Development and Analysis of Metallic Enclosures with Apertures for Improving Shielding Effectiveness

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Abstract— The main concern of any electronic circuit is its design and also its compatibility. Electronic circuits emit electromagnetic radiation. These radiations can interfere with the circuit and also with nearby circuits causing deviations in the design performance of the circuit. To control such type of interferences the compatibility of the conducting materials should be improved. Electromagnetic shielding is needed to protect the electronic components from unwanted signals. Electromagnetic shielding will divert the electromagnetic fields around it and varies in different directions.

To improve the shielding effectiveness we use an accurate and efficient method it will predict the shielding effectiveness with apertures. By varying the frequency in waveguide and width, length, thickness of the materials the efficient materials are predicted for better shielding effectiveness. When the equipment is encapsulated with a proper cases which contains a strong electric bond between segments, these cases provide protection against the radiated emissions or electromagnetic interferences.

Keywords: *Shielding, Electromagnetic interference, Aperture, Conductivity*

I. INTRODUCTION

EMI shielding is mainly used to reducing the magnetic field in free space by providing the barrier to blocking the field .The barrier is made of conductive or magnetic.[9]

A. Electromagnetic Interference

Electromagnetic interference is defined as which causes disturbance in the transmission path. The emission coming from the source produces electromagnetic inferences. The EMI is reduced by removing the unwanted emission by using different techniques

B. Electromagnetic Compatibility

The EMI is reduced by improving the compatibility of device. Electromagnetic compatibility is defined when the system is functioning without any errors caused by electromagnetic interference from the internal components or outside the system. To improve the EMC for any system it requires good conductive shielding for providing better shielding highly conductive material must be taken along with this acceptable thickness also taken into consideration, these highly conductive materials satisfies the electromagnetic compatibility requirements.[2].

C. Shield

Shield is used to partially or completely envelope an electronic circuit so as to protect it from EM radiation from surrounding environment and also to act as a barrier to restrict the emission of EM radiations emitted by circuit itself to the surrounding environment. Shielding effectiveness is measure of amount of shielding provided by the barrier.

D. Why to reduce EMI?

Electromagnetic interference is disturbance caused by undesired electromagnetic waves. In any active transmitting or communication system, electromagnetic interference determines the quality of the device. Engineers have to take EMI into consideration before designing a system because the performance of the device depends on the level of EMI it produces while operating in the noisy environment. In order to fulfil EMC requirement engineers have to follow best practices during the design stages, testing and product implementation.

II. MECHANISM OF SHIELDING

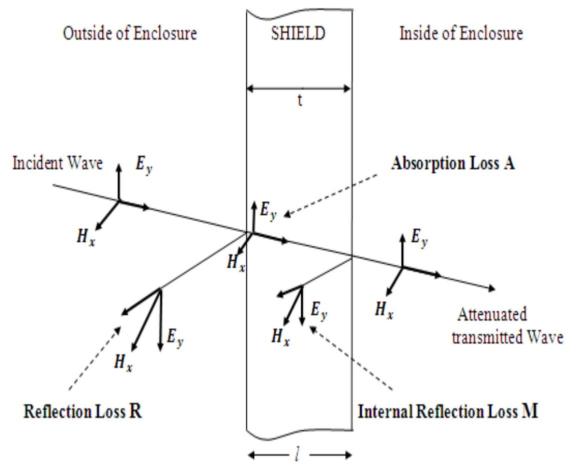

Fig 1: shielding mechanism for EM -Waves

The approach to shielding effectiveness can be persuade by following the main strategy that is interposition of barrier between source and area where EM field has to be reduced. When a wave is incident to the barriers major losses occur which form a major mechanism to determine shielding effectiveness. They are

A. Reflection loss
B. Absorption loss
C. Multiple internal reflection loss

A. Reflection loss:

It is mainly due to comparative mismatch of characteristic impedance of two media at interfaces. The amount of incident wave reflected depends on the reflection coefficient of surface. Gold, silver, aluminium are good choices for reflection. If the frequency of incident wave is high then reflection loss decreases.

$$R = 168 + 10\log(\sigma_r/\mu_r f)\, dB \quad (1)$$

B. Absorption loss:

It is a function of physical characteristics of a shield. As the EM wave strikes the surface of the shield, some of the wave gets attenuated as the shield absorbs some of the radiation this is called absorption loss. Absorption loss increases with increase of frequency of EM wave. The amount of attenuation depends upon the conductivity of the shield .Absorption loss is directly proportional to thickness of shield. Distance required for wave to be attenuated to 37% is called skin depth. The absorption loss for 1 skin depth is 9dB approximately.

$$A = 3.34t\sqrt{f\mu_r\sigma_r}\, dB$$

C. Multiple internal reflection loss:

Attenuation caused by multiple reflections of EM waves at both boundaries of shield inside it. Practically they are always not taken into consideration. If absorption loss more than 6dB multiple reflection loss can be eliminated. Only when shield is very thin and less conductive then multiple reflection loss is not considered.

III.MATERIAL

The shielding material is choose based upon its commercial availability, cost effectiveness and its wide spread usage. The metal should be highly conductive and relatively should be low cost and abundantly available; this metal should be corrosion resistant and durable. The choice of copper to be used in this project is its ability to impart good conductivity simultaneously; it is widely available at a minimal cost. It is also resistant to wear and tear and provides good durability.

IV. APERTURE

A typical metallic enclosure of dimensions $120mm \times 30mm \times 30mm$ (i.e,a=120mm,b=d=30mm) with rectangular apertures of dimensions $(w \times l)mm$ is used as shield to protect the circuit from incoming EM radiations and also to restrict the EM radiations generated by circuit. The apertures are necessary parameters in shielded enclosures for ventilation the internal circuits from thermal heat. The dimensions of the apertures must be kept minimal and number of apertures must be less in number. As the distance between aperture increases shielding effectiveness increases.

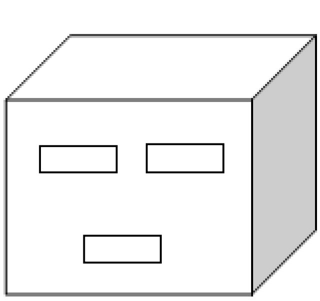

Fig.2 wave guide and aperture

The conductive material shielding effectiveness is degrades by using the enclosures along with apertures when compared to closed enclosures. When the apertures are taken into consideration, the method of calculating the shielding effectiveness for the integral structure would be different as follows (1) calculate the conductive material shielding effectiveness at different frequencies for a panel; (2) calculate the each and every aperture shielding effectiveness of the same frequencies; and (3) The shielding effectiveness value which is small at each frequency is consider for integral shielding effectiveness. [10]

$$\frac{1}{SE_{Total}} = \frac{1}{SE_1} + \frac{1}{SE_2} + \frac{1}{SE_3}$$

$SE = K\log(\frac{\lambda}{2L})$ (For aperture)

Where λ = Wave length

K = 20 for a slit or 40 for round hole

L = longest dimension of the aperture

V. MATHEMATICAL EQUATIONS

ABSORPTION LOSS:

When an EM waves travels from one medium to another medium the intensity of the waves decrease exponentially. This decay arises due to the current produced inside the shield which causes ohmic losses and heating of material. The equation can be written as.

$$E_1 = E_0 e^{-\frac{t}{\delta}} \text{(For electric field)} \quad \text{--- (1)}$$

$$H_1 = H_0 e^{-t/\partial} \text{(For magnetic field)} \quad \text{--- (2)}$$

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}}$$

$$A = 20\log\frac{E0}{E1}$$

From equation (1)

$$A = 3.34t\sqrt{f\mu_r\sigma_r}_{\,dB} \quad \text{--- (3)}$$

Where t=shielding thickness

f=frequency

μ_r, σ_r = relative permiability, realative conductivity

REFLECTION LOSS:

$$E_1 = \frac{2Z_2}{Z_1+Z_2} E_0 \quad \text{--- (4)}$$

$$H_1 = \frac{2Z_1}{Z_1+Z_2} H_0$$

When $Z_1 \gg Z_2$

$$E_1 = \frac{4Z_2}{Z_1} E_0$$

$$H_1 = \frac{4Z_2}{Z_1} H_0 R = 20\log\frac{E_0}{E_1} = 20\log\frac{Z_1}{4Z_2} = 20\log\frac{|Z_W|}{|Z_S|}\, dB \quad \text{-- (5)}$$

Z_W = impedance of wave

$$\left| Z_s = 3.68 \times 10^{-7}\sqrt{\frac{\mu_r}{\sigma_r}}\sqrt{f} \right|$$

$$R = 168 + 10\log(\sigma_r/\mu_r f)\, dB \quad \text{--- (6)}$$

TABLE I :Values of C, n, m

	C	N	m
Electric field	322	3	2
Plane wave	168	1	0
Magnetic field	14.6	-1	2

For electric field

$$R_e = 322 + 10\log\frac{\sigma_r}{\mu_r f^3 r^2} \text{ dB --- (7), from table 1}$$

For magnetic field

$$R_m = C + 10\log\left(\frac{\sigma_r}{\mu_r}\right)\left(\frac{1}{f^n r^m}\right) \text{ dB --- (8), from table 1}$$

MULTIPLE REFLECTION LOSS:

For electric field when $Z_2 \ll Z_1$ multiple reflections are not taken place so the loss is not taken into consideration.

For magnetic field when $Z_2 \ll Z_1$ the transmitted wave magnitude is twice than the incident wave. When the magnitude is very high the multiple reflections for magnetic field is consider within the shield. [1]

$$B = 20log\left(1 - e^{-2t/\delta}\right) dB \text{ --- (9)}$$

The shielding effectiveness

SE = A+R+B in dB --- (10)

VI. RESULTS

The shielding effectiveness results for various materials are obtained by analysing these results we come to know how shielding effectiveness is varied with respective to frequency and number of apertures by taking area of aperture 800mm, thickness of material 1mm, distance between apertures 10mm or 5mm, distance from source 1m.The changes in the shielding effectiveness as a function of frequency and distance between aperture is shown in figures 3.1 to 3.2. Fig 3.1 to 3.4 will represents the shielding effectiveness of different materials for electric field.

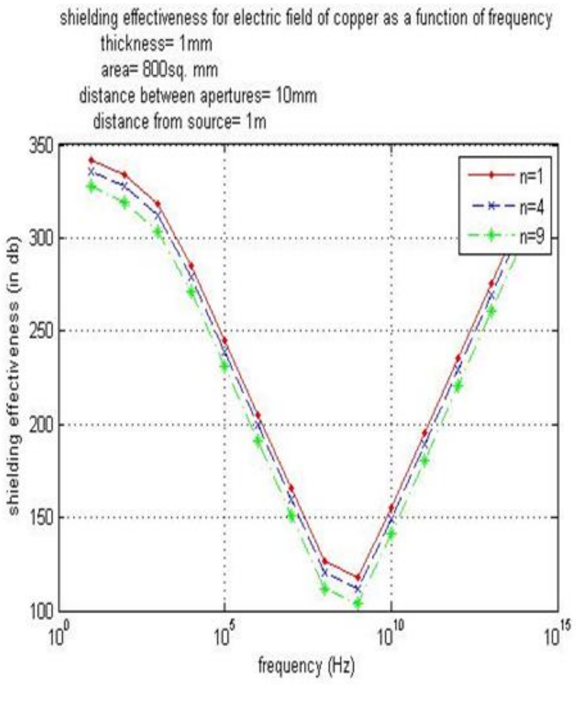

Fig. 3shielding effectiveness for electric field of copper as a function of frequency

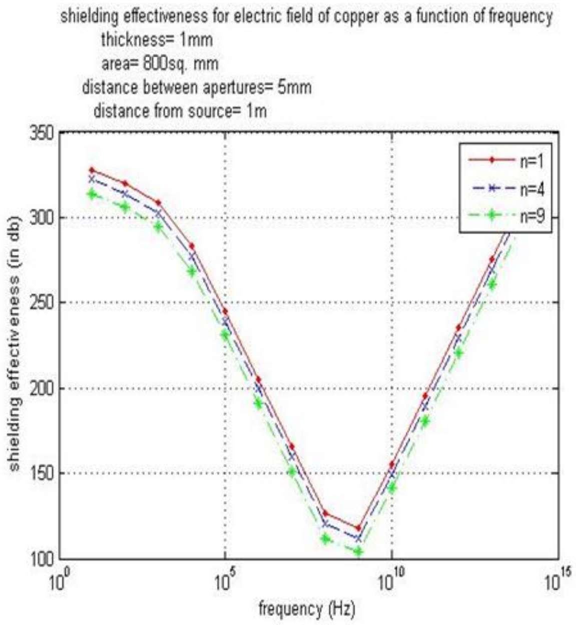

Fig 4. Shielding effectiveness for electric field of Copper as a function of frequency.

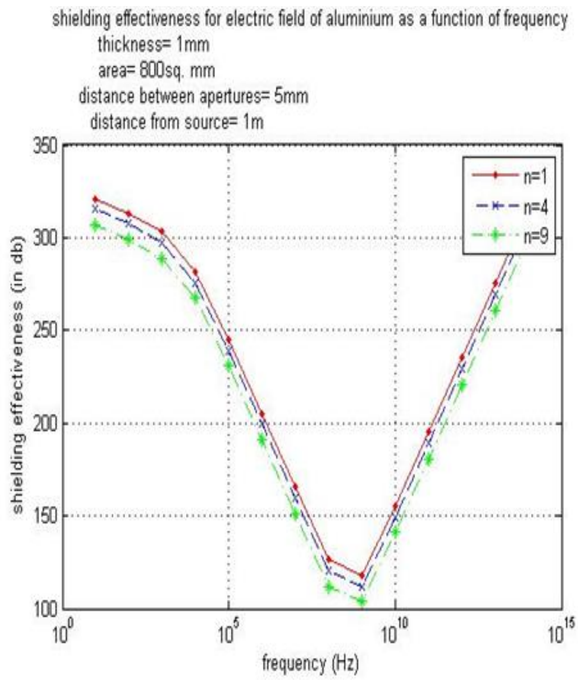

Fig 5 Shielding effectiveness for electric field of Aluminium as a function of frequency.

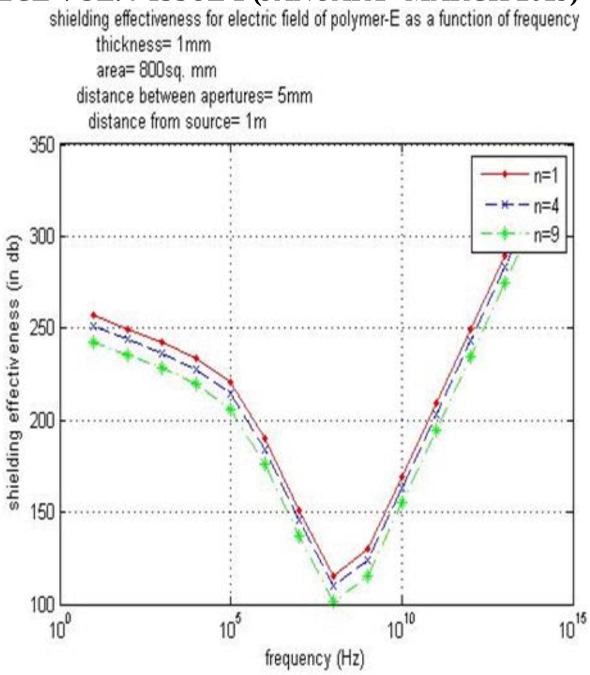

Fig 6. Shielding effectiveness for electric field of Polymer-E as a function of frequency.

VII. CONCLUSION

In this analysis, the shielding effectiveness of various metals is calculated by using transmission line equations. The high shielding effectiveness is obtained by increasing the frequency and distance between apertures and also obtained by decreasing the number of apertures for both Electric and Magnetic field. In the results copper exhibit high shielding effectiveness compare to aluminum and polymer-E because copper have high conductivity.

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