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Research Article

A Polarization Insensitive Triple Band Reject Frequency Selective Surface for the Reduction of Radar Cross Section

Monika Garg[1], Shweta Garg[2], Sanjeev Yadav[3], Rekha Chahar[4]

[1,2,3,4]Government Women Engineering College Ajmer, India.

Abstract

In this work, a novel polarization insensitive Frequency Selective Surface (FSS) has been proposed that employed reflection characteristics at selective frequency bands. In its designing, three different shape loops are preferred that is square, dodecagon and octagon shaped elements and these loops are embedded on the Teflon substrate, which worked as band reflective filter for the three frequency bands that are 3.6 GHz, 8.4 GHz and 11.4 GHz to reduce the radar cross section in X-band. Teflon material has qualitative properties that it has very low loss tangent of 0.0002 and dielectric constant of 2.1 and size of substrate is 0.18 λ x 0.18 λ. The designed FSS has been simulated and analyzed through CST Microwave studio. This work will employ band reject characteristics for 3.6 GHz, 8.4 GHz and 11.4 GHz frequency band. The simulated results have stable resonant frequency response for both TE and TM mode that prove the polarization independent behavior of the projected FSS.

Keywords: Dodecagon, Frequency Selective Surface (FSS), Octagon, Polarization Independent, Triple Band Reject, Radar Cross Section, X-band

Introduction

In the study of Radar Cross Section (RCS), antenna has greater endowment at a low observable platform. Therefore, it is a essential to reduce the RCS of antennas. Earlier to overcome the problem the stealth technology or low-observable technology that is basically refers to the technique of making the target less observable or ideally invisible to the enemy's radar detection system.[1,2] But the effective way to avoid this problem is design a band reject frequency selective surface that is ideally suited for Radar Cross Section (RCS) reduction of various strategic targets and objects, which ultimately help in reducing the detection range of these objects.

Frequency Selective Surfaces (FSS) are periodic structures in 2D or 3D that is worked as spatial electromagnetic filters in microwave engineering that produces very good filtering characteristics for the specific frequency bands. In the assembly of these spatial EM filters, periodic array of slots or patches with different shapes can be design on different substrate with their specific dielectric constant and tangent loss. It will employ as a different types of filters these are band pass, band stop, low pass or high pass spatial filters. These FSS structures can provide work in wide applications such as antenna, radar, millimeter wave communication system, energy saving, microwave lenses, radio astronomy, Electromagnetic Interference (EMI) reduction, cellular communication systems radomes and satellite communications.

In this work, a FSS is designed that incorporates three metallic loop elements of different shapes inbuilt on Teflon substrate which have very low loss tangent that is 0.0002. This FSS structure is designed to stop the three resonant frequency bands these are 3.6 GHz, 8.4 GHz and 11.4 GHz.

Corresponding Author: Monika Garg, Government Women Engineering College, Ajmer, Rajasthan, India.
E-mail Id: mgmonikagarg58@gmail.com
Orcid Id: http://orcid.org/0000-0002-4649-5390
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This FSS worked for X-band and this frequency band has wide applications for maritime civil and military navigation radars. This frequency band makes their attraction for defense tracking, weather monitoring and air traffic control and vehicle speed detection for law enforcement.

Design of the Projected FSS Unit Cell

Unit Cell

The proposed FSS unit cell demonstrated in Fig. 1 is designed for the reduction of radar cross section in X-band. The designed FSS structure is constructed over a Teflon substrate of height 1.6mm, dielectric constant of 2.1 and loss tangent of 0.0002. The unit cell of presented FSS has three loops including square, dodecagon and octagon shaped loop on the top of square shaped teflon substrate. In this design, a triple band reject characteristics has obtained for the reduction of radar cross section in X-band at frequency 3.6 GHz, 8.4 GHz and 11.4 GHz with effects of mutual coupling of each loop. The dimensions of the unit cell of FSS are mentioned in Table 1.

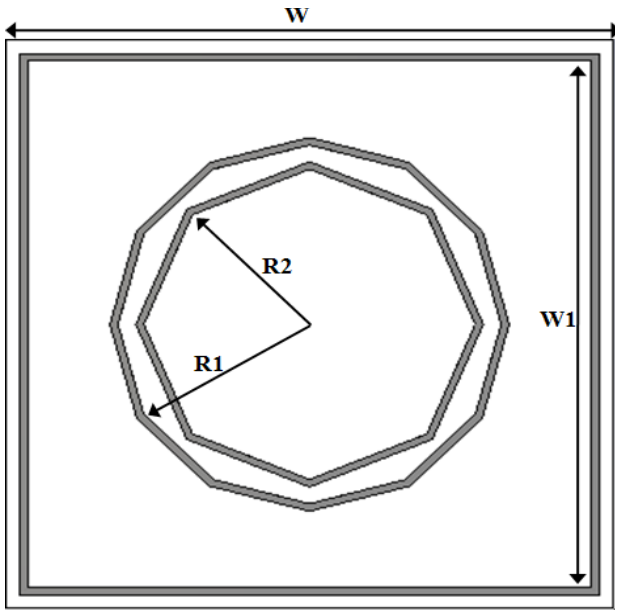

Figure 1.Front View of the Projected Unit Cell FSS

Table 1.Specification of Presented Unit Cell

Name	Symbol	Value in (mm)
Substrate width	W	15
Width of square loop	W1	13.9
Radius of dodecagonloop	R1	4.73
Radius of octagon loop	R2	4.09
Width of individual patch	S	0.2
Height of substrate	H	1.6

Design of Finite Array (8X8) FSS

An 8X8 array element structure of the proposed FSS unit cell has designed with length and width Ws (mm) x Ws (mm) and periodicity P in both X and Y direction as specified in Table 2 and Fig 2.

Table 2.Specifications of Presented FSS Array

Dimension's Name	Symbol	Value (in mm)
Width of substrate	Ws	120
Height of the substrate	H	1.6
Periodicity	P	15

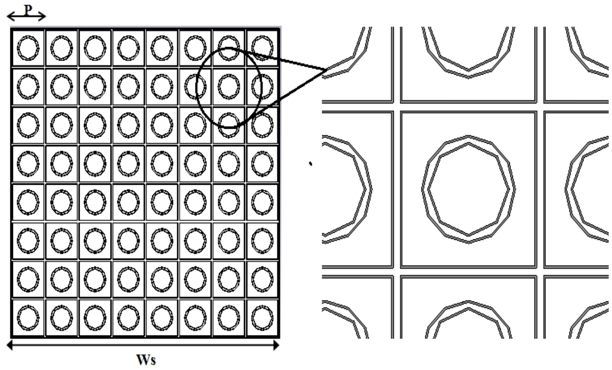

Figure 2.Front View of the Finite Array of FSS

Results of Proposed FSS

Simulated Results of Unit Cell of FSS

The projected FSS has been realized by using the CST Microwave studio software. The insertion loss or transmission characteristics has demonstrated the rejected power at frequency band 3.6 GHz, 8.4 GHz and 11.4 GHz with attenuation of -61 dB, -40 dB and -51 dB respectively. It is shown in Fig. 3.

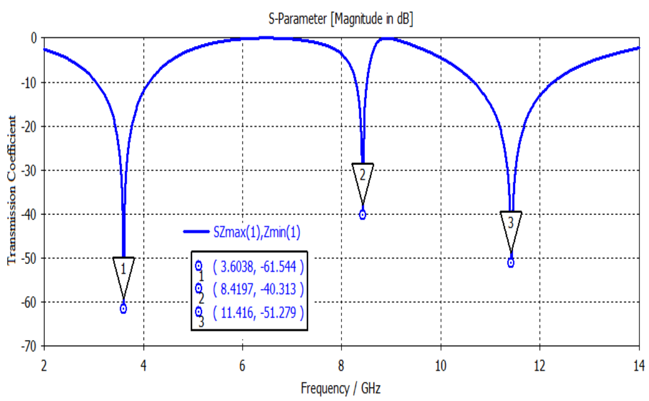

Figure 3.Simulated Transmission Coefficient (S21) of Unit Cell

From Fig. 4, it has verified that the frequency response for the designed FSS have ignorable change in the frequency bands which led to stability for resonant frequency response in both TE and TM mode.

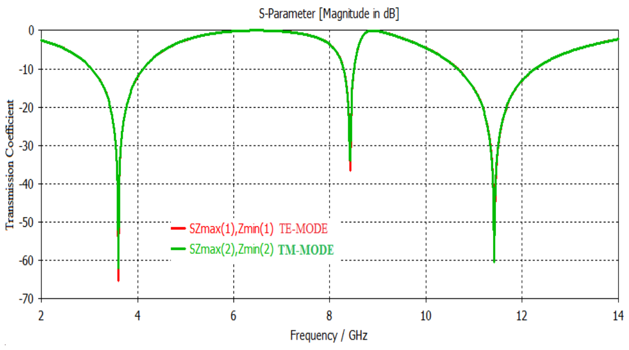

Figure 4.Simulated Transmission Coefficient (S21) FSS for TE and TM Mode

Surface Current

At resonant frequency 3.6 GHz, surface currents has its effects on each element but the maximum effect is on the edges of square loop shown in Fig. 5.

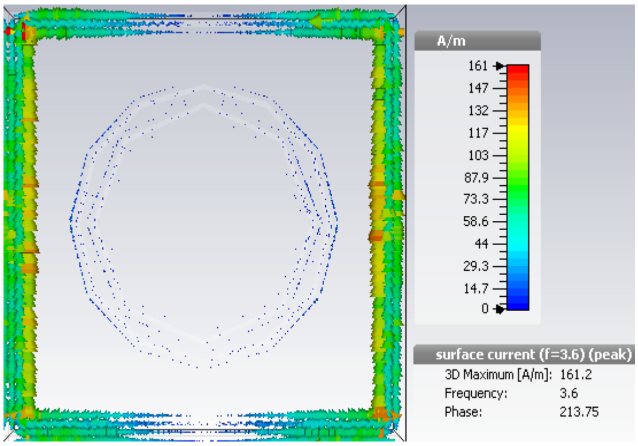

Figure 5.Surface Current for Frequency 3.6 GHz

In the same way, it can be seen for resonant frequency 8.4 GHz and 11.4 GHz from Fig. 6 and Fig. 7. Maximum effect of surface current has observed on the dodecagon and octagon loop respectively. There is also some effects on each other due to mutual coupling.

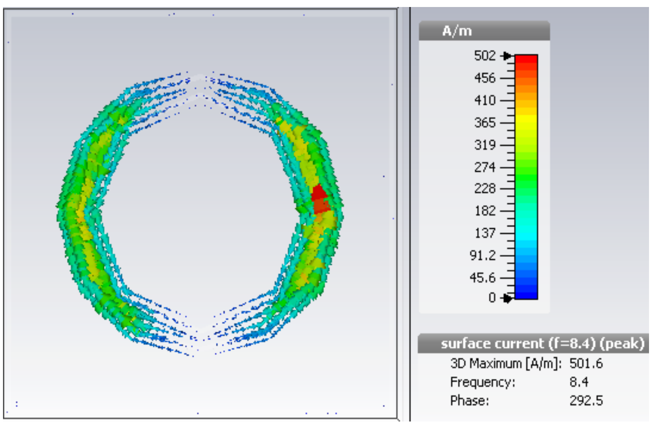

Figure 6.Surface Current for Frequency 8.4 GHz

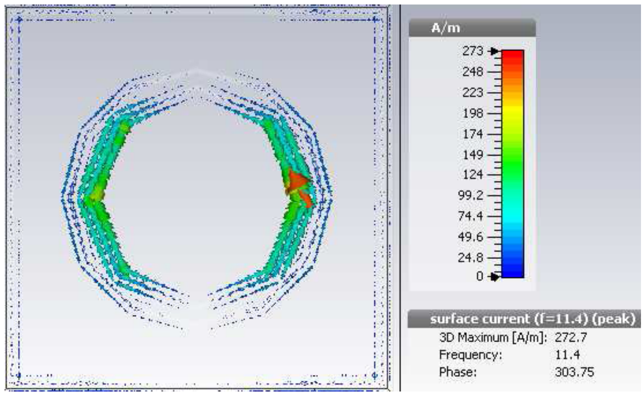

Figure 7.Surface Current for Frequency 11.4 GHz

Incidence Angle Variation (Theta = 0° to 75°)

Fig. 8 is demonstrated the stability of resonant frequency band with respect to incident angle variation from 0º to 75º. The transmission coefficient is stable for the lower frequencies and a small shifting for the higher frequency response, which is negligible.

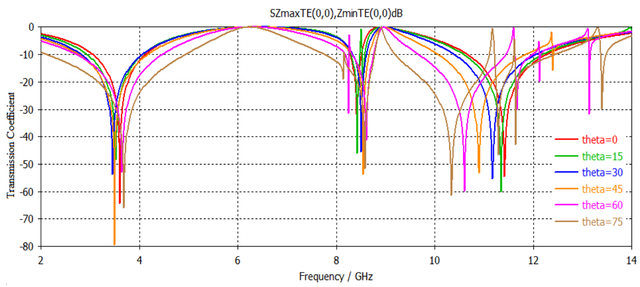

Figure 8.Incident Angle Variation (theta = 0° to 75°)

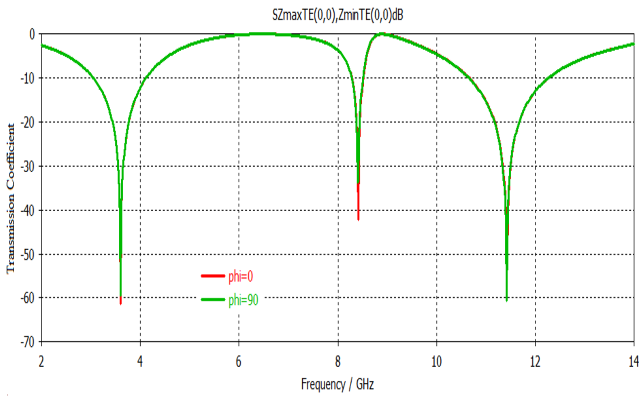

Figure 9.Incident Angle Variation for Phi = 0° and 90°

From Fig. 9, it has been observed that the transmission coefficient (S21) has stable response for the incident angle (phi=0º and 90º). Therefore, the projected FSS is polarization independent for both TE and TM modes due to the symmetrical structure.

Absorption, Reflection and Transmission

Fig. 10 is illustrated that More than 99% of the microwave signal is reflected at the band reject frequency 3.6 GHz, 8.4 GHz and 11.4 GHz and remaining signal is transmitted or absorbed. Here, Absorption characteristics (A) is calculated through this formula:

$A = 1 - |S11|^2 - |S21|^2$

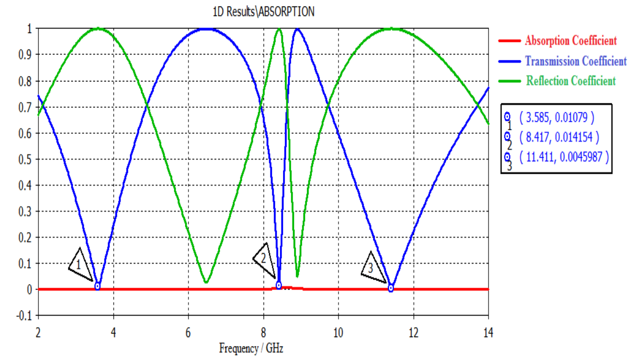

Figure 10.Simulated Results for Reflection and Transmission and Absorption of Proposed FSS

Parametric Variations

On varying the width of square loop, the frequency is shifting towards higher side for 3.6 GHz that is shown in Fig. 11. Moreover, there is also varying the frequency response of 8.4 and 11.4 GHz band due to mutual effects of each other loop on each other. Therefore, the optimum width of the square loop has considered according to this frequency band.

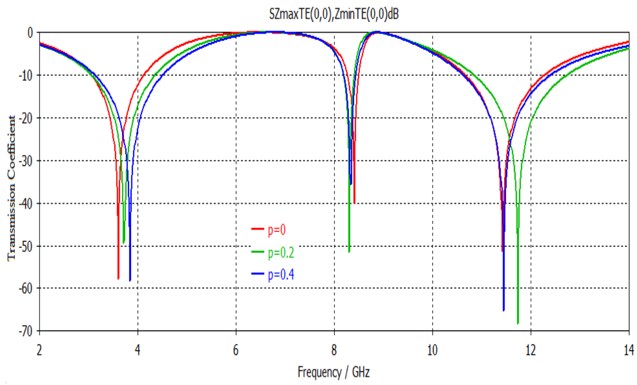

Figure 11.Variations in Width of Square Loop

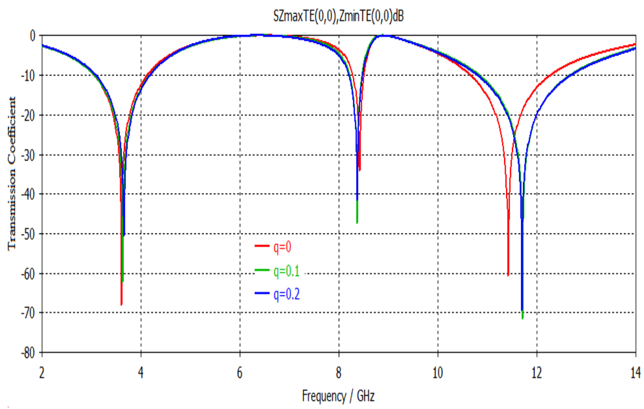

Figure 12.Variations in Radius of Dodecagon Loop

Similarly on varying the radius of dodecagon and octagon loop, there is become shifting in the frequency band 8.4 GHz and 11.4 GHz that is demonstrated in Fig. 12 and Fig. 13 Therefore, the optimized radius of these two elements are taken with the consideration of the mutual effects on each other.

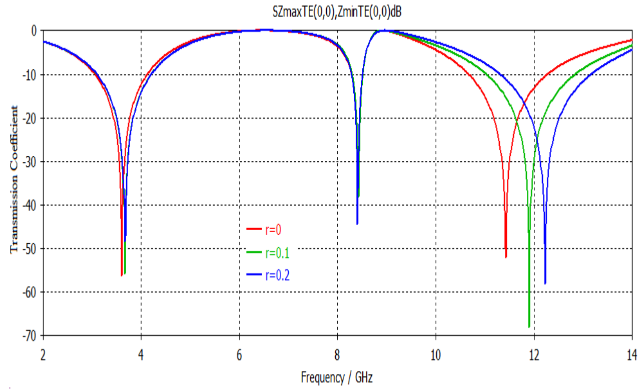

Figure 13.Variations in Radius of Octagon Loop

Conclusion

A simple frequency selective surface has been proposed for the reduction of radar cross section in X-band. The designed FSS structure is work as bandstop filter which is realized by CST Microwave studio. The proposed FSS is designed with the help of parametric analysis at different shapes and sizes of the patches. The simulated results of the projected FSS have verified that structure is insensitive to both incident angle and polarization. This stability of the frequency response for the variations of incident angle in both TE and TM mode is shown. In future, it can be extend to other broadband and multiband applications.

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