Protection from electromagnetic radiation using square wire-mesh

Parshuram Singh[1] , Reeta Pawar[2]

[1]B.Tech in Electrical and Electronics Engineering, Dhanbad, Jharkhand

[2]Assistant Professor, Electrical Dept., AISECT University, Bhopal

ABSTRACT

In modern era, ultra high voltage power transmission causes electromagnetic pollution which is a matter of great concern for the society. Persons working in the electromagnetic environment must be protected from receiving harmful electromagnetic waves because in some cases it may cause disorder in the human body. This paper deals with the design of protective shields using low weight wire-mesh shields to protect human being in most of the environment.

Keywords: shielding effectiveness, wire-mesh, electromagnetic radiation, human apron, EMI .

1. INTRODUCTION

Electromagnetic interference (EMI) is a disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source. It affects the devices which lies in its vicinity [1], [4], [6]. Electromagnetic shielding is the technique that reduces or prevents coupling of undesired radiated electromagnetic energy into equipment to enable it to operate compatibly in its electromagnetic environment. Electromagnetic shielding is effective in varying degrees over a large part of the electromagnetic spectrum from DC to microwave frequencies [2]. Shielding problems are difficult to handle when a perfect shielding integrity is not possible because of the presence of intentional discontinuities in shielding walls, such as shielding panel joints, ventilation holes, visual access windows or switches. Apparently, shielding is produced by putting a metallic barrier in the path of electromagnetic waves between the culprit emitter and receptor.

A person working in electromagnetic environment may be supplied with an apron acting as a shield to electromagnetic waves and pulses. The apron supplied, in a country like India, must be provided with ventilation through the shield. Also weight or mass of the apron should not exceed certain limit to avoid discomfort of the user. Hence an optimization between the mass of the shield and the field to prevent should be incorporated in designing the shield-apron. In this paper, wire-mesh [3]-[6] of square shape is considered as electromagnetic shied because of its reduced weight per unit area compared to metallic sheets. Due to its periodic structure, a mesh screen under the influence of an electromagnetic field carries a reactive field that is confined to the vicinity of the mesh surface.

2. DESIGN APPROACH

The wire-mesh shield structure of metal wire is shown in Figure 1. Here six parameters have been considered:

- Radius of the wire (r)
- Spacing between the wires(a)
- Frequency of operation(f)
- Permittivity of the medium(ε)
- Permeability of the medium(μ)
- Conductivity of the material(σ)

A wire mesh screen with bounded junctions can be described electromagnetically by an equivalent sheet impedance [3] parameters. When the mesh dimensions are small compared to wavelength, the sheet impedance parameter L is given by

$$L = -\left(\frac{a\mu_o}{2\pi}\right)\ln\left(1-e^{-\frac{2\pi r}{a}}\right) \qquad (1)$$

Where μ_0 = free space permeability

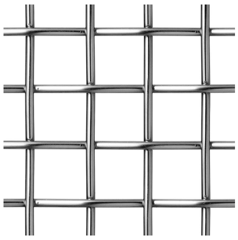

Figure 1 Wire-mesh

The internal impedance per unit length Z is

$$Z = R\frac{\sqrt{jw\tau}\,I_o\left(\sqrt{jw\tau}\right)}{2I_1\left(\sqrt{jw\tau}\right)} \tag{2}$$

Where $R = \left(\pi r^2\sigma\right)^{-1}$ is the dc resistance per unit length of mesh wire and $\tau = \mu\sigma r^2$ is the diffusion time constant.

The effective sheet impedance of the wire mesh for perpendicularly polarized plane wave is

$$Z_s = Z_a + jwL \tag{3}$$

The transmission coefficients is

$$T = \frac{2\left(\frac{Z_s}{Z_o}\right)\cos\theta}{1+2\left(\frac{Z_s}{Z_o}\right)\cos\theta} \tag{4}$$

Where $Z_o = \sqrt{\frac{\mu_o}{\varepsilon_o}}$ is the intrinsic impedance of free space and ε_0 is the free space dielectric constant.

And the Shielding Effectiveness for the perpendicularly polarized plane wave is

$$SE\left(\theta\right) = -20\log_{10}\left|T\left(\theta\right)\right| \tag{5}$$

To design the apron the effective mass for the apron was calculated using complex optimization technique. The formula used are

$$l = 2n(n+1)a \tag{6}$$

$$A = \left(na\right)^2 \tag{7}$$

$$M = \frac{2\pi\rho r^2(a+1)}{a} \tag{8}$$

Where, n = Size of the square matrix.
A= area of the wire-mesh = 1 sq. m
ρ = density of copper = $8940\,kg/m^3$

3. RESULTS

3.1 The wire mesh having radius (r=0.5 mm) is considered to form a shield. The spacing of the wire is selected as (a=1 cm). The frequency of operation is change from 1 KHz to 1 GHz and the shielding effectiveness is calculated for copper, aluminium and iron wire-mesh. For optimization we require maximum shielding effectiveness with minimum effective mass. The result is shown below (Figure 2)

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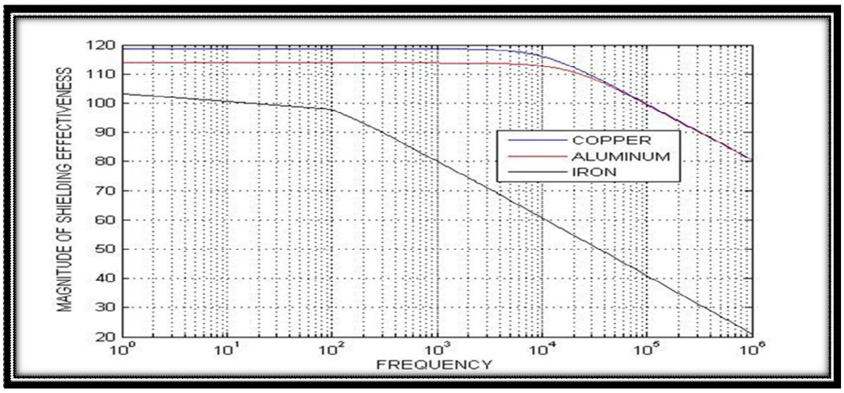

Figure 2 Shielding effectiveness of different material

From figure 2. From the graph so obtained we can thus draw the conclusion that the performance of copper wire mesh gives a better shielding effectiveness in comparison to iron and aluminium wire mesh.

3.2 Now for copper wire-mesh, the wire spacing was changed for different radius (r=0.1 mm, 0.5 mm and 1 mm). The frequency of operation is fixed (f=900 MHz) and the internal impedance, sheet impedance, transmission coefficient and shielding effectiveness are calculated. The result is shown below (Figure 3 (a-d))

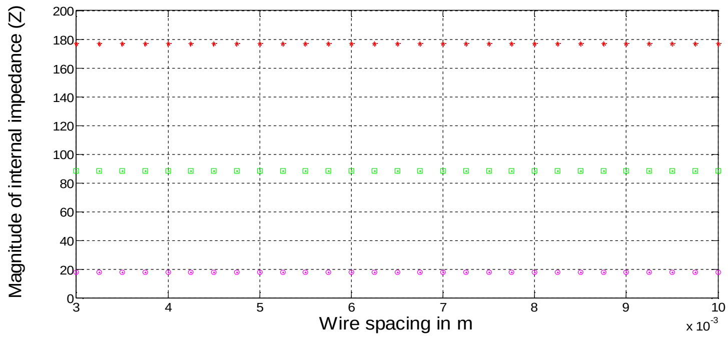

Figure 3 (a)

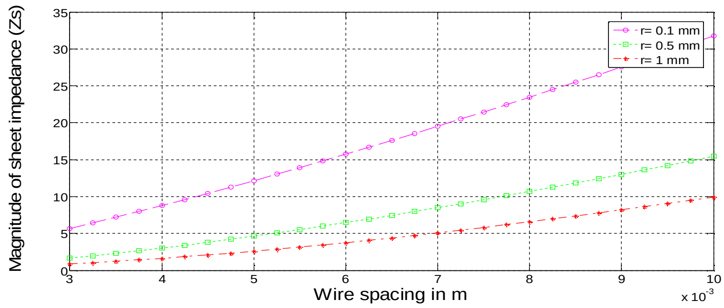

Figure 3 (b)

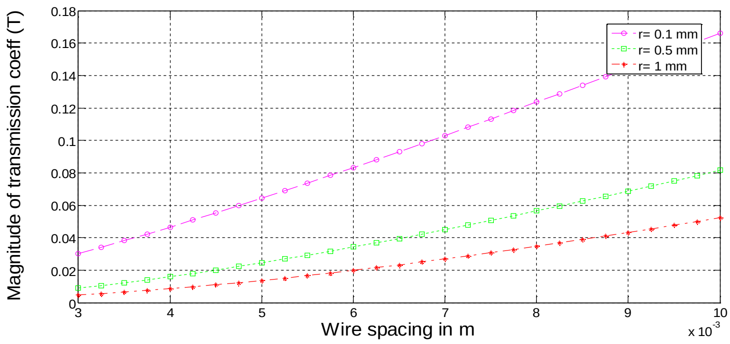

Figure 3 (c)

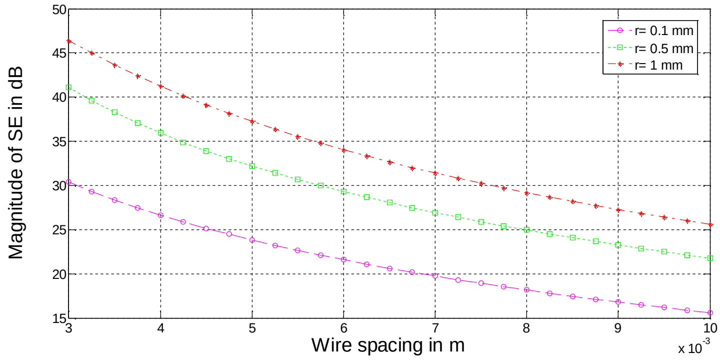

Figure 3 (d)

From the graph it is observed that shielding effectiveness of copper wire mesh decreases with increase in wire spacing and this decrease is more for the wire mesh whose radius is small.

3.3 Now for copper wire-mesh, the wire radius was changed for different wire spacing (a=3 mm, 6 mm and 1 cm). The frequency of operation is fixed (f=900 MHz) and the internal impedance, sheet impedance, transmission coefficient and shielding effectiveness are calculated. The result is shown below (Figure 4 (a-d))

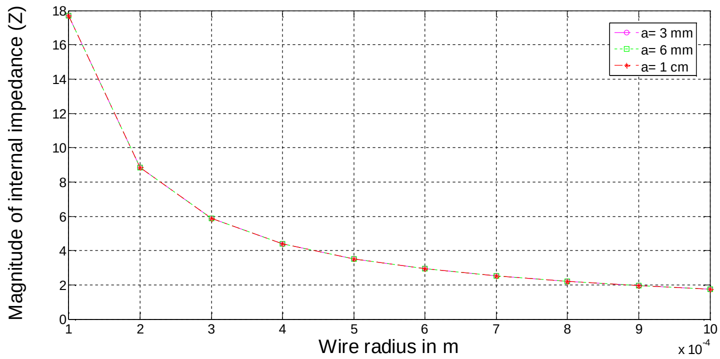

Figure 4 (a)

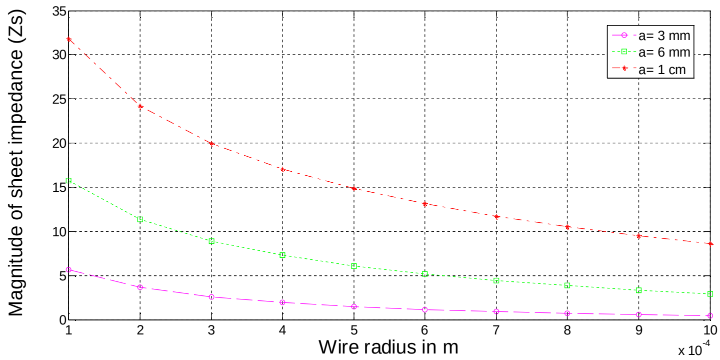

Figure 4 (b)

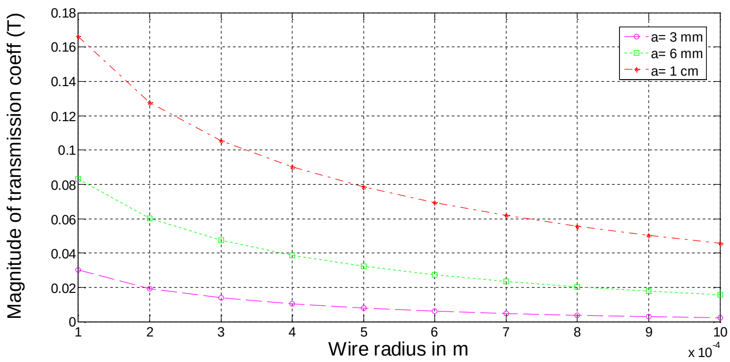

Figure 4 (c)

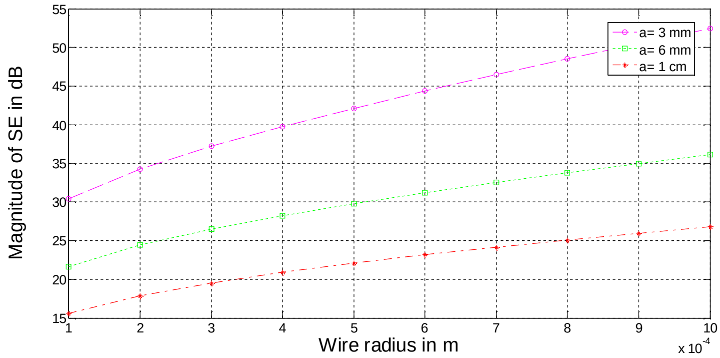

Figure 4 (d)

From the graph it is observed that shielding effectiveness of copper wire mesh increases with increase in wire radius and this increase is more for the wire mesh whose spacing is small.

4.CONCLUSION

The shielding effectiveness values for copper, iron and aluminum were compared at 900 MHz and based on that copper was selected as the shielding material for wire mesh as it provided better shielding against high frequency electromagnetic radiation. The inferences which can be drawn on the basis of nature of shielding effectiveness with respect to wire spacing and wire radius are shielding effectiveness of copper wire mesh decreases with increase in wire spacing and this decrease is more for the wire mesh whose radius is small. Whereas shielding effectiveness of copper wire mesh increases with increase in wire radius and this increase is more for the wire mesh whose spacing is small.

With the help of COMPLEX METHOD optimizing technique the optimized Shielding Effectiveness (SE) was found out to be 30.5215 dB at 900MHz mobile band for the wire spacing 0.0031 m and radius of the wire 0. 11mm which is the average shielding effectiveness. The effective mass of the shielding fabric which should be utilized to design the protective clothing is found out to be 0. 2239 Kg.

The shielding effectiveness obtained theoretically shows average protection. The practical results may be lower than the theoretical values obtained. Still the shielding effectiveness will be within the normal acceptance range.

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AUTHOR

Parshuram Singh received the B.Tech degree in Electrical and Electronics Engineering from Vinoba Bhave University in 2011 and is presently persuing M.Tech degree from AISECT University. During the year 2012-2015, he has served as an assistant professor in Electrical department in DAV Institute of Engineering and Technology, Jharkhand.