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Analyzing the different conditions for Conductorplaced on Waveguide projected by EMP & PlaneWave signals

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Abstract- *The study of shielding effectiveness of the shielded room for Electromagnetic pulse [EMP] signal with the effect of penetration of conductor through a waveguide. The EMP signal is a having a large amount of electromagnetic energy with large amplitude. The Electromagnetic pulse (EMP) produces interference current into the shielded room when the conductor is penetrated into the waveguide of the shielded room. The induced currents vary with the length of the conductor and angle of incidence of the EMP signal. The reflection of signal occurs at the other side of shielded room, when current passes through the conductor. Shielding Effectiveness [SE] is calculated for different conditions like with no conductor, conductor is placed at the center, conductor attached to shielded room, is done by using the plane wave and transient EMP signal. The results explain about the suitable technique to minimize the coupling, when the penetration of conductor takes place in the shielded room.*

Keywords- *Plane Wave Signal, Shielded Room, Rectangular Waveguide, Electromagnetic Pulse [EMP] Signal, Conductor, Shielding Effectiveness*

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I. INTRODUCTION

The usage of electronic systems and the technologies around the world has been increasing in our day to day life. Now, the research is going on to minimize the size of the system. The large number of electronic systems creates the electromagnetic interference [EMI] problem within the systems. The electromagnetic interference [EMI] occurs in 2 modes, Radiated EMI, Conducted EMI [1].

When an electromagnetic pulse [EMP] signal from the external environment interacts with the cable, voltages and currents are induced inside the conductor. These signals occur inside the conductor damage electronic equipment that is attached by the cable. Electromagnetic pulse is having large amplitude of energy like electrical energy, magnetic energy and electromagnetic energy [2]. The electronic equipment inside the shielded room from EMP signal can be protected in two modes. Firstly, the coupling of EMP signals to the electronic equipment through the waveguide of the shielded room, because the shielded room is having a different point of entry like apertures, waveguides, and honeycomb structure [3], [4]. Secondly, the coupling of EMP signal on Input-Output [I/O] cables, signal wires, and then generates currents flow in the system inside the shielding room [5].

The paper explains about the calculation of shielding effectiveness of the shielded room with penetration of conductors on the rectangular waveguide of shape, and its effect [6]. Shielding Effectiveness [SE] is calculated for different conditions like with no conductor, conductor is placed at the center, conductor attached to shielded room, is done by using the plane wave and transient EMP signal.

II. THEORETICAL CONCEPTS OF SHIELDED ROOM

Electromagnetic shielding is used for the protection of equipment from the EMP signals. In practical conditions, the leakage of signal through aperture at higher frequency is negligible [6]. The efficiency of shielded room is obtained by calculating the shielding effectiveness value. Shielding effectiveness is calculated by taking the difference between the electric field inside the outside of the shielded room. Another method for finding shielding effectiveness value is by taking the ratio of the wave incident on the shielded room to the wave reflected from the shield [7]. The shieldingeffectiveness [8]SE can be defined as.

$$SE = 20 \log (E_{ns}/ E_s) \qquad (1)$$

E_{ns} = Electric field with no shield and E_s= Electric field with shield. The rectangular enclosure is having multiple resonantfrequencies. The resonant frequency is calculated by

$$f = 150\sqrt{\frac{m^2}{l} + \frac{n^2}{h} + \frac{p}{w}} \qquad (2)$$

Where dimensions of the shielded room are represented by length[l], height[h], width[w] (in meters). The mode of propagation of the rectangular enclosure with positive integers are m, n and p (0,1,2,3…. etc.). The mode used in the propagation of rectangular room is TE101 for calculation of resonant frequency of shielded room.

A. Plane wave

A plane waves of sinusoidal signal is considering for calculation of shielding effectiveness of shielded room with penetrating conductors, the sinusoidal wave is having the magnitude of 1V/m and propagates in all directions with the same magnitude has been considered.

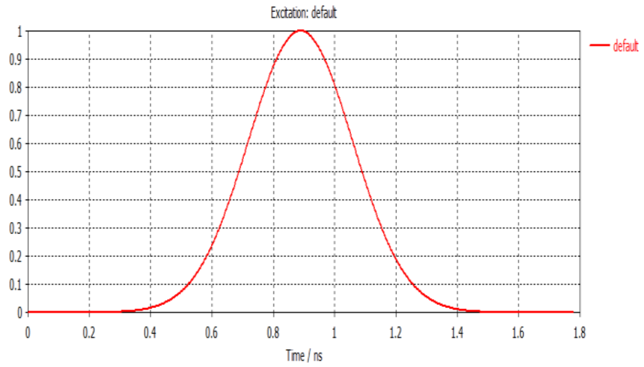

Fig.1. Waveform of Plane wave

B. Transient wave

The transient wave is a EMP signal is given to the input of the shielded room. The EMP signal is a Double exponential signal with high amplitude of 55kV, rise time and fall time of the signal is 2.3ns, the width of the pulse is 22.73ns was applied to the shielded room as per MIL-STD 461 E/F, RS-105 test[4].

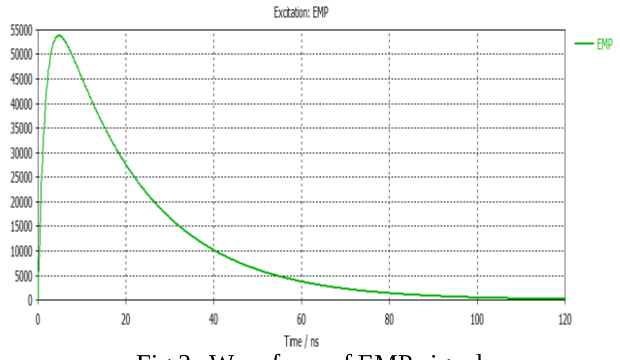

Fig.2. Waveform of EMP signal

III. MODELLING AND SIMULATIONS

The shielded room was designed with dimensions of (2m*1m*2m) to protect the equipment from EMP signal. The room was designed with point of entry for routing the cables into the shielded room. The point of entry is wave guide of rectangular shape. The cut of frequency of rectangular waveguide is considered as 4GHz so that it does not allow theEMP signal inside the shielded room.

The shielded room was designed and simulated by using the CST Software. The shielded room was projected by the plane wave and EMP signal with frequency of 2 GHz is transmitted

A. Projection of signal to Shielded Room

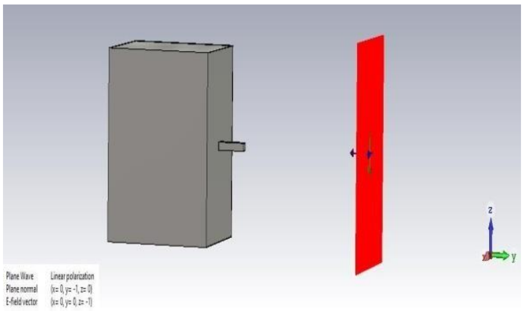

Fig.3. The signal given to the shielded room with rectangularwaveguide in the absence of a conductor

The shielded room with rectangular waveguide was designed with no conductor, the Plane wave signal of frequency 2GHz is given to shielded room and the shielding effectiveness of the shielded room was calculated. The shielding effectiveness value for plane wave with no conductor is 120 dB.
The transient signal known as EMP signal is subjected to the shielded room with rectangular waveguide in the absence ofconductor. The shielding effectiveness value for EMP signalis 80 dB

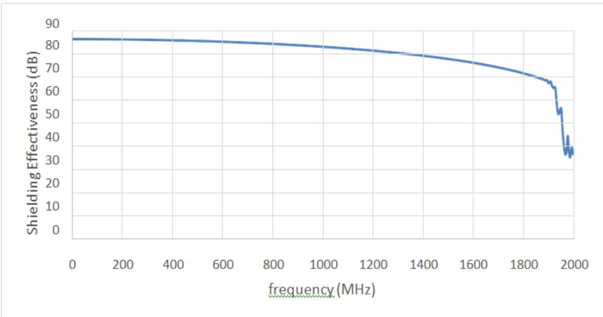

Fig.4. The shielding effectiveness value obtained by projectingthe EMP signal to shielded room with no conductor

The shielding effectiveness value is calculated for both sinusoidal wave and EMP signal is by placing the electric field probes inside the shielded room in the coordinates (0,- 20,120) mm. the shielding effectiveness value is calculated by taking the difference between the electric field inside theoutside of the shielded room

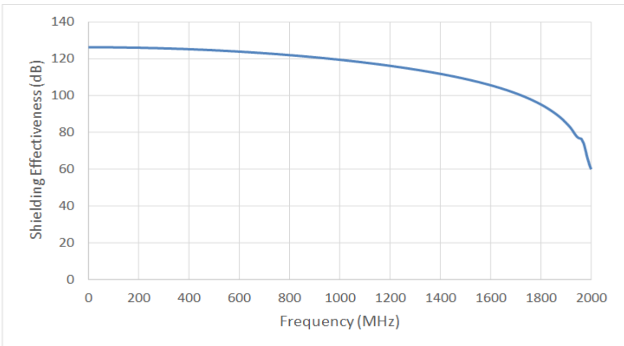

Fig.5**.** the shielding effectiveness value obtained by projectingplane wave to shielded room with no conductor

B. Conductor placed at the center of the Waveguide
When the conductor of length 0.45m is fixed at the center of shielded room in rectangular wave guide. The conductor is penetrated at a depth of 0.25m inside the waveguide of shielded room. The value of shielding effectiveness for shielded roomis obtained by placing the electric field probes in the axis of(0, -20,120) mm.

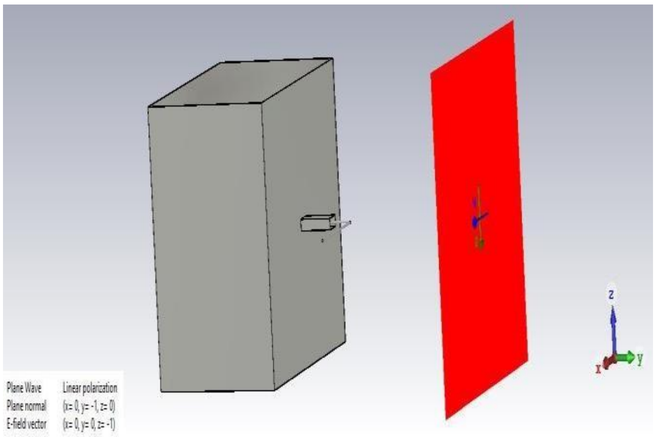

Fig.6. Conductor is placed at the center of waveguide of the shielded room

From simulations it is observed that, the shielding effectiveness [SE] value reduces when the conductor is placed at center of waveguide of shielded room. It states that by placing the conductor at the center of waveguide reduces theperformance of shielded room due to the coupling of electromagnetic fields.
From the analysis, it is observed that SE value decreases with increasing frequency, the better shielding value is obtained at lower frequency for sinusoidal signal and EMP signal.

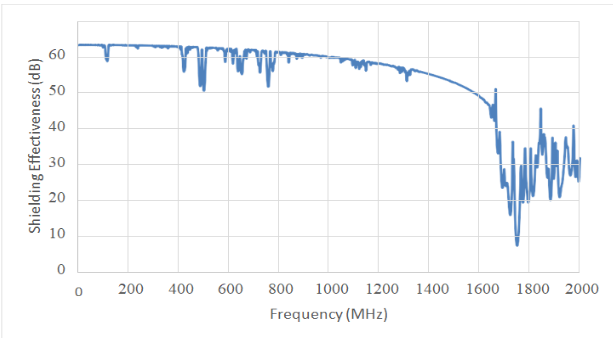

Fig. 7. The shielding effectiveness value obtained by projecting the EMPsignal to shielded room with conductor at center

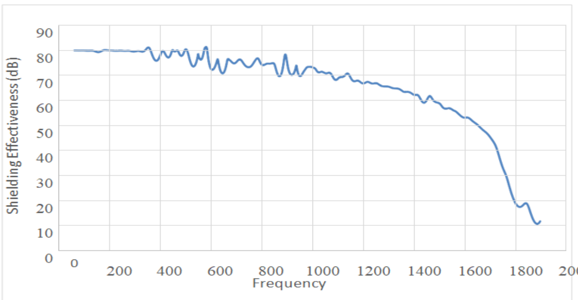

Fig.8. the shielding effectiveness value obtained by projectingplane wave to shielded room with conductor at center

C. Conductor placed at the center of the Waveguide withconnection to the shielded room

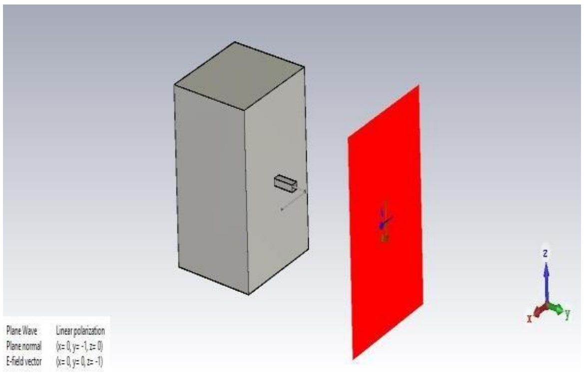

Fig.9. the metallic shielded room with a conductor connected to the shielded room

The shielded room was designed with dimensions of (2m*1m*2m) to protect the equipment from EMP signal. The room was designed with point of entry for routing the cables into the shielded room. When the conductor of length 0.45m is placed at the center of the waveguide with connection to the shielded room, the SE value is calculated by fixing the field probes in the shielded room with coordinates (0,-20,120) mm.

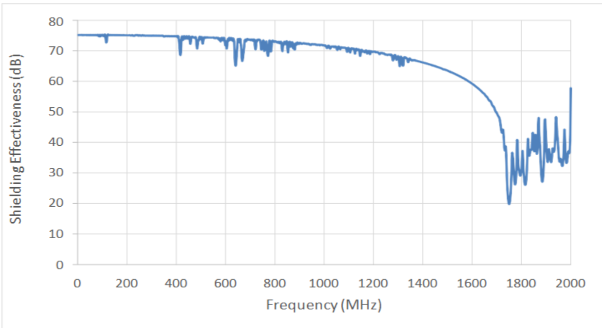

Fig.10. the shielding effectiveness value obtained by projectingEMP signal with conductor connected to shielded room

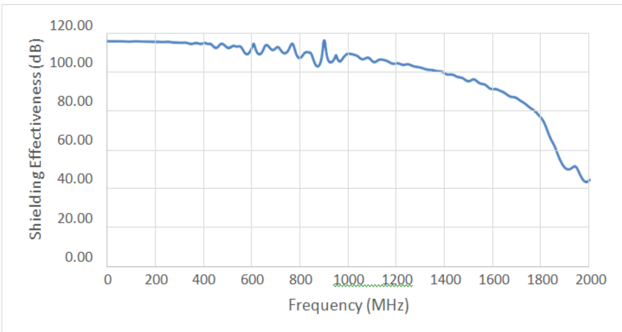

Fig.11. the shielding effectiveness value obtained by projectingplane wave with conductor connected to shielded room

IV. SHIELDING EFFECTIVENESS VALUE COMPARISON FORDIFFERENT CONDITION OF CONDUCTOR.

By considering various conditions on the Conductor i.e. with no conductor, conductor placed at center, conductor connected to shielded room. When the Plane wave is transmitted to the shielded room, the shielding effectiveness value is plotted on the same graph.

By considering various condition on the Conductor, the shielding effectiveness values of the enclosure is plotted onthe same graph. When the EMP Pulse passes to the shielded enclosure.

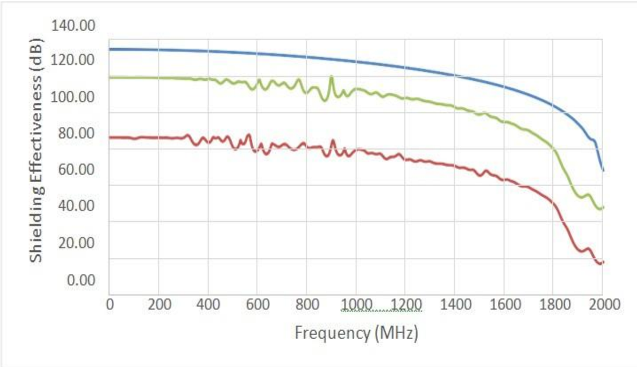

Fig.12. When Plane wave is subjected to the shielded room theshielding effectiveness value for different conditions of conductor

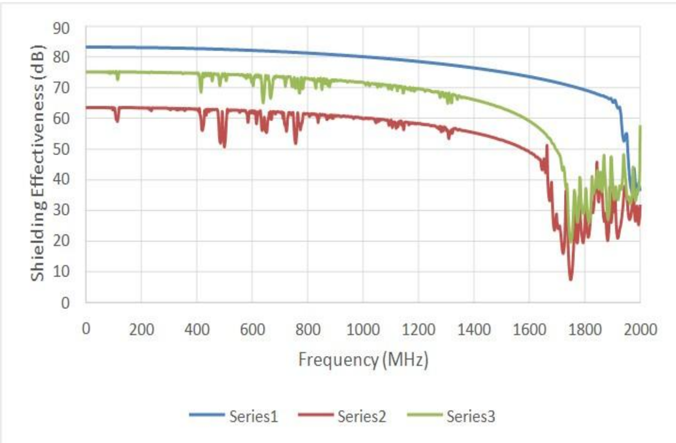

Fig.13. When EMP signal is subjected to the shielded room theshielding effectiveness value for different conditions of conductor

TABLE.1. SHIIELDING EFFECTIVENESS VALUE FOR DIFFERENT CASES OF CONDUCTOR WHEN PLANE WAVE AND EMP SIGNAL IS TRANSMITTED

CONDITIONS	**PLANE-WAVE**	**EMP WAVE**
Shielded room with no conductor at rectangularwaveguide	120dB	80 dB
Shielded room with conductor at center of rectangular waveguide	100dB	70 dB
Shielded room with conductor connected to thecenter of rectangular waveguide	80dB	60 dB

V. CONCLUSION

This paper gives a detailed analysis of the coupling effect by changing the position of conductor in shielded room. The conductor is placed at the center of rectangular waveguide of shielded room. From the simulation, observed that the shielding effectiveness value for shielding room decreases when 0.45m (20cm outside, 25cm inside) conductor is placed at the center of the rectangular waveguide when compared to the conductor connected to the shielded room. After analyzing these simulation results, concluded that the conductor connected to the shielded room reduces the coupling effect from electromagnetic fields.

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