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Multilayered Electromagnetic Shield With Conductive Polymers and Wire Meshscreens – Analysis

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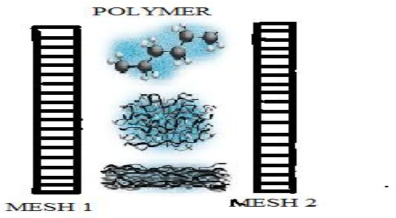
***ABSTRACT*--Good conductors are used as electromagnetic shields with high performance of shielding effectiveness [1]. The conductive shields have disadvantages like high weight and volume. In order to reduce the weight of an electromagnetic shield conductive wire mesh screens are used [2]. Conductive polymers are also employed as electromagnetic shields since they are flexible and lightweight [3]. In this paper a combination of a conductive polymer sandwiched between two wire mesh screens is considered. Such a multilayered electromagnetic shield is considered. Such a multilayered electromagnetic shield has great advantage of light weight and flexibility while achieving the targeted shielding effectiveness. In the present work an analysis is carried out for the estimation of shielding effectiveness and polarizations of the proposed multilayered electromagnetic shield**.

Keywords—Multiplereflections, Non degreadebles ,Shielding effectiveness

INTRODUCTION

Electromagnetic shielding for an electronic circuit is of prime concern in its design .With exponentially growing technology of VLSI; the circuit size is drastically reduced. Developing an electromagnetic shield for such a reduced size of electronic circuits requires ultra thin conductor shields while achieving the required shielding performance. The drawback of conductor is high weight and its flexibility is less. Wire meshes are potentially attractive for use as electromagnetic shields because of their reduced weight per unit area compared to metallic sheets. Their physical flexibility would also make them convenient for use in "Retrofit" shielding applications for large facilities. The reactive character of the mesh surface, the plane wave shielding effectiveness decreases with increasing frequency. The disadvantage of wire mesh screen is Wire mesh screens are frequency sensitive. Shielding Effectiveness decreases as the frequency increases. A conductive polymer has a very high conductivity to weight ratio and thus, it can yield same shielding effectiveness performance as that of conductor with less weight. High conductive polymer sheets with thickness small compared to skin depth can be used as electromagnetic shield. The need for new conducting materials technologiesis ever growing with the consumer push to make electronics faster,lighter and lessexpensive. Electromagnetic field theory was applied to calculate the reflection loss and shielding effectiveness. With and without reflection loss the shielding effectiveness of a shield is measured. Several investigations were carried out to find the shielding effectiveness of a shield by replacing different types of polymers .The field transmitted through the polymer was observed to have small amplitude over the microwave frequency range of 2 GHz to 10 GHz, indicating potential usefulness of the polymer as an electromagnetic interference (EMI) shield in an environment containing high-data-rate electronics, such as supercomputers.



placing polymer between two wire mesh screens

The laminated shield can be described electromagnetically by an equivalent sheet-impedance dyadic operator $Z_s$when the mesh dimensions are small compared to wavelength.

The operator $Z_s$relates the tangential electric field E_s to the surface current density on the screen J_s as:

$$E_s = Z_s * J_s \qquad (1.1)$$

The equivalent sheet impedance for a screen with square meshes[2] of dimensions $a_s * a_s$ is

$$Z_s = (Z_w a_s + jwL_s)(I - nn) + \frac{jw\,L_s}{2k_0 \epsilon_r} \Delta_s * \Delta_s \qquad (1.2)$$

Where $Z_w^{'}$ is the internal impedance per unit length of the mesh wires, $=K_o = \omega\sqrt{\mu_o \varepsilon_o}$ is the free-space wave number (μ_o and ε_o denote respectively the permeability and the permittivity of free space), and ∇_s denotes the surface del operator. I is the idem factor or identity dyadic and *n*is a vector normal to the surface occupied by the mesh.The sheet inductanmce parameter L_s is given by[3]

$$L_s = \frac{\mu_0 a_s}{2\pi} ln\left(1 - e^{-2\pi r_w / a_s}\right)^{-1} \qquad (1.3)$$

If we use the plane wave with a normal incidence, in order to evaluate the effectiveness of a planar mesh screen, we only need to evaluate the transmission coefficient that, in case the mesh wires are perfectly conducting, is

$$SE = -20 * \log 10 \frac{{}^{2wL_s}/_{Z_0}}{\sqrt{1+\left({}^{2wL_s}/_{Z_0}\right)^2}} \qquad (1.4)$$

Where Z_0 is the free - space characteristic impedance.

Here polymer is inserted between two wire mesh screens so Z_0 is equal to the Z_P.$Z_P$is the intrinsic impedance of the polymer material[5].

$$Z_P = (1+j)\sqrt{\frac{\pi f \mu_P}{\sigma_P}} \qquad (1.5)$$

$\mu_P$is the relative permeability which is equal to $\mu_P = \mu_0 * \mu_{rp}$ (1.6)

$\mu_0$is free space permeability and σ_P is conductivity of conductive polymer given as

$\sigma_p = 2\pi f_0 \varepsilon_0 \varepsilon''$. $f_0$is resonant frequency of the cavity[6].$\varepsilon_0$is permittivity of free space ε'' is the imaginary part of relative permittivity of the conductive polymer.

Consider the equation for SE

$SE_{dB} = A_{dB} + R_{dB} + B_{dB}$

A is the *absorption loss* of the wave for a screen thickness much greater than a skin depth, Moreover, *R* is the *reflection loss* term, Finally, *B* represents the *multiple-reflection loss* term and is equal to

$$B_{db} = 20 * log_{10} \left|1 - e^{-2\alpha l} e^{-j\beta l}\right| (1.8)$$

The SE for a double layer shield can be written as

$$SE_{double} = 2 * SE_{single}$$

Therefore effective RF shields for electric fields can be constructed with thin shields, because for far-field (uniform plane-wave) and near field sources, reflection loss is the predominant shielding mechanism at the lower frequencies, while absorption loss is the predominant shielding mechanism at the higher frequencies

$$B_2 = 20 * log_{10} \left|1 - \left(1 - 4\frac{\eta}{Z_w}\right)\left(cos4\pi\frac{l_2}{\lambda_0} - jsin4\pi\frac{l_2}{\lambda_0}\right)\right| \; (1.9)$$

Where l_2 is the air space thickness, η is the screen impedance (equal to L_s for our wire-mesh screen), and$Z_w = Z_0$ is the free-space characteristic impedance.

For much of frequency range where ${}^{l_2}/_{\lambda_0} \ll {}^{1}/_{8}$

$$B_2 = 20 * log10\left|4\frac{\eta}{Z_w} + j4\pi\frac{l_2}{\lambda_0}\right|$$

Since $\left|4\frac{\eta}{Z_w} + j4\pi\frac{l_2}{\lambda_0}\right|$ is much less than one,B_2 is negative and the double shield is considerably less effective than sum of two single shields over a considerable portion of the frequency spectrum.

For instance at frequencies high enough such that, $l_2 = (2k-1)\frac{\lambda_0}{4}, \quad k = 1,2,3, \ldots..$

At shielding interspace resonances, performance of the double shield can be much as 6dB better than the sum of two separate single shields having the same total metal thickness.

Considering the B_2(B2 is a periodic factor), our final model becomes

$$SE = -40 * log_{10} \frac{(2\omega L_s/Z_0)}{\sqrt{1+(2\omega L_s/Z_0)^2}} + B_2 (1.10)$$

Based on the above analysis showed that the surface impedance eigenvalue$Z_{S_1}$and Z_{S_2}were characterization of transverse electric field and transverse magnetic field in the direction perpendicular to the metal net surface respectively. For the matter of the reflection and transmission of plane waves incident metal mesh ,electric field perpendicular to the incident plane transverse magnetic field.Therefore ,the incident plane wave shielding effectiveness evaluation of metal net can analyze by using only the surface impedance operatorZ_{S_1} andZ_{S_2} respectively.[8]

So the shielding effectiveness of vertical and horizontal polarizations is respectively

$$SE_1(\theta) = -20 * log\frac{\left({}^{2wL_s}/_{Z_0}\right)cos\theta}{\sqrt{1+\left({}^{2wL_s}/_{Z_0}\right)^2 cos^2\theta}}$$

$$SE_2(\theta) = -20 * log\frac{\left({}^{2wL_s}/_{Z_0}\right)\left(1-\frac{1}{2}sin^2\theta\right)}{\sqrt{\left({}^{2wL_s}/_{Z_0}\right)^2\left(1-\frac{1}{2}sin^2\theta\right)^2 + cos^2\theta}}$$

Where θ is the electromagnetic wave incidence angle.

RESULTS AND DISCUSSION

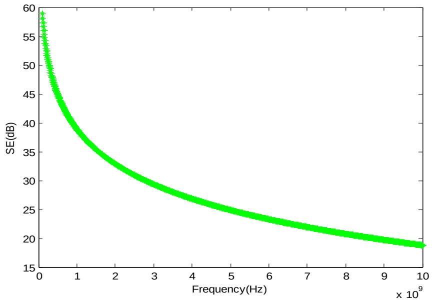


Fig. 1: Shielding effectiveness verses frequency of a single wire mesh screen

Here single wire mesh is considered. The plot is taken for shielding effectiveness verses frequency. As the frequency is increasing, the shielding effectiveness decreases. The highest shielding effectiveness is 60 dB.

.For the single mesh the shielding effectiveness is 60 dB and for the double mesh the shielding effectiveness becomes double .120 dB is the shielding effectiveness of double wire mesh screen.

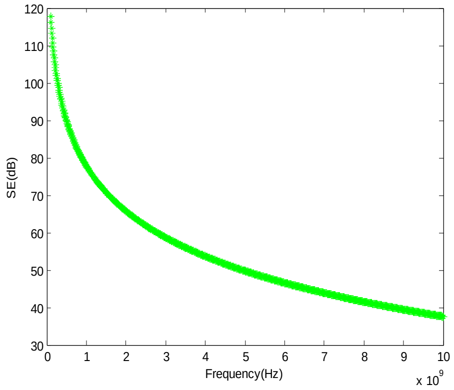


Fig. 2: Shielding effectiveness verses frequency of double wire mesh screen.

Three types of polymers are placed between two mesh screens. Then the shielding effectiveness of each and every polymer is indicated.

S.NO	NAME OF THE POLYMER	SE IN DB	IMAGINARY PART OF RELATIVE PERMITIVITY
1	POLY P PHENYLENE BENZOBIS THIAZOLE	22 20	838 1158
2	POLY ACETYLENE CIS-(CHI0.045)	25	607
3	POLY ACETYLENE TRANS-(CHI0.045)	22 25	909 4E5

Now by considering multiple reflections, Asthe thickness between two meshes increases shielding effectiveness also increases.At different frequencies, the plot between the shielding effectiveness and the thickness between two mesh screen.

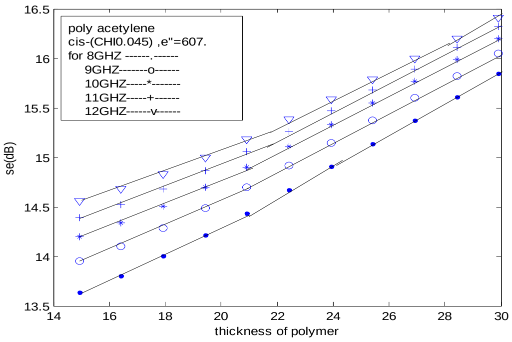


Fig. 3: Shielding effectiveness verses thickness of the polymer poly acetylene cis(CHI-0.045) having imaginary part of permittivity 607.

As the frequency increases ,the shielding effectiveness decreases.here thickness of the polymer is varied between two wire meshes. Frequency is from 8GHZ to 12GHZ . That is x band frequency. The highest shielding effectiveness is 16.4 dB. So by this as the thickness increases,the shielding effectiveness also increases.

In the fig 4

The polymer between the two wire meshes is PBT The varying shielding effectiveness from 8GHZ to 12 GHZ is 14.3 to 15 dB. The highest shielding effectiveness is 16.6 dB.

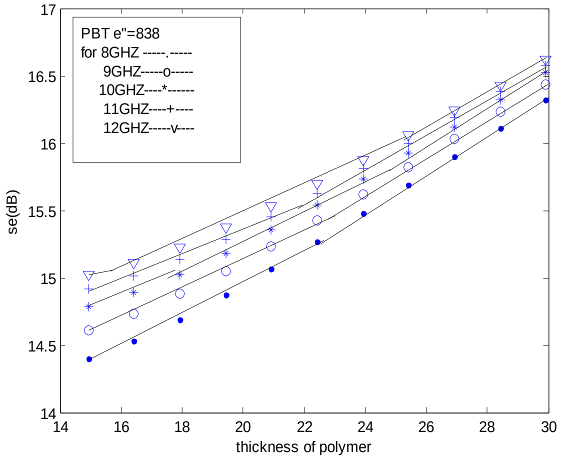


Fig 4: Shielding effectiveness verses thickness of the polymer PBT having imaginary part of permittivity 838.

Coming to the horizontal and vertical polarizations as the incidence of electromagnetic wave changes ,the shielding effectiveness also changes.

In the next graph,

Frequency verses shielding effectiveness of the polymer poly acetylene trans(CHI-0.045) having permittivity 909. the incidence of electromagnetic wave changes ,the shielding effectiveness also changes. The highest shielding effectiveness is 15.4 dB.

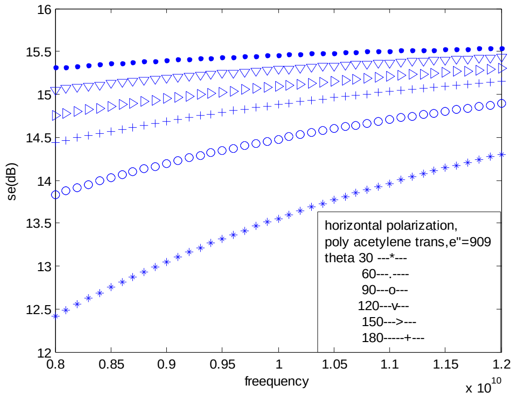


Fig. 5: Horizontal polarization of the polymer poly acetylene trans(CHI-0.045) having imaginary part of permittivity 909

In the below graph ,Frequency verses shielding effectiveness of the polymer poly acetylene trans(CHI-0.045) having permittivity 4E5. the incidence of electromagnetic wave changes ,the shielding effectiveness also changes. The highest shielding effectiveness is 14.9 dB.

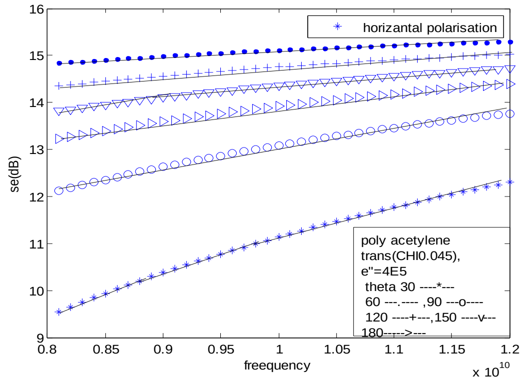


Fig. 6: Horizontal polarization of the polymer poly acetylene trans(CHI-0.045) having imaginary part of permittivity 4E5.

In Fig.7 The plot is shielding effectiveness verses frequency in the frequency range of 8GHZ to 12GHZ. As the wave is undergoes to vertical polarization the shielding effectiveness is more and more compared to others. The highest shielding effectiveness is 37dB.

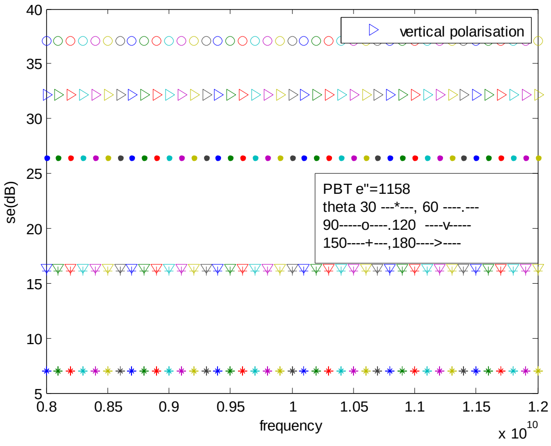


Fig. 7: Vertical polarization of polymer PBT having imaginary part of permittivity 1158

In Fig 8 ,The plot is shielding effectiveness verses frequency in the frequency range of 8GHZ to 12GHZ. As the wave is undergoes to vertical polarization the shielding effectiveness is more and more compared to others. The highest shielding effectiveness is 43dB

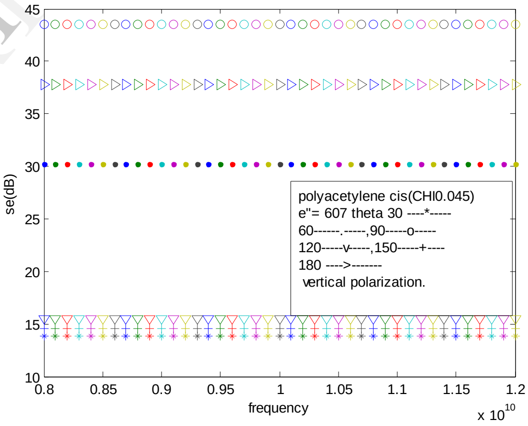


Fig. 8: Vertical polarization of polymer poly acetylene cis(CHI-0.045) having imaginary part of permittivity 607.

CONCLUSION:

By using single wire mesh screen the shielding effectiveness is 60 dB and for double wire mesh screen double the shielding effectiveness of single mesh is achieved. Inside the two wire mesh screens a medium is used. That medium is nothing but conductive polymer. Three types of polymers are used. They are (1).Poly p phenylenebenzobisthiazole (2) poly acetylene CIS-(CHI0.045) (3) Poly acetyleneTrans-(CHI-0.045)are used. Out of these poly acetylene have highest shielding effectiveness. As the thickness of the polymer increases the shielding effectiveness increases. Compared to previous planar shields the shield has good and highest shielding effectiveness. Horizontal and vertical polarizations of the planar shield is also done .

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