Abnormal Phenomenon on Shielding Effectiveness of Metallic Enclosures with One Aperture at Normal and Oblique incidences

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Abstract

Abnormal phenomenon on shielding effectiveness (SE) of metallic enclosures with one rectangular aperture when illuminated by the oblique and normal incidence vertical polarized plane wave has been studied by using MoM and FIT techniques. To the best knowledge of authors, the similar phenomenon and analysis for it has not been investigated. The work shown that the usual assumption about the normal incidence being the worst-case scenario for shielding effectiveness values may not be valid when there is even only one aperture in the cavity. In addition, the SE of normal incidence is perfectly able to exceeds that of oblique incidence. The paper emphasizes the extension of the existing cognition of shielding effectiveness problem of metallic enclosures with apertures about oblique and normal incidence.

1. Introduction

Metallic enclosures are employed to protect against radiation from both external interference and electromagnetic leakage from electronic devices, and hence meet the electromagnetic compatibility (EMC) requirements. However, the integrity of these enclosures is often compromised by all kinds of apertures that interconnect various components, subassemblies, equipment, and subsystems. Such openings provide exterior electric and magnetic fields to penetrate into the interior space, where they may further couple in printed circuit boards (PCBs) thus inducing currents and voltages on interior conductors [1–2]. Therefore, it is very important and necessary to know the electromagnetic (EM) shielding effectiveness of metallic enclosures in the presence of these apertures at all kinds of incidence.

Generally, the normal incidence is considered to be the worse-case scenario of shielding effectiveness. Therefore, most researchers usually only consider the normal incidence in their studies. Unfortunately, however, only a few unusual results in recent years have been uncovered. Among them, Zulfiqar Ali Khan， Charles F. Bunting and Manohar D. Deshpande notified earlier that the most common assumption of maximum field penetration for normal incidence is not always valid for four rectangular apertures on cavity by Modal/MoM [3]. And they have concluded: “The most common assumption of maximum field penetration for normal incidence is valid only for a single aperture on cavity” [3]. Beyond that, to the author's knowledge, there is little information available in literature about such phenomenon on shielding effectiveness of metallic enclosures at normal and oblique incidences, especially for the enclosures with one aperture. Even in [3], their studies may be more reasonable if they had considered this situation that the SE of oblique incidence is not always more than that at normal incidence.

In this paper, for a rectangle enclosure with a centered rectangle aperture, it is found an abnormal phenomenon

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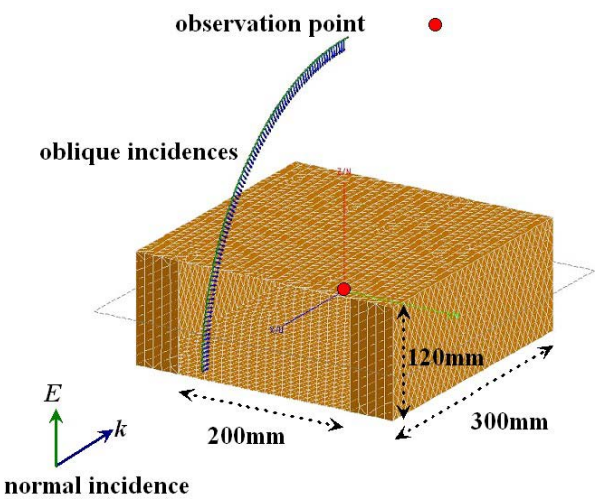
that shielding effectiveness of oblique incidence are less than those of normal incidence in certain condition. It can be regarded as an extension of the conclusion of Charles F. Bunting's team. In the meanwhile, the surface current on the enclosure of that scenario has been discovered. Additionally, we obtained comparison between them in a wide band (0-8GHz) by time domain method (FIT, finite integration technology) and Fast Fourier transform (FFT). From the results, we will find that while the frequency is varied, the difference between both SE of scenarios changed accordingly. Finally, a qualitative analysis of the phenomenon is presented to explain it in virtue of idea of multiple reflection.

2. Phenomenon

In our study, the metallic enclosures with one aperture (200mm×120mm) at normal and oblique incidences, is shown in Fig. 1. In this paper, the main calculated variable, SE is the electric field shielding effectiveness.

In Fig. 2, we show the calculations for that enclosure based on the MoM at 3GHz (vertical polarization, VV). Obviously, we can see that as the elevation angle increases, the SE at the center of enclosure does not exhibit linear character, but the character of quasi-parabola. Accordingly the minimum of SE is discovered at 56° with 5.4dB's difference between it with that of 90°. The phenomenon represents that SE of metallic enclosures with one aperture at oblique incidence (O) is not always greater than that of normal incidence (N), namely N can greater than O. Moreover, it means that more EM wave penetrate into the enclosures at O, which may change the traditional view.



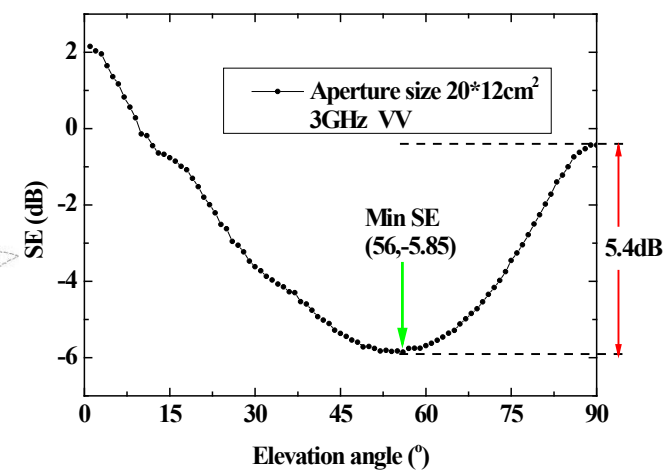


Fig. 1. Rectangular enclosure with a large aperture. Fig. 2. Calculated SE at the center of the enclosure with 200×120mm aperture by MoM at 3GHz.

3. Discussion and Analysis

In order to study the generation of external abnormal field, the distributions of surface current at 3GHz (elevation angle 56° and 90°) are presented in Fig. 3 and Fig. 4 respectively. On the whole, from these pictures, we can find that surface current of 56° is greater than that of 90°, while the two distribution maps of surface current are similar. This indicates that more external field may come from more surface current on the enclosure. To throw further light on this phenomenon, we calculated the SE from about DC to about 8GHz by FIT. From the Fig. 5, we can see that there are not a few times of N > O in this wide frequency band. However, the first time may be at 3GHz. In the meanwhile, Fig. 6 shows the local enlarged image of Fig. 5. From this picture, there is a clear difference at about 3GHz between the curves of normal and oblique incidences. Therefore, this

phenomenon is considered to be verified by different numerical method. Thus, the usual assumption about the normal incidence being the worst-case scenario for shielding effectiveness values may not be valid when there is even only one aperture in the cavity. Combined the view of Charles F. Bunting's team, we hold the opinion that no matter the single aperture or multiple apertures, the normal incidence is not always the worst-case scenario for SE.

In addition, with the increase of frequency, it seems to happen more often. Therefore, it is automatically associated with ray theory for understanding the phenomenon. Fig. 7 shows the sketch of the typical route of incident and reflected waves inside the enclosure with elevation angle 56 ^{o}. In the view of ray, incident ray (wave) will incident on the walls of the enclosure by multiple reflection, then radiate in the term of scattering ray (wave). So, zone 1 and zone 2 (all in the Fig. 7) apart, the SE of all other zone may occur that phenomenon. In the meanwhile, larger aperture also facilitates more rays run into the enclosure.

Finally, some important new observations were also made. We give our observations as the following.

1. The most common assumption of maximum field penetration for normal incidence is not always valid even only for a single aperture on cavity.

2. This phenomenon may be conceived as the results of multiple reflection of incident ray (wave) in the enclosure.

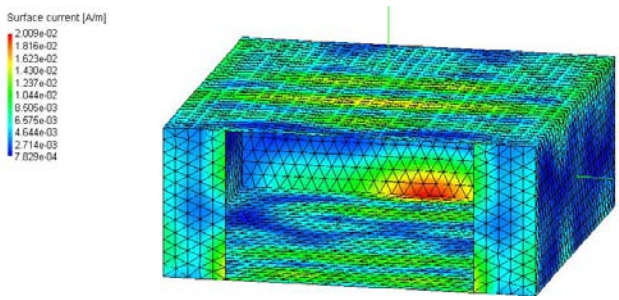


Fig. 3. Calculated distribution map of surface current at current at 3GHz (elevation angle 56°).

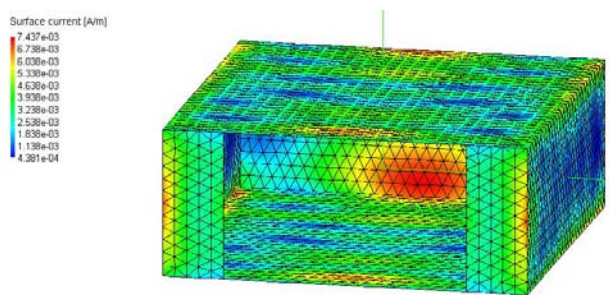


Fig. 4. Calculated distribution map of surface 3GHz (elevation angle 90°).

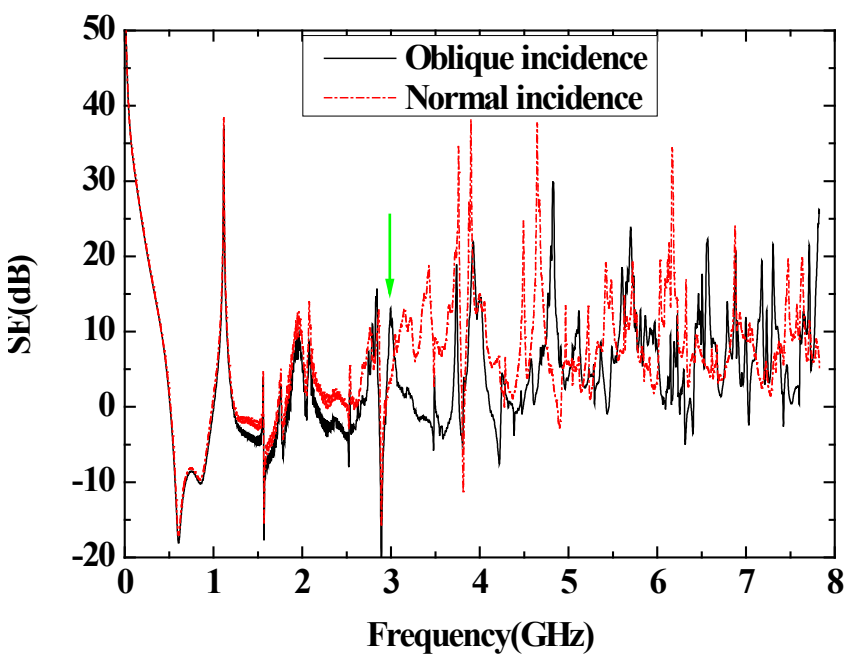
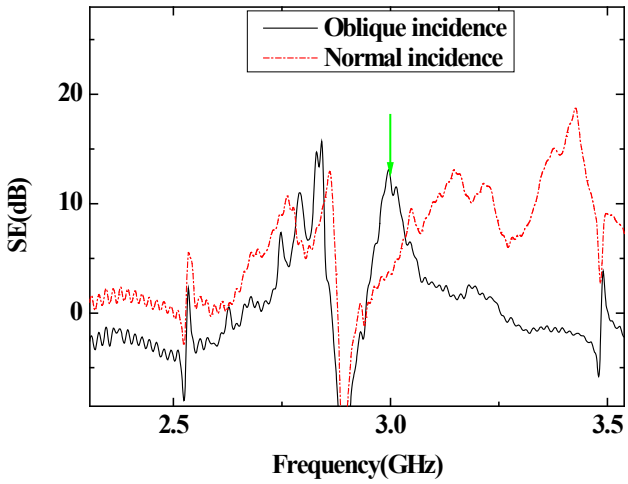


Fig. 5. Calculated SE at the center of the enclosure with 200*120mm aperture by FIT from about 0～8GHz.



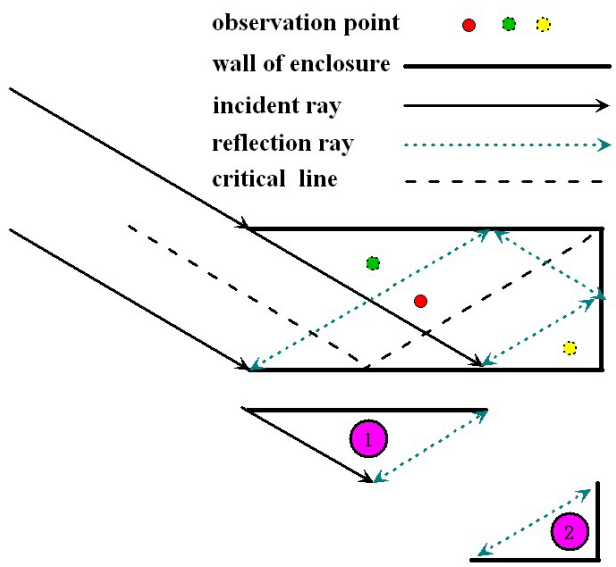


Fig. 6. Local enlarged image of Fig. 5.

Fig. 7. Sketch of the typical route of incident and reflected waves inside the enclosure with elevation angle 56 ^{o}.

4. Conclusion

We presented in this paper an abnormal phenomenon of comparison between shielding effectiveness of metallic enclosures with one aperture at normal and oblique incidences. Our simulation results shown that this abnormal phenomenon does not simply come about by chance. In our view, it may be occasioned by higher frequency (>3GHz) and larger aperture. Finally, we have used the idea invokes ray and multiple reflection to qualitatively explain this phenomenon.

The value of this study is that it may change our traditional view about studying shielding effectiveness. Thus, researchers should not only consider study the case of normal incidence, sometimes but also consider study that of oblique incidence.

It is important to note that this abnormal phenomenon has to be fortified by experimental evidence. Therefore, future work to be performed will include an experimental study of it.

5. Acknowledgments

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6. References

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