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OPTIMISATION OF JERUSALEM CROSS FREQUENCY SELECTIVE SURFACE

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***Abstract*— Frequency Selective Surfaces (FSS) are periodic structures in either one or two dimensions that perform a filtering operation. Bandwidth and frequency stability are the two important characteristics of a typical Frequency Selective Surface. The most important Frequency Selective Surface is called Jerusalem Cross Frequency Selective Surface (JFSS). In this paper a Jerusalem Cross FSS is modeled using infinite periodic boundary condition and excited with an incident plane wave to perform the optimization and observe the frequency dependent reflection and transmission coefficient of the filter using an electromagnetic simulator CADFEKO.**

***Index Terms*— CADFEKO, Jerusalem Cross, Optimisation, Plane wave excitation**

I. INTRODUCTION

Frequency Selective Surface came into operation during the early 1960’s even though they were discovered in 1919 by Marconi [1]. A lot of research is going on in this area since 1969. Most of the works concentrated on the use of an FSS in a cassergrain sub reflectors in parabolic dish antennas. But now FSS is employed in fields like military (Missiles), electromagnetic shielding applications etc.

The most commonly used frequency selective surface is called Jerusalem Cross Frequency Selective Surface which consist of two crossed dipoles placed over each other. Frequency stability of Transverse Electric (TE) and Transverse Magnetic (TM) polarized incident waves for a large angular spectrum is one of the unique feature of a Jerusalem Cross Frequency Selective Surface [2]. By using such frequency selective surface as the ground plane of an antenna the off axis radiation can be realized.

Some of the earlier works in this field include a journal paper by Prof Parker and his research team at Kent University which discuss the effect of conductivity on the performance of optically transparent conductor in which frequency selective surface was located on an opaque dielectric substrate.

When JSS is used over the ground plane, the current distribution is varied [3] and is used to reduce the interference and improve the efficiency. Another advantage is that when the number of unit cells are increased the bandwidth may be increased. They may also be employed to regain the broad band region of an antenna. These regions got affected while using traditional antennas such as log periodic. Optimisation is also achieved using a Jerusalem cross Frequency Selective surface.

Some of the advantages of this cross include the availability of more tuning parameters [4] as a result of which band pass transmission capability is enhanced and any choice of band stop frequency is achieved. Another advantage is that the same cross can be used to maximize the reflection and minimize the transmission at various frequencies [5]. Plane waves are used to calculate the near fields present inside the structure. Such plane wave excitations have infinite power and extent.

II. ANTENNA GEOMETRY

The Fig 1 shows the structure of a Jerusalem Cross Frequency selective surface.

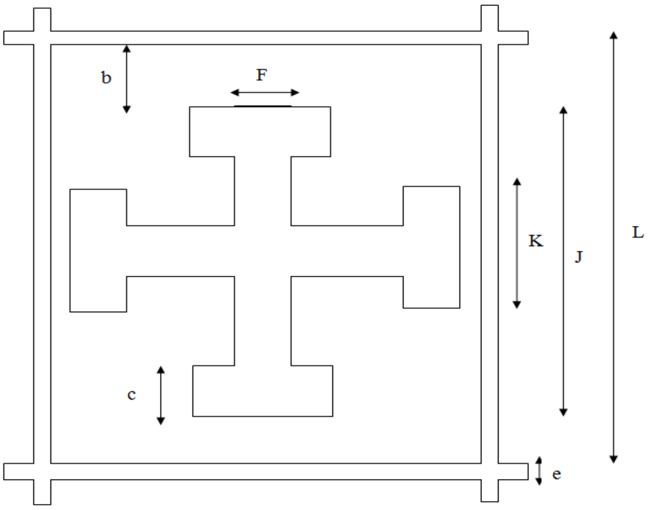


Figure 1: Structure of Jerusalem Cross Frequency Selective Surface

Let T be the thickness of the metal of a Jerusalem cross such that

$$T \ll e \quad (1)$$

$$T \ll F < L \quad (2)$$

$$c \ll L < \lambda \quad (3)$$

$$b \ll K < \lambda \quad (4)$$

A JSS of size 13.3 X 5.7 is used and the resonant frequency of operation is from 2-12 GHz. Table 1 shows the parameters for the design of a Jerusalem Cross Frequency Selective Surface.

Table 1 Parameters of the Jerusalem Cross Frequency Selective Surface

Parameters	h	w	D	J
Value (mm)	1.9	1.9	5.7	13.3

The equivalent circuit theory is used to model the frequency selective surface and is given by Fig 2 which shows a series LC circuit [8].

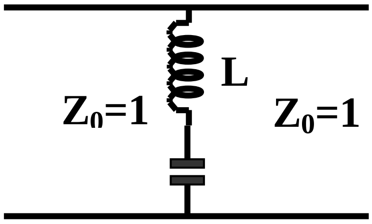


Figure 2: Equivalent Circuit Model

If L and C represents the Inductance and capacitance of the circuit then,

$$\omega L \approx \frac{L}{\lambda}\ln\left(\frac{2L}{\Pi\omega}\right) \qquad (5)$$

$$\omega C \approx \frac{4K}{\lambda}\ln\left(\frac{2L}{\Pi b}\right) \qquad (6)$$

& Impedance

$$Z = jX = j\left(\omega L - \frac{1}{\omega C}\right) \qquad (7)$$

At resonance,

$$\omega_r\sqrt{LC} = 1 \qquad (8)$$

$$f_r = \frac{1}{2\pi\sqrt{LC}} \qquad (9)$$

So at Resonance,

$$\lambda_r \approx 2\sqrt{LK\ln\left(\frac{2L}{\pi F}\right)\ln\left(\frac{2L}{\pi b}\right)} \qquad (10)$$

The power transmitted is given by

$$|T|^2 = 1 - |R|^2 = \frac{4X^2}{1+4X^2} \qquad (11)$$

This equation shows that inorder to optimize the power transmission in pass band value of X must be very large which implies that ωL and $\frac{1}{\omega C}$ must be large as possible [6]. But L and C should be compromised at the resonance condition.

Fig 3 shows the basic structure of a Jerusalem Cross Frequency Selective Surface simulated using CADFEKO software. The plane wave excitation is shown in the figure and the structure is enclosed inside a cuboid.

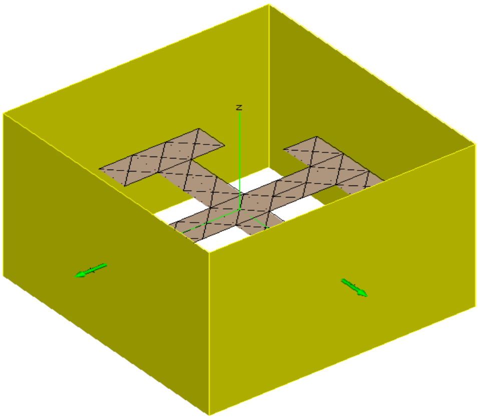
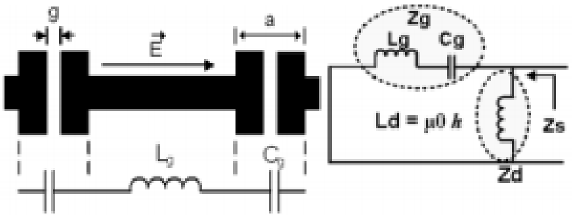


Figure 3: Geometry of a Jerusalem Cross FSS using CADFEKO

The stop band frequency range in a Jerusalem Cross Frequency Select Surface may be increased by increasing the value of K and F or by reducing the value of c and b [7]. The pass band and stop band comes closer by increasing the value of e or by reducing the value of b. The period of a FSS is chosen to be less than 0.5λ to avoid grating lobes [8]. Identical layers of FSS are stacked one over the other so that the attenuation of pass band and stoop band increases. Resonant frequency of FSS depends upon the medium where the FSS grid is placed [9]. When placed inside the dielectric the resonant frequency is reduced. Such FSS must be placed atleast $\frac{\lambda}{2}$ from the transmitting or receiving antennas to avoid coupling phenomena and to avoid dielectric separation. FSS grids must be placed $\frac{\lambda}{4}$ apart [10].

Fig 4 a) shows the structure of a unit cell of a Jerusalem Cross Frequency Selective Surface [8] and Fig 4b) its equivalent circuit to determine the resonant frequency of operation.



(a) (b)

Figure 4: a) JSS Unit Cell b) Equivalent Circuit

L_g represent the impedance at the ends. The charges gets built across the plates making them capacitive in nature. Resonant frequency is given by

$$f_r = \frac{1}{2\Pi\sqrt{(L_G + L_d)C_g}} \qquad (12)$$

III. RESULTS AND DISCUSSION

Fig 5 and 6 shows the plot of near field as a function of frequency (In GHz). The incident plane wave is of magnitude 1 V/m arriving at an angle θ =0. Hence these graphs represent the reflection and transmission coefficient of the Jerusalem Cross frequency Selective surface. The reflection and transmission coefficients can be used to calculate the reflected and transmitted powers by considering the plane wave to be incident normal to the surface of the Frequency selective surface. The magnitude of the scattered near field above the surface represent the reflection coefficient of the frequency selective surface and the magnitude of the near field below the surface represent the transmission coefficient of the frequency selective surface.

Reflection Coefficient is defined as

$$\text{Reflection Coefficient} = \frac{\text{Reflected field in } {}^{V}\!/_{m}}{\text{Incident field in } \frac{V}{m}} \qquad (13)$$

Transmission coefficient is defined as

$$\text{Transmission Coefficient} = \frac{\text{Transmitted field in } {}^{V}\!/_{m}}{\text{Incident field in } \frac{V}{m}} \qquad (14)$$

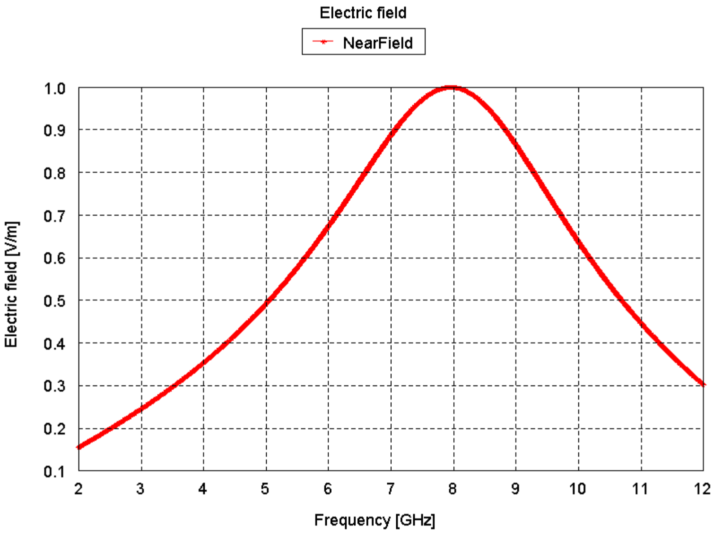


Figure 5: Magnitude of near field above the surface (Reflection coefficient).

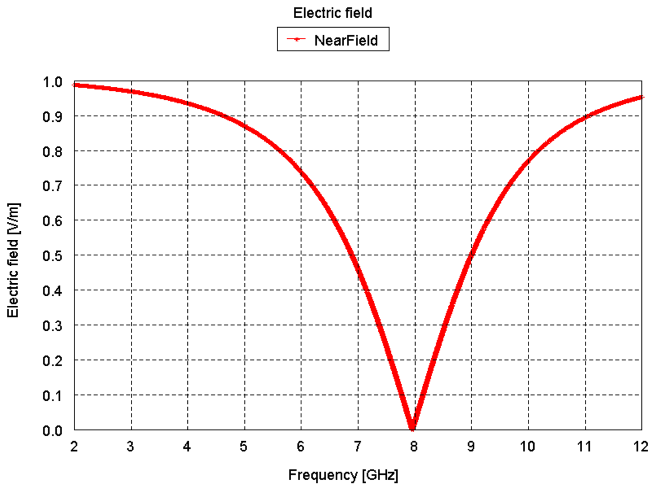


Figure 6: Magnitude of near field below the surface (Transmission Coefficient).

The near field is calculated at a distance of 10λ distance away from the surface. Boundary conditions are also defined so that elements are spaced evenly.Poynting vector represents the direction and density of power flowing through a surface at a particular point. It is given by

$$P = E \times H \qquad (15)$$

For periodic signals it is possible to calculate the average poynting vector and is represented as P_{avg}. For a time varying field the average poynting vector is defined as

$$P_{avg} = \frac{1}{T}\int_0^T P\,dt \qquad (16)$$

The average poynting vector may be expressed in terms of electric and magnetic field as

$$P_{avg} = \frac{1}{2}\mathrm{Re}\left[E(x,y,z)\ X\ H(x,y,z)^*\right] \qquad (17)$$

Fig 7 and 8 represents the average poynting vector of the periodic signals.

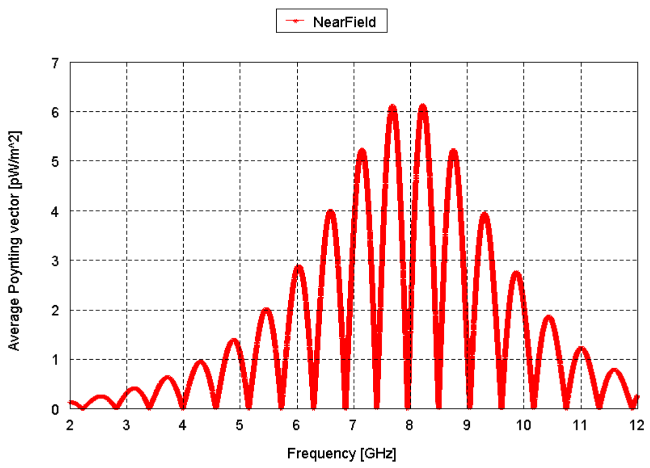


Figure 7: Average Poynting Vector for the near field above the surface.

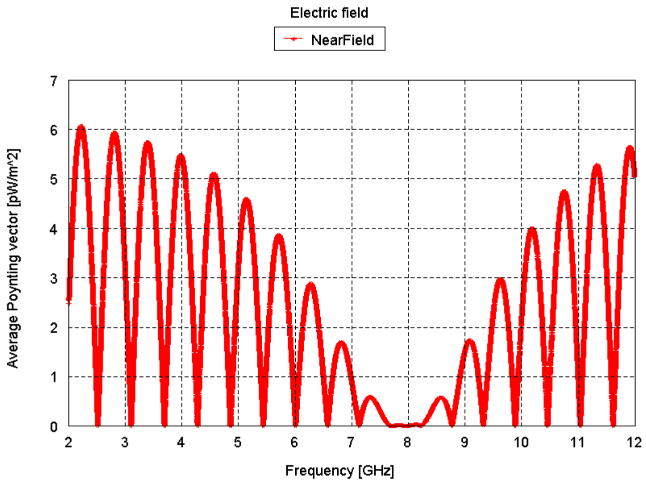


Figure 8: Average Poynting Vector for the near field below the surface.

IV. CONCLUSION

A Jerusalem Cross Frequency selective surface structure modelled using infinite periodic boundary conditions and plane wave excitation has been discussed. The various parameters like Reflection coefficient, Transmission coefficient and average poynting vector of the frequency selective surface have been plotted using CADFEKO. The various parameters are optimised so that the reflection coefficient attains its maximum value whereas the transmission coefficient reaches its minimum value.By increasing the number of unit cells the bandwidth may be improved and may be used in broad band antennas.

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