SHIELDING EFFECTIVENESS OF DOUBLE SQUARE PATCHES REFLECTING AT 900 AND 1800 MHz FREQUENCIES

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Abstract

The shielding effectiveness of frequency selective surfaces (FSS) with double square elements reflecting at 900 Mhz and 1800 Mhz are analyzed using modal expansion techniques in this paper. Shielding effectiveness is obtained as the ratio of the total transmitted field component to incident field component. It is shown that shielding effectiveness, bandwidth and resonant frequencies are dependent upon the value of dielectric constant and incident angle for TE and TM polarized incident plane wave. Good agreement between our results and measured results in the literature verifies that double square FSS can be used to shield the sensitive devices from the noise caused by use of cellular phones at improper places and time.

I.INTRODUCTION

Recently cellular phones are used worldwide as convenient communication tools. The usage of cellular phone antenna is a big social problem because of its influence on environment, such as the influences on several electronic devices and the noise caused by use of cellular phones at improper places and time.

Electromagnetic pollution has been categorized as a new form of pollution as consequential as air and water pollution. Therefore an increasing attention has been devoted by scientific community to environmental problems related with the effects of electromagnetic fields. Various techniques have been implemented in order to shield the electric and magnetic field at microwave frequencies.

The ability to reflect the electromagnetic energy can be defined by shielding effectiveness. The shielding effectiveness depends on the frequency of the electromagnetic wave and the electromagnetic properties of the shielding material.

Sensitive electronic devices are being introduced into almost every facet of our daily life. There is a need for shielding, because radiation from GSM sources to sensitive environment is not desired. Cell phones and other radio sources produce interference which can cause equipment to malfunction in sensitive environment. This sensitive environment includes control systems, data-processing equipment, communications networks and medical electronic equipment like pacemakers, crib monitors, and electric wheelchairs. Electromagnetic interference disrupts the operation of electrical and electronic equipment, creating malfunctions and faulty readings.

Shielding the source of interference may be less expensive. However, it may not be applicable, because all interference sources must be shielded, otherwise the sensitive device will still be affected. Therefore the general approach is to shield the sensitive device, which will prevent interference from both present and future sources.

II. DOUBLE SQUARE FSS

An array of periodic metallic patches or apertures on a dielectric substrate constitutes a frequency selective surface to electromagnetic waves. Periodic array of metallic patches, capacitive FSS, is similar to a low pass filter and exhibits total reflection near the resonance wavelength. Such structures have been well known for half a century. Many technical publications on the interaction of electromagnetic waves in various structures of FSS are available in the literature. Various geometrical structures of the FSS have been studied extensively using numerical and analytical methods [1-10].

Electromagnetic scattering from such periodic structures has been studied for many years. According to Wu [5], modal expansion techniques are the most widely used methods for analyzing FSS. They can also be applicable in the low frequency region where the periodicity of the structure is small compared to the wavelength.

A design of a periodic array of metallic double square elements with high reflection at 900 MHz and 1800 MHz is presented in this paper. A similar procedure is used as the basis of numerical analysis for the thin, planar, perfectly conducting frequency selective surfaces modeled in Figure 1, as described by Chen [2], Montgomery [3], and Dawes [4].

The unknown reflected and transmitted fields are each expanded into an infinite series of Floquet modes with unknown coefficients. The integral representation of the reflection and the transmission coefficients are substituted for these unknown reflection and transmission coefficients, resulting in an integral equation. After imposing the boundary conditions, the field expansion is substituted into the integral equation. Using Galerkin's moment method, the integral equation is transformed into a matrix equation, and solved for using matrix inversion. Shielding effectiveness is then obtained as the ratio of transmitted field component to incident field component.

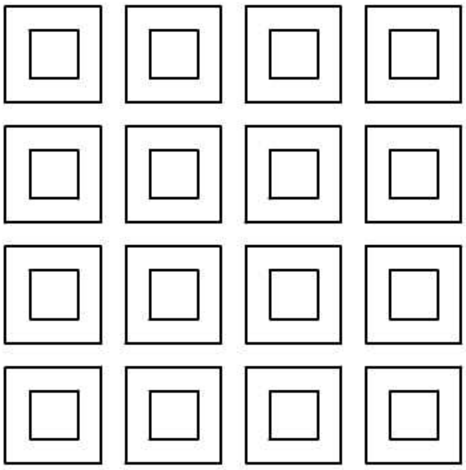

Figure 1. Periodic array of metallic double square patch elements.

The geometry of unit cell under consideration is shown in Figure 2.

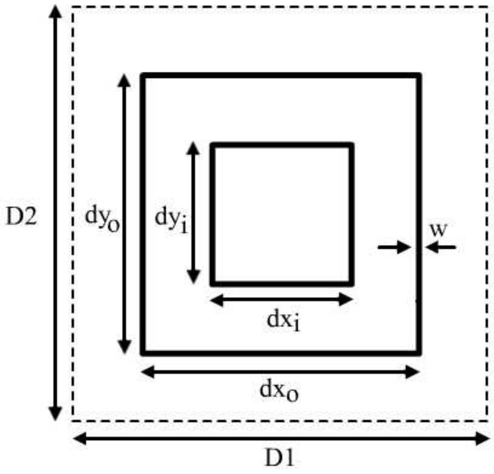

Figure 2. The geometry of unit cell

The frequency behavior of the FSS depends on the shape, size and spacing of the element, and on the thickness of the metallic screen. At frequencies of 900 Mhz and 1800 Mhz, metallic patches are assumed to be perfectly conducting and infinitely thin since the wavelength is much greater than the thickness of metallic patch. It should be pointed out that the incident field is considered to be a plane wave. The angle of incident and polarization is not restricted in this work.

III. FORMULATION

The modal expansion method is used as the basis of numerical analysis for the thin, planar, perfectly conducting frequency selective surfaces modeled in this paper.

The side view of the structure on a supporting substrate dielectric material is shown in Figure 3. In this figure, the first and third regions are free spaces and second region is the dielectric substrate.

The boundary conditions at the two plane interfaces as shown in Figure 3 are;

1) At z = 0, the continuity of tangential electric field components require that :

$$\vec{E}_1 = \vec{E}_2^+ + \vec{E}_2^-$$

On metal plates, the continuity of the tangential components of the electric field and magnetic fields yield

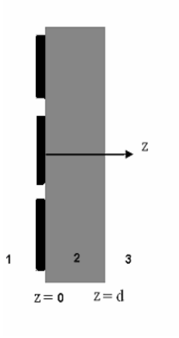

Figure 3. The side view of the structure on a supporting substrate dielectric material.

$$\vec{E}_{inc}(x,y,0)+\vec{E}_{ref}(x,y,0)+\vec{E}_{s}(x,y,0)=0$$

$$\vec{a}_{z}\times\left\{(\vec{H}_{2}^{+}+\vec{H}_{2}^{-})-\vec{H}_{1}\right\}=\vec{J}$$

where E_{inc} , E_{ref} , and E_s represent the incident, reflected and scattered electric fields, respectively.

2) At z = d, the continuity of tangential electric and magnetic field components require that:

$$\vec{E}_{3}=(\vec{E}_{2}^{+}+\vec{E}_{2}^{-})$$

$$\vec{H}_{3}=(\vec{H}_{2}^{+}+\vec{H}_{2}^{-})$$

Throughout the application of Floquet's theorem, the field in any other periodic cell will be related to the reference cell in terms of an exponential function. This field expansion is then substituted into the integral equation. Using Galerkin's moment method, the integral equation is transformed into a matrix equation in the following form, and solved using matrix inversion.

$$V_{n}=[E_{0}+E_{r0}]<\vec{f}_{n},\vec{\psi}^{*}>$$

$$[V_{n}]=[Z_{kn}][\alpha_{n}]$$

Where, V_n and Z_{kn} represent source and impedance matrices, respectively and α_n represents the unknown current coefficients to be solved.

The transmitted and reflected field components are calculated using a FORTRAN program and then the shielding effectiveness is obtained as the ratio of the transmitted field component to the incident field component using the following equation [11].

$$SE_{dB}=-20\log\left|\frac{E_{trans}}{E_{i}}\right|$$

IV. RESULTS AND DISCUSSIONS

A computer program was coded in FORTRAN and the numerical calculations are carried out for FSS shown in Figure 1 and 2. The permitivity of the dielectric, the angle of incidence and the polarization were varied in order to see their affects on the shielding effectiveness. Various values specifying the dimensions of the square loops were checked in order to obtain a good reflection at 900 MHz and 1800 MHz.

In Figure 4, the results are compared to experimental results in the literature for normal incidence [10]. It is seen from this figure that the results are in good agreement with experimental results.

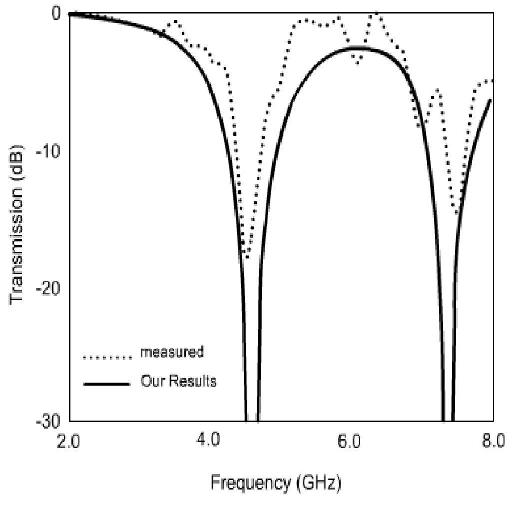

Figure 4. Comparison of our results to experimental results.

As previously stated, if the periodic elements within the FSS possess resonance characteristics, the inductive FSS will exhibit total transmission at wavelengths near the resonance wavelength, while the capacitive FSS will exhibit total reflection. This feature allows FSS with the proper elements to perform like a reflector at GSM frequencies.

It should be pointed out that the incident field is considered to be a plane wave. The angle of incidence and polarization are not restricted in this study. Polarization states are typically divided into the orthogonal TE (electric field perpendicular to the plane of incidence) and TM (magnetic field perpendicular to the plane of incidence) states.

In order to obtain a resonance characteristics at 900 MHz and 1800 MHz frequencies, the dimensions of double square patch element are chosen as follows: $d_{xo} = d_{yo} = 6.4$ cm, $d_{xi} = d_{yi} = 4.35$ cm, $w = 0.1$ cm, and $D_1 = D_2 = 7.0$ cm.

In Figure 5, the shielding effectiveness, for a TE polarized wave, is shown with incidence angle $\theta = 0$, and $\varepsilon_r = 1$, 2.1, and 5. The relative permitivity of the dielectric is varied in order to see its effect on the shielding effectiveness.

Figure 5 also shows that an increase in the relative permitivity of the dielectric, ε_r results in an increase in the shielding effectiveness. On the other hand, as ε_r increases the resonance frequency decreases. This is due to the loading effect of the dielectric. As pointed out by Wu [5], this decrease can also be obtained using the following relation.

$$f_o^{'} = \frac{f_o}{\sqrt{\frac{\varepsilon_1 + \varepsilon_2}{2}}}$$

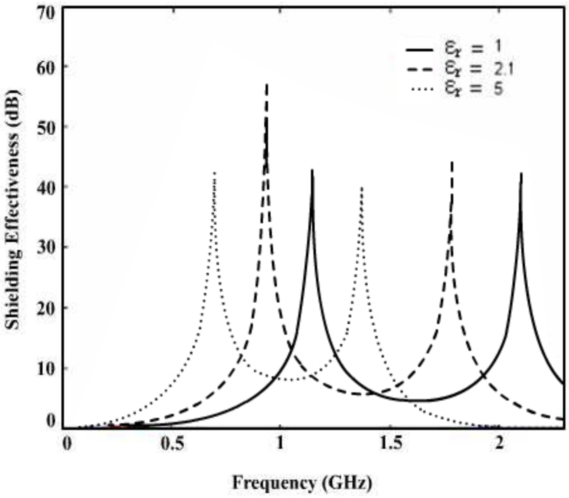

Figure 5. The effects of variations in the relative permitivity of the dielectric on shielding effectiveness for TE polarized wave ($\varepsilon_r = 1$, 2.1, and 5, at normal incidence).

In order to see the effect of incidence angle on the shielding effectiveness, incidence angle is varied and the results are plotted in Figure 6 for a TE polarized wave with $\varepsilon_r = 2.1$.

Due to the symmetry, the shielding effectiveness for a TM incident wave is the same as that of TE polarized wave when the incidence angle $\theta = 0$.

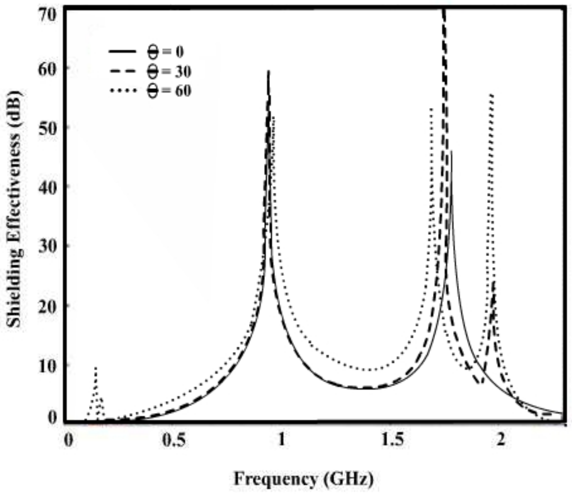

Figure 6. The effects of variations in the angle of incidence on shielding effectiveness for TE polarized wave ($\varepsilon_r = 2.1$, and incidence angle $\theta = 0^o, 30^o, 60^o$).

It is shown in Figure 6 that, as the incidence angle increases, new resonance occurs which is known as grating lobes. These lobes appear when the electrical length of the lattice becomes larger than one half of the free space wavelength [5].

As seen in Figure 7, varying the angle of incidence changes the resonance characteristics for TM polarized wave as in the case of TE polarized wave. These characteristics are bandwidth, resonance frequency and shielding effectiveness. However incidence angle influences the transmission characteristics of TE and TM polarized wave in opposite manner.

Upon comparison of Figures 6 and 7, it is apparent that as the incidence angle increases, shielding effectiveness, first resonance frequency and bandwidth increase for TE polarized wave. However, for TM polarized, first resonance frequency and bandwidth decrease as incidence angle increases. For the grating lobes the situation is quite different. An increase in incidence angle results in an increase in the resonance frequency and bandwidth.

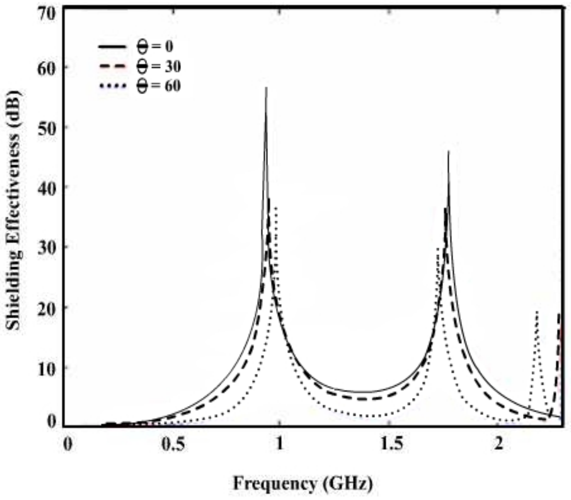

Figure 7. The effects of variations in the angle of incidence on shielding effectiveness for TM polarized wave ($\varepsilon_r = 2.1$, and incidence angle $\theta = 0^o$, 30^o, 60^o).

An arbitrary polarized wave can be considered as a combination of TE and TM polarized waves or as a circularly polarized wave. The effect of incidence angle for TE and TM waves is opposite, therefore the angular sensitivity is not very important since its effects reduce each other for an arbitrary polarized wave [10].

It has been shown that the shielding effectiveness of the structure described in this work is greater than 60 dB at 900 Mhz and greater than 40 dB at 1800 MHz. Such effectiveness can be classified as good shielding effectiveness. For shielding the GSM frequencies, this work describes an alternative scheme which is simple, practical, and involves no additional components. Additionally, good agreement between our results and measured results in the literature verifies that double square FSS can be used to shield the sensitive devices from the noise caused by use of cellular phones at improper places and time.

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