Investigation of Shielding Effectiveness Caused by Incident Plane Wave on Conductive Enclosure in UHF Band

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***Abstract*— 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. Shielding an electromagnetic field is a complex and sometimes formidable task. The reasons are many, since the effectiveness of any strategy or technique aimed at the reduction of the electromagnetic field levels in a prescribed region depends largely upon the source(s) characteristics, the shield topology, and materials. In this paper, the effect of an incident plane wave with linear polarization on aluminum shield in UHF frequency is investigated, then, the type of shield material is changed and shielding effectiveness caused by it is investigated. Also, the linear polarization of incident wave is converted to circular polarization and shielding effectiveness variation is obtained in this stage. Slots and apertures are very important parameters to determine suitable shielding effectiveness. In following paper, slot is placed on shield, and its shielding effectiveness is evaluated. The effects of slot width variation, slot length variation and slot displacement, on shielding effectiveness are investigated. Finally, the effect of different aperture structure is evaluated and shielding factor is obtained in any stage. The whole of simulations in this paper, are done with CADFEKO.**

Keywords- incident wave; shield enclosure; shielding effectiveness; slot; aperture

I. INTRODUCTION

Recently, the usage of electrical and electronic devices has grown rapidly. Many devices such as AC motors, digital computers, calculators, point of sale terminals, printers, modems, transmission line, electronic home appliance and cellular phones are capable to emit electromagnetic wave that will result in some electromagnetic interference (EMI) problems[1].Electromagnetic waves consist of two oscillating fields at right angles (Fig. 1). 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 [2].One of ways to limit the penetration electromagnetic fields into systems is shielding.

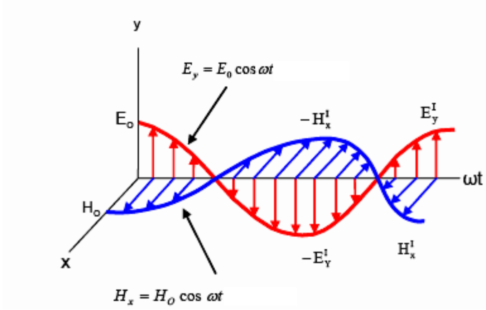


Figure 1. Electromagnetic plane polarized waveform[2]

Electromagnetic shielding is the process of limiting the penetration of electromagnetic fields into a space, by blocking them with a barrier made of conductive material. Typically it is applied to enclosures, separating electrical devices from the 'outside world', and to cables, separating wires from the environment the cable runs through. The shape of the shield is in many cases restricted by practical limitations, and only partial shielding may be possible to use. In electromagnetic, shielding effectiveness (SE) is a concise parameter generally applied to quantify shielding performance [3]?

In present paper, the effect of various parameters on electromagnetic shielding effectiveness is studied in UHF band. A plane wave is radiated to aluminum shield and shielding effectiveness is evaluated. Also, the shielding factor for slotted shield and aperture shield is investigated. The effects of polarization variation, slot displacement on shield and slot width changing are evaluated and the interesting results are achieved. Finally, different aperture structures are placed on shield and their corresponding shielding effectiveness is determined.

II. SIMULATION STRUCTURE

Electromagnetic pulses are fields of energy that they can damage electrical and electronic circuits at once. New technology of microelectronic circuits is sensitive to interference power. An intentional or inadvertent risk and unforeseen create irreparable damages, so that it is important to investigate electromagnetic interference from viewpoint: generation source, the effectiveness on electronic components and safekeeping methods [4].

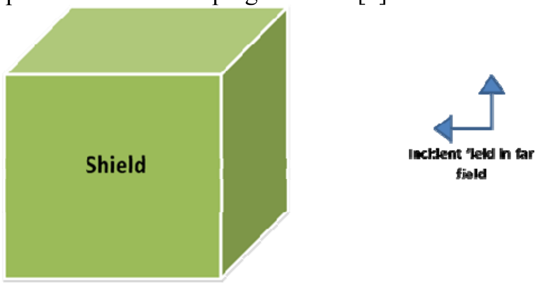
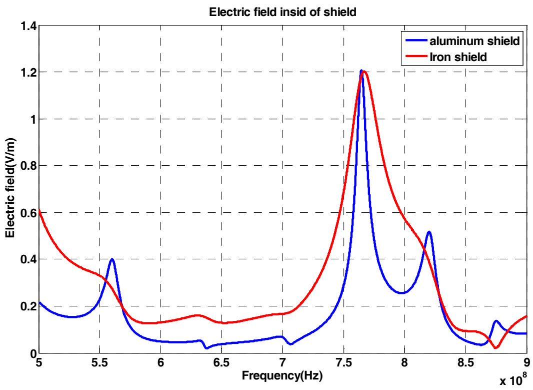


Figure 2. The radiation of a plane wave on shield

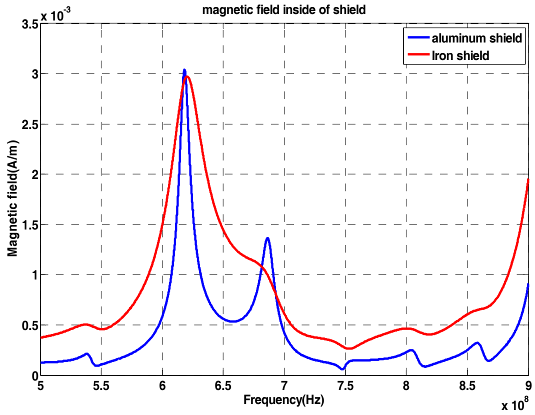
In the case of industrial applications, electromagnetic shielding materials are used to exclude the unwanted electromagnetic radiation or interference signals and shield operates as barrier against the interference. Selected shield structure is a cubic shield. The dimension of shield is 1m×1m×1m. Shield material is selected aluminum. A plane wave with linear polarization is radiated to shield. The incident wave has the below characteristics:

$$|E| = 1\ \mathrm{V/m},\ |H| = 1\ \mathrm{A/m}$$

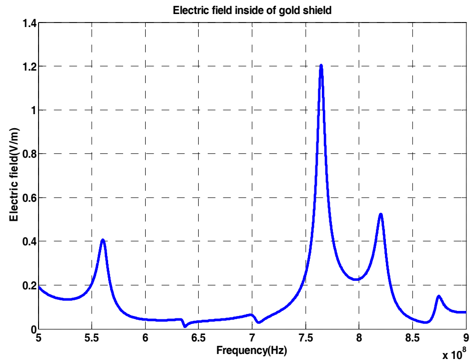
The simulation structure is shown as Fig.2. The electric field is radiated to shield vertically and magnetic field vector and shield are parallel. The penetrated field inside of shield is shown as Fig.3. Here, the penetration field inside of shield is equal to shielding effectiveness. In following, shield material is exchanged to: gold, copper, silver, Iron.



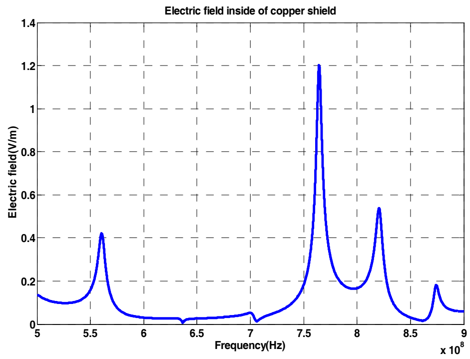
(a) Electric field



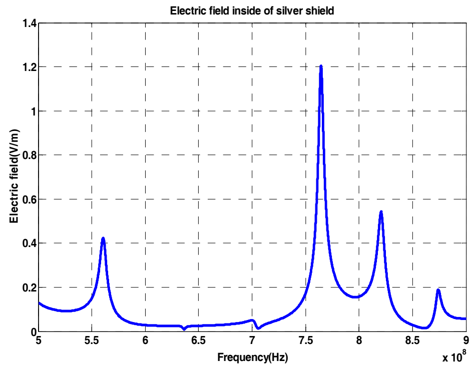
(b) Magnetic field



(a) Gold



(b)Copper



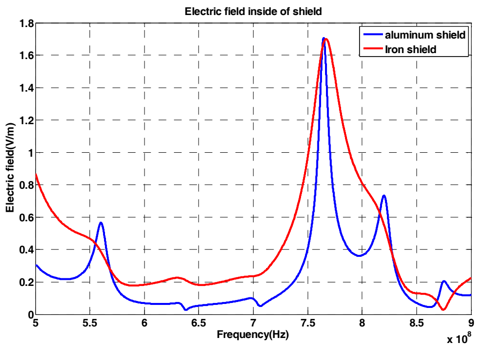
(c) Silver

Figure 3. The penetrated electric field inside of various shields

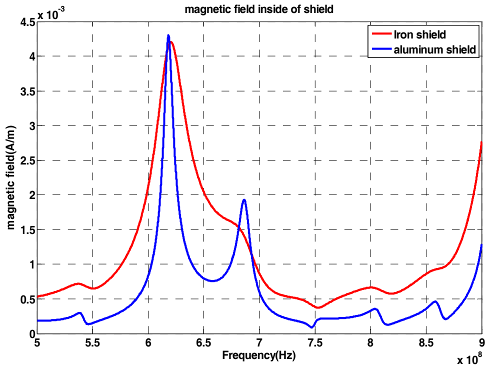
As seen, penetrated field is increased in iron shield; therefore, shielding effectiveness is reduced. Since, iron metal has high relative permeability, reflection loss is decreased. Also, absorption loss is increased. Reflection loss is commensurate to $(1/\mu_r)$ and absorption loss is corresponding with $(\sqrt{\mu_r})$. Growth factor $(1/\mu_r)$ is quicker than growth factor $\sqrt{\mu_r}$. consequently; Reflection loss is dominant parameter to determine shielding effectiveness in thin shields [5]. Finally, shielding effectiveness is reduced. Note that shielding effectiveness will be a positive result, since the incident field is expected to be greater than the field that exits the shields. But it is shown in fig.3; the penetrated field is greater than incident field in (760 MHz). This frequency is resonant frequency that related to shield configuration. In following paper, the polarization of plane wave is changed to circular polarization. The effect of polarization variation is shown in fig.4. A plane wave with circular polarization is caused by shielding effectiveness reduction. Since, the plane wave with circular polarization generates vertical and horizontal components on shield surface and these components create a lot of penetrated fields and consecutively, shielding effectiveness is decreased.

III. EFFECT OF SLOTS AND APERTURES ON SHIELD

The efficiency of enclosures is often compromised by slots and apertures located on the walls of the enclosure; such apertures may be intentional (e.g., necessary for ventilation purposes or access to interior equipments) or not (e.g., cracks around plates covering access ports) [6]. At first, slot is placed on enclosure. The dimension of slot is supposed 20cm×0.5cm. It is shown in fig.5. The incident wave is radiated to slot vertically.



(a) Electric field in aluminum shield



(b) Magnetic field in aluminum shield

Figure 4. The effect of wave polarization variation on shield

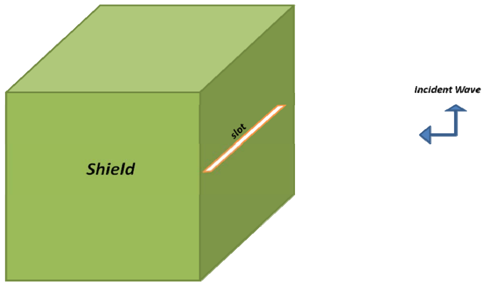
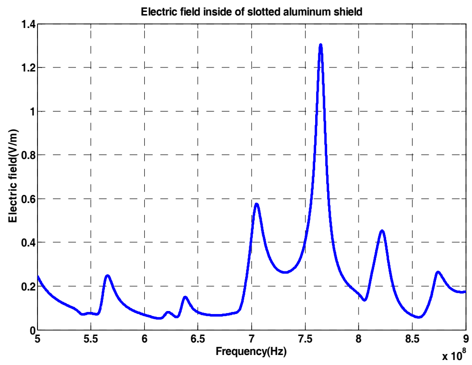
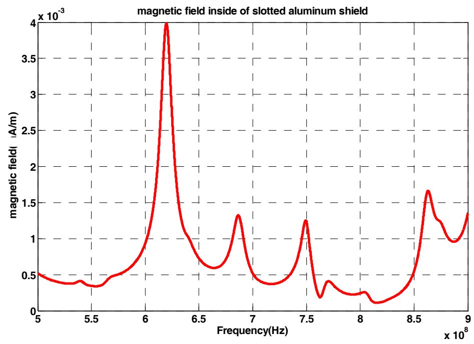


Figure 5. Slotted shield



(a)Electric field in aluminum shield

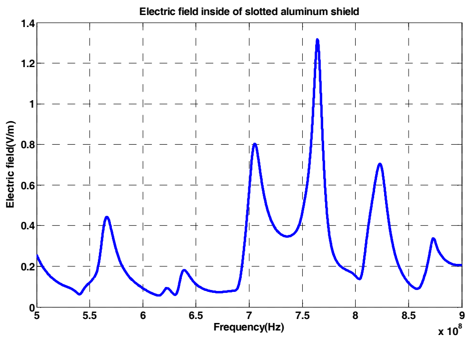


(b) Magnetic field in aluminum shield

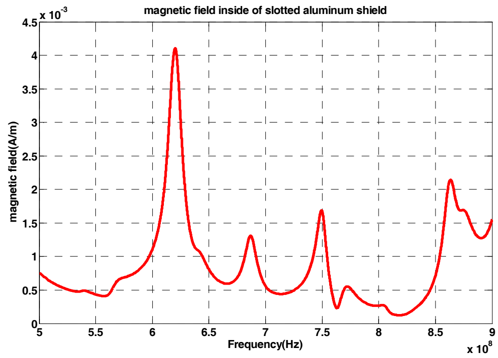
Figure 6. The penetrated fields at frequency caused by slotted shield

The shielding effectiveness is reduced with slot creation. Because of field components are arrived to shield enclosure by slot. The penetrated electric fields at frequency are shown in fig.6. In following paper, slot width and slot length is increased and the shielding effectiveness caused by them is evaluated. In this stage, the dimension of slot is changed to 20cm×2cm. As seen in fig.7, shielding effectiveness is reduced with width increasing and a lot of fields are penetrated by slot. For example, these variations are seen in frequencies (570MHz, 770MHz).

Now, slot length is increased and it is changed to 40cm×0.5cm. As it is shown in fig.8, in this state, the penetrated fields had a lot of peaks in some of frequency in respect of the previous state. Consequently, shielding effectiveness is decreased.

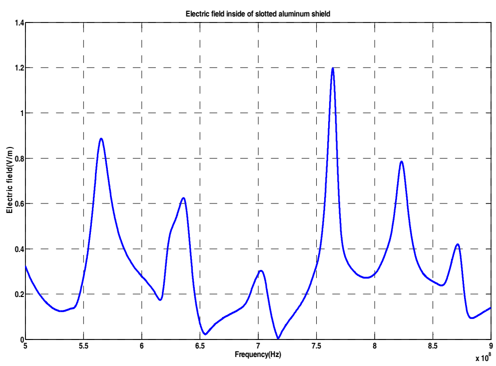


(a)Electric field in aluminum shield

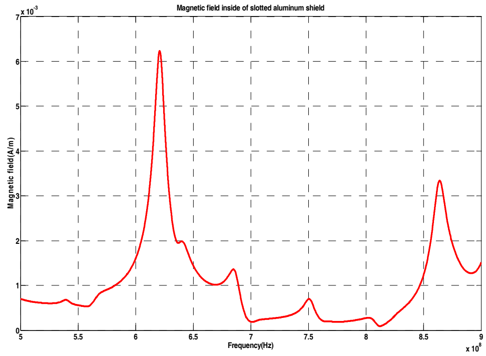


(b) Magnetic field in aluminum shield

Figure 7. The effect of slot width icreasing



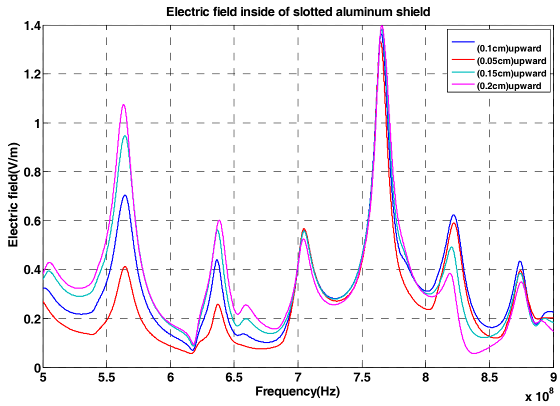
(a)electric field in aluminum shield



(b) Magnetic field in aluminum shield

Figure 8. The effect of slot length increasing

Next, slot is displaced from surface center to upside edge of surface on shield and shielding effectiveness is evaluated in any stage. The difference between slot center positions in any stage is 0.05 cm and incident wave is radiated to surface center of enclosure vertically. Comparison of figures shows that penetrated field peaks are increased with slot displacement. In generally, incident angle is important to determine shielding effectiveness and it may decrease or increase shielding factor in some of frequency that it depends on incident angle and can optimize its in a special frequency. Penetrated fields caused by slot displacement are shown in fig.9. As seen, the angle between slot and incident wave may increase the number of resonant frequencies.



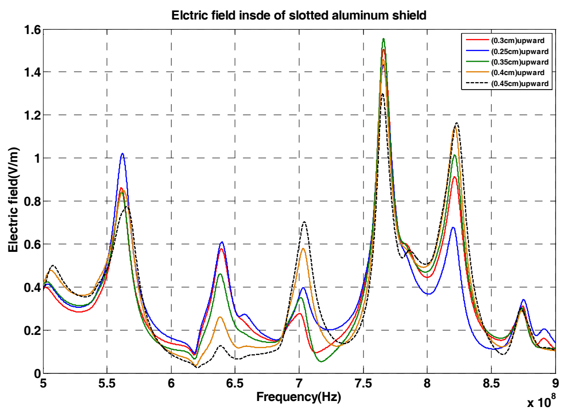


Figure 9. Electric field penetration inside of shield with slot displacment

In following paper, aperture is placed instead of slot on shield surface. The radius of shield is designed to 0.01m. Apertures are very important to determine shielding effectiveness, because they may operate as aperture antenna in high frequencies. Therefore, aperture size and aperture position are important parameters for shielding. Simulation structure is shown in fig.10. Penetrated electric field is shown in fig.11.

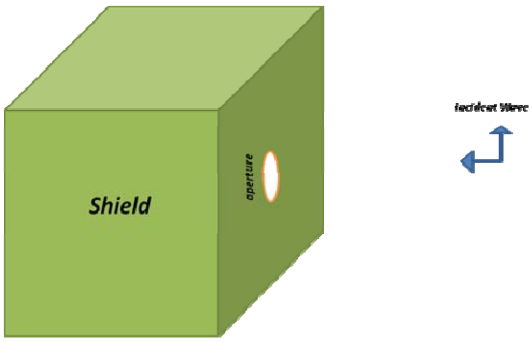
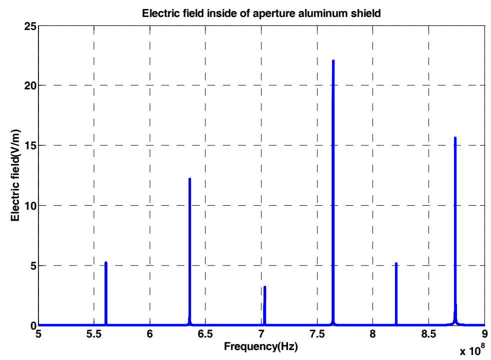
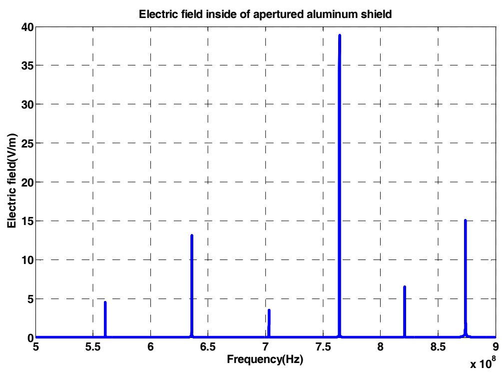


Figure 10. The radiation of a plane wave on aperture shield

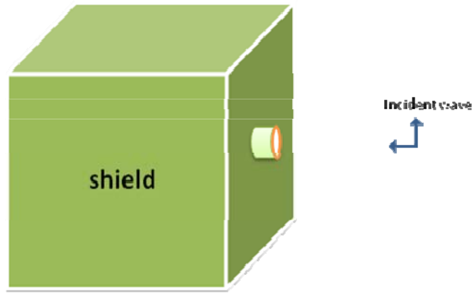


(a) Circular aperture

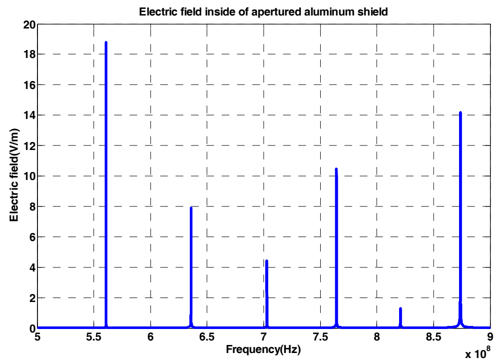


(b) rectangular aperture

Figure 11. Electric field inside of enclosure



(a)



(b)

Figure 12. a) Enclosure with circular aperture (b) Electric field inside of enclosure

As seen, shielding effectiveness is decreased in some of frequencies suddenly. In other words, penetrated electric field is increased in those frequencies. It is resulted that aperture is operated as antenna in those frequencies but in frequencies expect to resonant frequencies, shielding effectiveness is very desirable. It is one of main proofs to use apertures instead of slots for ventilation on the walls of the enclosure. Of course, in aperture design on enclosure, it is necessary to attention aperture size carefully. Since, it may operate as antenna. In following paper, aperture structure is changed to rectangular aperture (2cm×2cm). Rectangular aperture is larger than circular aperture and Electric field inside of shield is increased, so that shielding factor is reduced. Finally, aperture structure is changed to cylindrical structure (h=1cm, r=1cm). Cylindrical aperture operated as cylindrical waveguide and attenuated electric field inside of shield extremely. Since, attenuation coefficient in cylindrical aperture is very high, hence TM and TE modes is decreased in respect of the previous states in enclosure. Consequently, shielding factor is improved. It is shown in fig.12.

IV. CONCLUSION

In this paper, the effect of an incident plane wave with linear polarization on aluminum shield in UHF frequency is evaluated. Also, it is shown, shielding effectiveness is affected from magnetic permeability extremely and shield material is important factor to determine shielding effectiveness. It is prevalent to use materials for shielding in high frequencies that their magnetic permeability is equivalent to 1. As shown, the variation of polarization is effective to increase or decrease shielding factor. Also, it is specified, slots and apertures for ventilation are affected on shielding effectiveness. They are reduced shielding effectiveness, but slot or aperture creation is necessary on shield. In shield design, slot size, slot position and the angle between slot and incident wave is important to determine shielding effectiveness and they should optimize in shield design. Finally, the effect of aperture structure is investigated and the interesting result is obtained that shielding factor is reduced suddenly in shields with aperture structure.

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