A Novel Miniaturized Frequency Selective Surface with Stable Performances

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Abstract— A novel stable miniaturized band-reject frequency selective surface (FSS) is proposed in this paper. Compared to previous miniaturized structures, the dimension of the proposed FSS unit cell is only $0.050\lambda_0 \times 0.050\lambda_0$ where λ_0 represents the wavelength of the resonant frequency. And characteristics of the new structure are stable with respect to waves with different polarizations and incident angles. Simulation of structure with different parameters is also taken, and the results demonstrate the claimed performance and the possibility of better miniaturization by changing the parameters of the structure. Thus, the proposed structure is suitable for practical application in limited space.

1. INTRODUCTION

Frequency selective surfaces (FSS) which can be widely used as shielding, antenna reflectors, spatial filters, radomes and electromagnetic absorbers, are usually formed by two-dimensional array of metallic patterns printed on a dielectric substrate or etched out of a conductive layer [1]. The array is usually considered to be unlimited in dimension when it is analyzed and simulated. However, the dimension of array is usually limited in dimension in practical measurements and applications. So the enough minituration of FSS that can make the finite FSS perform the characteristics of the original infinite one is very meaningful [2].

Recently, different methods have been used to design the miniaturized FSSs which are much smaller than the wavelength of the resonant frequency. Substrate integrated waveguide (SIW) technology is used to realize a low frequency miniaturized dual-band FSS with close band spacing in [3]. Lumped reactive components can provide a new methodology for miniaturized FSS [4]. Furthermore, utilizing new structures in single-layer and multi-layer FSSs is still an important method for miniaturization of FSS such as the new structure proposed in [5].

In this letter, a new type of miniaturized FSS is proposed, which is composed of a pattern of Y-type metallic spiral strips and a dielectric substrate. Compared with traditional Y-type FSS, it has better miniaturation and better stability with respect to different polarizations and incident angles. The effects of varying the distances between strips, the widths of strips and the relative dielectric constant of the dielectric substrate are analyzed. The results demonstrate good performance of the proposed miniaturized FSS. Moreover, the miniaturization can be further improved by adjusting the parameters.

2. FSS STRUCTURE AND ITS PERFORMANCES

2.1. FSS Structure and Its Transmittances

The structure of the unit cell is presented in Fig. 1 and the FSS array is shown in Fig. 2. The spiral structure can increase the equivalent inductance and capacitance which means the resonant frequency will decrease. Parameters of the structure are defined as follows: length of the metal strips of the first rank $D = 3.7$ mm with the width $y = 0.2$ mm, gap for the metal strips on the dielectric substrate $w = w_1 = w_2 = w_3 = w_4 = w_5 = w_6 = 0.2$ mm and $w_7 = 0.1$ mm, gaps between each strip $g = 0.02$ mm, dielectric substrate height $h = 1.6$ mm, relative dielectric constant $\varepsilon_r = 2.65$ and loss tangent $\tan\delta = 0.025$.

It can be observed from the Fig. 3 that the transmission coefficients are almost same for perpendicularly incident waves of different polarization and the resonant frequency is 2.44 GHz. So the dimension of the equal area square unit is $0.050\lambda_0 \times 0.050\lambda_0$ where λ_0 represents the wavelength of the resonant frequency. The results also show the great stability of incident waves with different polarizations.

2.2. Angle Stability and Polarization Stability

Practical application of the FSS usually requires the stability of the FSS with respect to waves of different incident angles. Transmission results under different incident angles of both polarizations are simulated and results are shown in Fig. 4. It can be observed that there is no resonant frequency

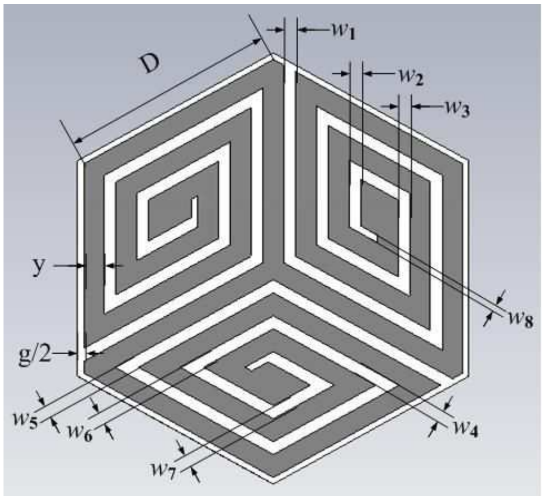


Figure 1: Structure of a unit cell.

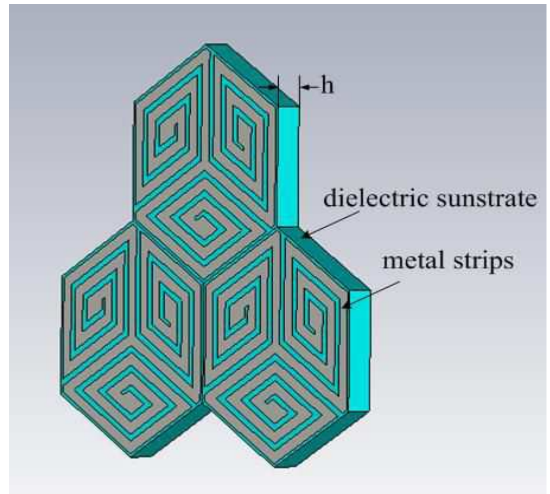


Figure 2: Structure of the FSS array.

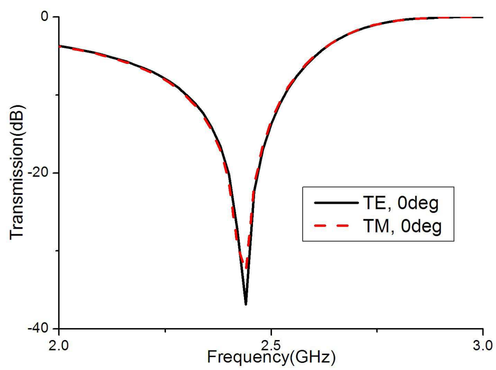


Figure 3: Transmission of the FSS for normal incident waves.

deviation when the incident angle is less than 60° for both polarizations. Therefore the proposed FSS performs excellent polarization and angle stability. It can be applied in the shielding wall to prohibit the transmission of the WiFi, BlueTooth and one of the WLAN band.

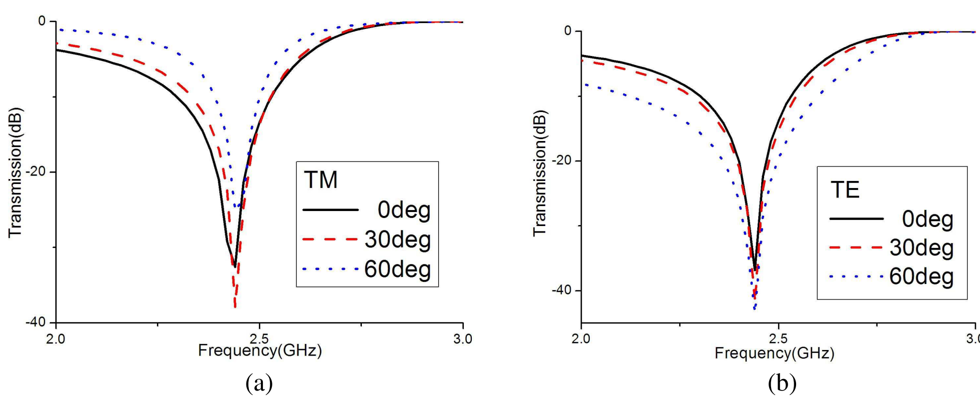
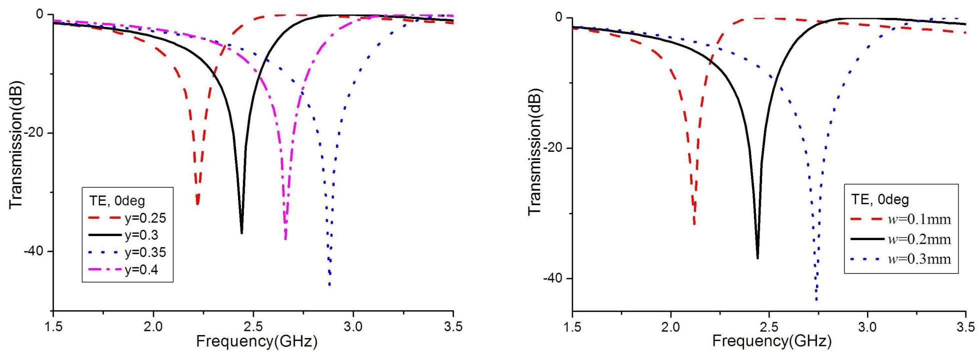


Figure 4: Transmission coefficients of the FSS of different incident angles. (a) TE-polarized. (b) TM-polarized.

2.3. Effects of Parameters

1) Width of strips: Transmission coefficients of different widths of metal strips are presented in Fig. 5(a). It can be observed that the resonant frequency varies significantly due to the change of metal strips width value. In this paper, y is taken as 0.3 mm to satisfy the requirement for the bandwidth.



(a) (b)

Figure 5: Transmission coefficients of the FSSs with different parameters for normal TE-polarized waves. (a) Widths of strips for normal TE-polarized waves. (b) Distances between strips.

2) Distance between strips: Distance between strips can not only affect equivalent capacitance of a unit cell but also affect equivalent inductance by changing the total length of the strips while other conditions are fixed. Simulations for the proposed structures with different distances between strips are done and the results are presented in Fig. 5(b). It can be seen that with the decrease of distance between strips, values of the resonant frequency decrease significantly. However, as the distance gets smaller the bandwidth also gets smaller. So, when it is utilized in a practical situation, the distance between strips should be controlled so that requirements of both miniaturization and bandwidth can be satisfied.

3) Relative dielectric constant: The dielectric substrate can help improve the miniaturization performance. Resonance of stop-band shifts to lower frequency with the increase of the relative dielectric constant. So the structure proposed in this paper can be further miniaturized. However, it can also be seen in the Fig. 6 that the insertion loss will also raise due to the increase of the

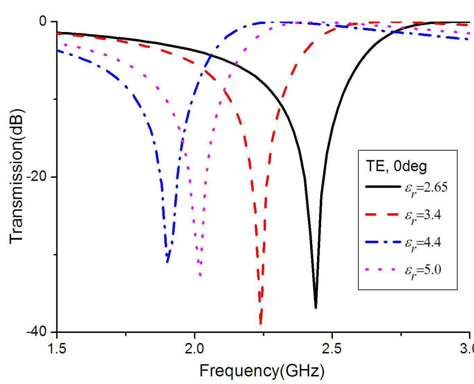


Figure 6: Transmission coefficients of the FSSs of different material permittivity.

Table 1: Results of comparison to other FSSs.

ε_r	FSS structure	Unit cell size
2.65	structure in [5]	$0.077\lambda_0 \times 0.077\lambda_0$
	structure proposed	$0.050\lambda_0 \times 0.050\lambda_0$
3.4	structure in [6]	$0.086\lambda_0 \times 0.086\lambda_0$
	structure proposed	$0.046\lambda_0 \times 0.046\lambda_0$
4.4	structure in [7]	$0.063\lambda_0 \times 0.063\lambda_0$
	structure proposed	$0.041\lambda_0 \times 0.041\lambda_0$
5	structure in [8]	$0.088\lambda_0 \times 0.088\lambda_0$
	structure proposed	$0.039\lambda_0 \times 0.039\lambda_0$

relative dielectric constant.

To prove the excellent miniaturization of the proposed structure, comparison of different structures proposed in previous papers is carried out and the results are presented in Table 1. From the Table 1, it can be observed that the proposed FSS exhibits better miniaturization characteristic.

3. CONCLUSION

A novel miniaturized band-reject FSS is proposed in this paper. This novel miniaturized structure not only shows the great miniaturization with the dimension of the unit cell which is only $0.050\lambda_0 \times 0.050\lambda_0$, but also presents excellent stability with respect to different polarizations and incident angles. It can prohibit the transmission of the WiFi, BlueTooth and one of the WLAN band. Moreover, effects of varying width and length of strips, distance between strips and the relative dielectric constant of the dielectric substrate are analyzed. The results prove great characteristics of the structure. Thus, the proposed FSS is suitable for piratical applications, especially in limited space.

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