enclosures. Analytical methods are accurate but can be applied only to very simple geometries with approximations. The analytical theory which characterized shielding properties of metallic enclosures was first developed by Mendez [1] where the aperture is replaced by equivalent electric and magnetic dipoles radiating in free space. In [2] and [3], MoM is used to solve Electric Field Integral Equation (EFIE) and therefore calculating the scattered field inside the enclosure.

In most of the mentioned methods, the perforated wall thickness is ignored to simplify the analysis and the calculation. In few numerical analysis such as mode matching [4] and FDTD [5], the wall thickness is taken into account. The robustness of the FDTD techniques is severely limited by the size of the apertures and its thickness relative to the cavity's dimensions. The convergence of mode matching technique is also very sensitive to the number of modes at each region.

Here, we propose an approximate model to include wall thickness in a MoM solution of scattered field calculation from an enclosure with aperture. To this end, only the interior surfaces of the enclosure and the aperture are discretized. A very good agreement is observed between the results of this technique and experimental data for enclosures with single or multiple apertures. It is verified that the effect of wall thickness can not be ignored in SE evaluation of the enclosures. For the considered enclosures and indicated frequency range, SE is improved for thicker walls. It seems that in thick wall enclosures, the aperture acts as a waveguide that attenuates the interfering waves at the frequencies below its cut-off frequency which improves the SE. The method is also reliable for the frequencies higher than cavity's first resonance frequency.

2. Formulation

In our simulations, we consider a rectangular metallic enclosure with interior dimensions of $a \times b \times c$ and wall thickness of d , as illustrated in Fig. 1. An array of rectangular aperture with length L_r and width W_r is located on the cavity's surface.

The EFIE is solved numerically in order to estimate the coupled wave at any point inside the enclosure which is exposed to an incident plane wave (as Fig. 1). The field values calculated by EFIE for non-completely enclosed scatterers like aperture perforated cavities are correct even at the resonance frequencies [2].

Assume $\vec{E}^{i}$ is the incident field and $\vec{E}^{S}$ is the scattered field described as

$$\vec{E}^{S} = -j\omega\vec{A} - \nabla\phi \tag{1}$$

Where, $\vec{A}$ and ϕ are the magnetic vector and electric scalar potentials, as defined in [6]. The continuity of the tangential component of total electric field at any point on the descritized metallic surface of the structure provides the well-known EFIE:

$$-\vec{E}_{\tan}{}^{i} = \left(-j\omega\vec{A} - \nabla\phi\right)_{\tan}. \tag{2}$$

We solved (2) with the aid of the method of moments and the well-known Rao-Wilton-Glisson (RWG) basis functions for the unknown surface currents [7]. Detailed study on code implementation of MoM solution of EFIE is presented in [8] which results in an accurate SE estimation over wide range of frequency. Problem discretization is completed by generating triangular meshes on the interior surfaces of the enclosure. Then, in order to include the wall thickness the inside surfaces of the aperture is also added to discretized region, (Fig. 2). Using the model, there is no need to generate meshes on external surface of the enclosure and therefore the technique has better efficiency compared with Combined Field Integral Equation (CFIE) solution (a general solution for the completely enclosed metallic structures) which needs all internal and external surfaces to be discretized.

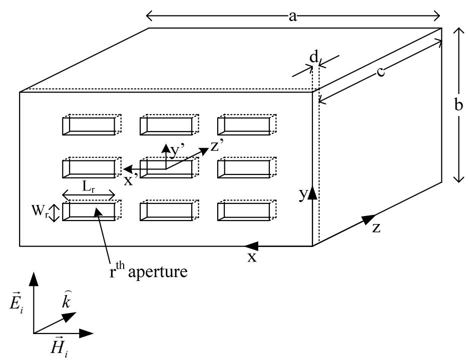

Fig. 1 Geometry of the problem

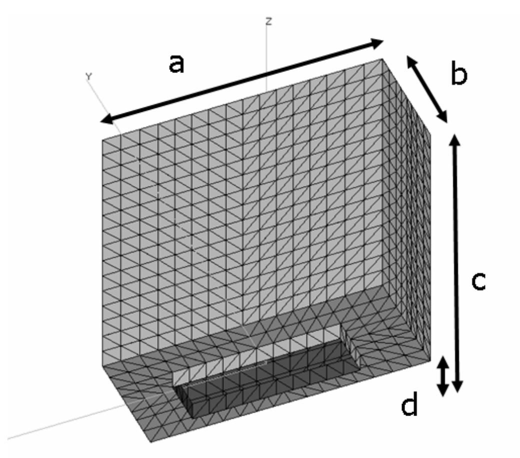

Fig. 2 A view of metallic enclosure with wall thickness mode

4. Analysis Validation

As a first case, a front panel with a rectangular aperture of $18 \times 5\,cm$ and wall thickness of $d = 0.4\ cm$ located at the center is considered. Fig. 3 compares the SE_y (SE calculated for y component of the electric field) resulted from our model, MoM solution for zero thickness, our measurement and also FEKO (see [9]).

As can be seen, there is a good agreement between measurements and the results from present model. As observed, considering the wall thickness in our model leads to more accurate results compared to zero thickness MoM solution. For further validation, we replace the front panel with a plate of $d = 1\,cm$ thickness consisted of an array of four rectangular apertures of $6 \times 2\,cm$, equally spaced as shown in Fig. 4. Results from the present model, MoM with zero thickness, measurement and also FEKO are shown in Fig.5.

As can be seen the improvement in SE estimation in some frequencies is even more than 10 dB. Simulations are performed for frequencies between 10-1200 MHz where the measurements are conducted for frequencies above 500 MHz. As shown, there is an increase in SE of the enclosure due to the wall thickness.

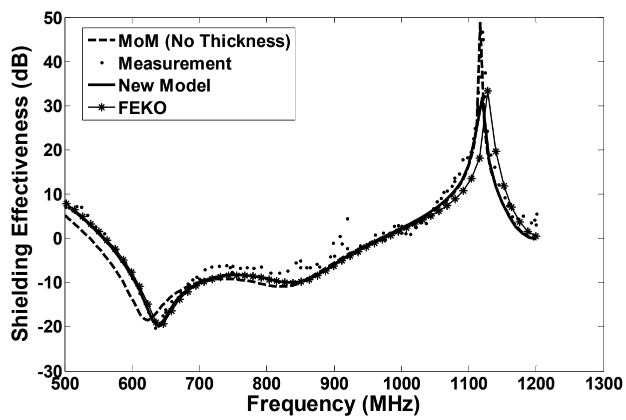

Fig. 3 SE_y comparison of an $(30 \times 12 \times 30)$ enclosure with a rectangular aperture of $L = 18$ *and* $W = 5\,cm$ and wall thickness of $d = 0.4\,cm$

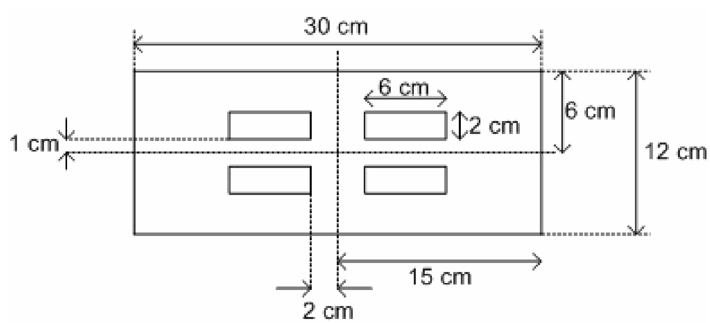

Fig. 4 Perforated array in the front panel of a $30 \times 12 \times 30\,cm$ enclosure.

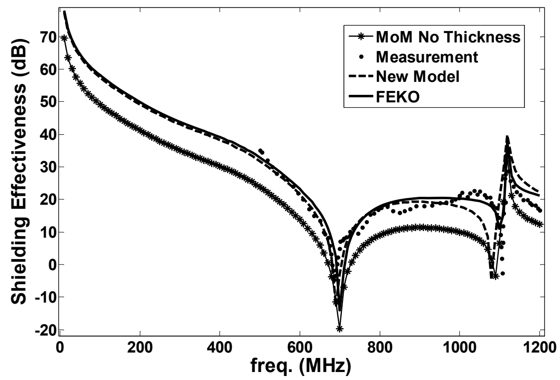

Fig. 5 SE_y comparison of a $(30 \times 12 \times 30)$ enclosure with apertures of Fig. 4 and wall thickness $d = 1\,cm$

5. Conclusion

In this paper, we propose an approximate model for SE calculation of a metallic enclosure with aperture where the wall thickness of the enclosure is also considered. The model has the advantage of less unknowns compared with CFIE solution where both inside and outside of the enclosure need to be discretized. It is observed that including wall thickness in SE estimations gives more accurate results. As shown, there is an improvement in SE as the thickness is increased especially in frequency ranges lower that aperture's cut off frequency. The model is validated by results from measurements in an anechoic chamber and also a commercial CAD.

7. References

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