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Research Article

A Triple Band Pass Frequency Selective Surface for the Intensification in the Performance of C and X Band Applications

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Abstract

With the advancement in the wireless technologies where transmission of the microwave or radio frequency wave signals gains attentions, predominantly in residential areas where the number of wireless connected devices may increase exponentially. But due to several factors like path loss, propagation effects and interference led to signal degradation. However, these bands suffer large attenuations, so a band pass frequency selective surface has proposed in the paper that led to the intensification in the transmission of C and X band signal to reduce the effect of path loss. A single sided Teflon substrate has integrated with the square and three other elements which results in triple band (4.5 GHz, 7.5 GHz and 9.5 GHz) characteristics. The single sided substrate dielectric constant is 2.1 with loss tangent 0.0002 and thickness 1.6mm. With respect to different incident angles, offered structure had excellent band pass response as the structure is symmetrical and polarization independent. For evaluating the performance, the CST Microwave computer simulation is used.

Keywords: Triple Pass Band Frequency Selective Surface (FSS), Polarization Independent, C and X Band 4.5, 7.5 and 9.5 GHz Band

Introduction

With the encroachment in the wireless technology, the concern towards its security or transmission becomes much important. As the world is getting wireless so the transmission of the signals from one user to other without any distortion or losses becomes a matter of apprehension. So in order to overcome various interferences many researchers have investigated Frequency Selective Surfaces that are poised of periodic arrays and provide better frequency response in front of electromagnetic waves.

Frequency selective surfaces due to their pass band and stop band characteristics are used for many applications such as radomes, preventing WLAN intrusion, spatial filters for radar communication, absorbers, feeding antenna system etc. (5). For FSS applications in limited space, the element size and periodicity should be electrically small as large structure and periodicity leads to bothersome problems for curved surfaces (10).

Few other factors governs the stable frequency response of FSS such as the proposed design should be independent of incident wave, the dimension and the design parameters of the elements should be order half of the wavelength, the spacing between the elements, patch size, substrate thickness, conduction element length etc. Conventional FSS are easy to design and fabricate but have fluctuating frequency response due to sensitivity towards incident wave and polarization proliferation characteristics. In order to achieve stable frequency response various other geometry came into nimble like fractal, meander line geometry, 3-D FSS unit cell etc. Electromagnetic interference can cause breakdown or failure of electronic/ electrical equipment in susceptible environment. So shielding the sensitive device with 2-D or 3-D FSS rather than shielding the source

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of interference is the optimal solution (2). Many FSS configurations are listed in the literature for shielding and isolation. In communication environment where incident and polarization wave occur at different angles, so to achieve a good band stop FSS the symmetrical structure is preferable (3). A square patch FSS entrenched with magnetic absorbing substrate to improve the bandwidth of radar absorbers. Various dipoles provide WLAN shielding Whereas Minkowski fractal structure provides X-band shielding. The aperture type FSS show band pass characteristic whereas patch type FSS show band stop characteristics. In this paper we present a Tri-band pass FSS for C and X band applications. Various boundary conditions such as PEC, floquet port, PMC etc are applied on a single unit cell to obtain frequency response of FSS. For stable frequency response simulation of single unit cell is of prime importance. Number of methods is used for simulating FSS such as Method of Moment (MOM), Finite Element Method (FEM) and FDTD etc. Simulation of the proposed structure is carried out with the help of CST MW software that is based on FDTD method in frequency domain. The structure is symmetrical and polarization independent at various angles of incident.

Designing of Superstrate

Unit Cell

When interacting with electromagnetic waves a steady frequency response has achieved by specific arrangement of each element in the unit cell. A single sided Teflon superstrate with dielectric constant 2.1, thickness 1.6mm and dimensions W (mm) × W (mm) that is square shaped has used as shown in Fig. 1. It consist of a square loop and other three elements that are engraved on the metallic surface. A band of 4.5 GHz has obtained due to the pact of First Square whereas other bands 7.5 GHz and 9.5 GHz are due to the inner Circle and Octagon respectively as shown in Fig. 1.

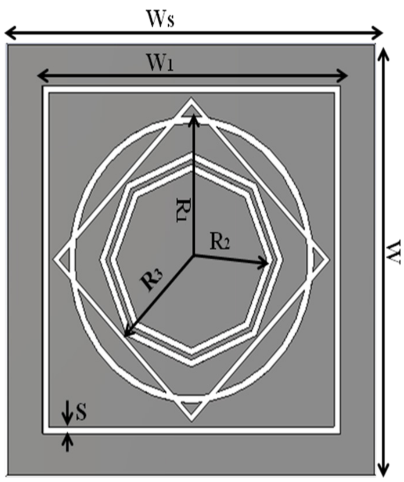

Figure 1.Front View of the Proposed Unit Cell with Dimensions

Table 1.Dimensions of Proposed Unit Cell

Name of Dimensions	Symbols	Values in (mm)
Width of substrate	Ws	18
Width of square	W1	7.3
Radius of outer Circle	R1	6
Radius of Outer Octagon	R2	4.5
Radius of Inner Octagon	R3	4
Thickness of the Substrate	H	1.6
Spacing between the Inter Elements	S	0.3

Finite Array

An array of 8x8 element of dimension WsxWs has been designed after simulating the structure. Elements are repeated in both X and Y directions that consist of periodicity P as illustrated in Fig. 2 and Table 2. Other parameters of unit cell remain same.

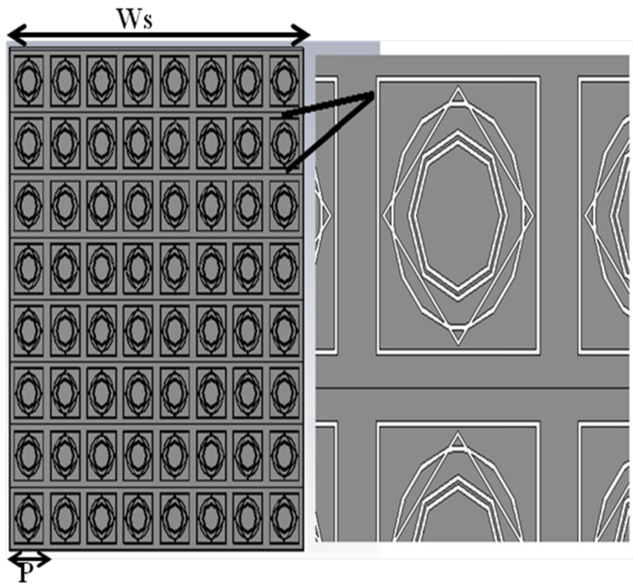

Figure 2.A 8x8 finite Array of Unit Cell with Periodicity P

Table 2.Dimensions of Proposed Finite Array

Name of Dimension	Symbol	Value (in mm)
Width of Substrate	W_s	72
Height of Substrate	H	1.6
Periodicity	P	18

Results and Discussion

Insertion Loss of Unit Cell

Various boundary conditions are used to simulate the proposed design to calculate its frequency response. Due to the proper and specific arrangement of the elements of the unit cell, the structure works as band Pass for three bands 4.5, 7.5 and 9.5 GHz for C and X band applications. Simulation of the unit cell has carried out to calculate the insertion and return losses, which depicts how much power has transmitted and reflected by the structure respectively both in TE and TM wave modes. Transmission coefficient at 4.5 GHz, 7.5 GHz and 9.5 GHz having insertion loss of -.16 dB, -.63 dB and -.05 dB respectively in TE wave mode has shown in Fig. 3. A good insertion loss for band pass in both TE and TM wave modes has achieved as shown in Fig. 4.

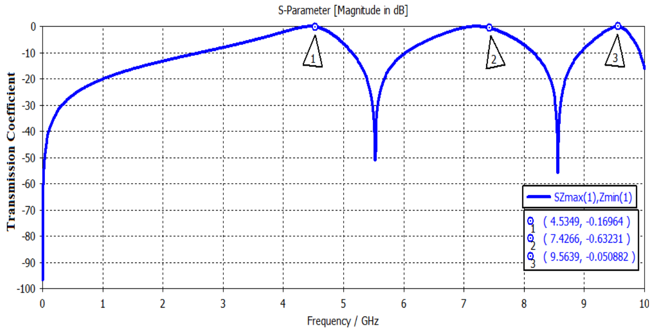

Figure 3.Insertion Loss of Unit Cell in TE Mode

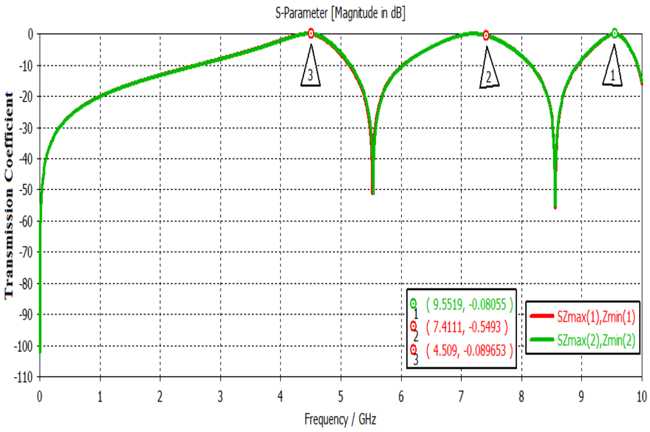

Figure 4.Insertion Loss of Unit Cell in TE and TM Mode

Absorption, Reflection and Transmission

Absorption, Transmission and reflection are the three main features of FSS. Absorption (A) is calculated from following equation:

$$A=1-|S_{21}|^2-|S_{11}|^2$$

Where, A = Absorption,

$|S_{21}|$ = Transmission Parameter

$|S_{11}|$ = Reflection Parameter

Absorption reveals that the signal is neither transmitted nor reflected.

Fig. 5 illustrate that 98% of signal is transmitted at 4.5 GHz 7.5 GHz and 9.5 GHz and only 2% signal is absorbed.

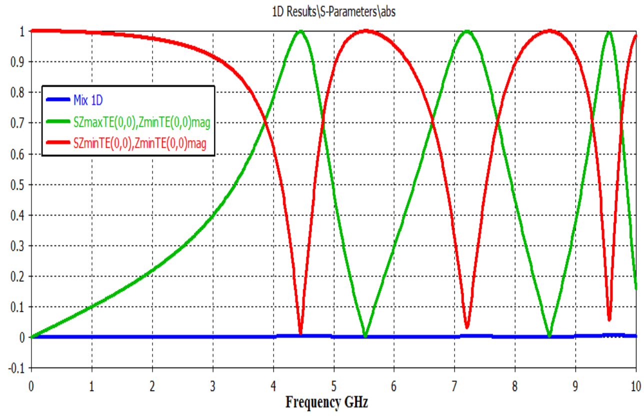

Figure 5.Transmission Absorption and Reflection of Unit Cell

Incidence Angle Variation

Electromagnetic waves strike the FSS at any angle when kept in space. Therefore, incident angles acts an imperative parameter while calculating the frequency response of the filters as its discrepancy can influence its stability. In band pass FSS the important parameter is transmission coefficient. Fig. 6 depicts the variation in incident angle for TE mode from 0 to 75 degree. By carrying out simulation, different resonant frequencies (4.5 GHz, 7.5 GHz and 9.5 GHz) for Pass band have achieved but as we increase the frequency the stability is affected. For a structure to be angularly stable the design and geometry plays a vital role. As the proposed structure is symmetrical and polarization independent a stable frequency response at frequency 4.5 GHz, 7.5 GHz and 9.5 GHz at 0 and 90 degree has achieved as illustrated in Fig. 7.

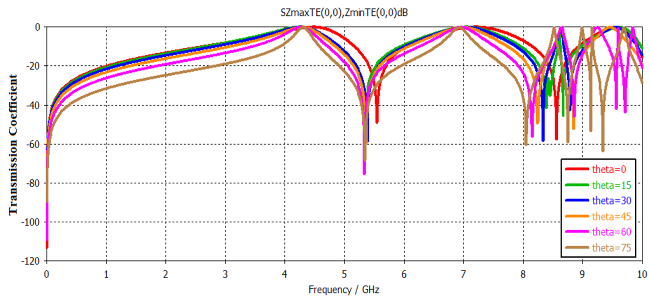

Figure 6.Incident Angle Variation of Unit Cell

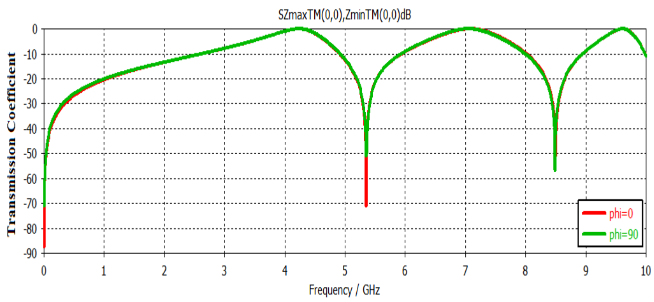

Figure 7.Phi Variation of Unit Cell

Surface Current

Which element is responsible for the resonating frequency of FSS is calculated by Surface current. Mutual coupling holds great importance while calculating surface current of FSS. At the edge of the first square 4.5 GHz, has its maximum surface current as shown in Fig. 8. Due to mutual effect of inner Circle and a Square, a 7.5 GHz has its maximum surface current as shown in Fig. 8 and utmost effect has seen at the periphery of inner and outer octagon at 9.5 GHz shown in Fig. 9.

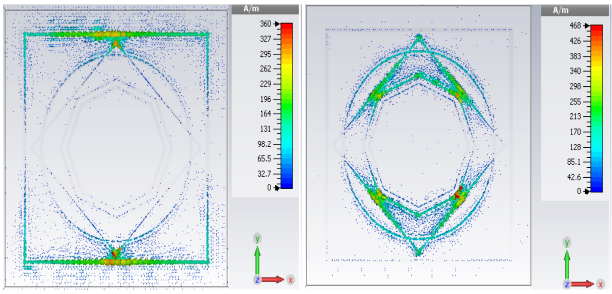

Figure 8.Surface Current of Unit Cell at 4.5 GHz and 7.5 GHz

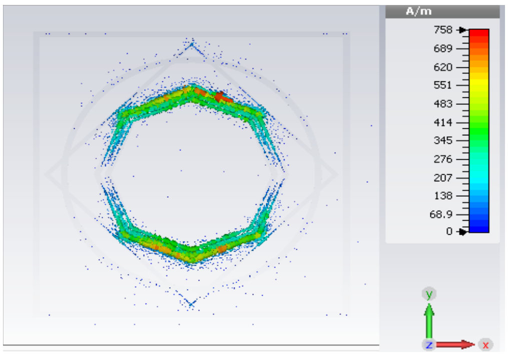

Figure 9.Surface Current of Unit Cell at 9.5 GHz

Parametric Variations of Unit Cell

- **Outer Square**

Parametric variation holds great attention while calculating the frequency response of unit cell, as it tell at what value the structure will resonate to the desired frequency. Fig. 10. depicts that on varying the parameters of First Square, a shifting towards higher side has observed. Therefore for the desired frequency response at 4.5 GHz the value listed in table is well thought-out.

- **Inner Circle**

Parametric variation holds great attention while calculating the frequency response of unit cell, as it tell at what value the structure will resonate to the desired frequency. Fig. 11. depicts that on varying the parameters of Inner Circle, a shifting towards higher side has observed. Therefore for the desired frequency response at 7.5 GHz the value listed in table is well thought-out.

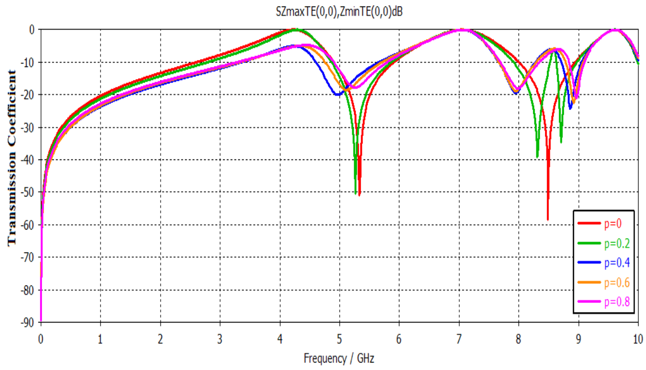

Figure 10.Insertion Loss of Unit Cell due to the Variation in the Parameters of Outer Square

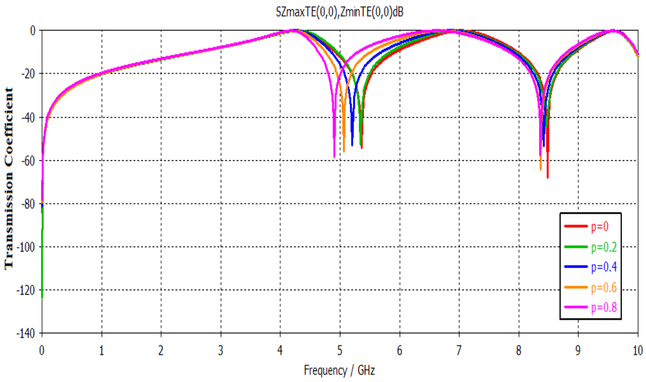

Figure 11.Insertion Loss of Unit Cell Due to the Variation in the Parameters of Inner Circle

Conclusion

A pass band operation for C and X band application has achieved. The structure has polarization independent characteristics and less angularly stable as we increase the angles for the resonating frequency. In order to get stable frequency response the geometry and inter element spacing holds great attention. As we increase the spacing in either of the side of unit cell, the bandwidth is affected. A pass band frequency response of 4.5 GHz, 7.5 GHz and 9.5 GHz has obtained. The structure has been simulated using CST Microwave studio using tetrahedral mesh in frequency domain to cover the entire structure. Simulation processing time can be reducing by simulating only single unit cell. In future, this structure would further extended for various radar and satellite applications and can be simulated in various other softwares like ANSYS HFSS.

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