A Dual-Band Frequency Selective Surface Structure with Stable Performance for Oblique Incidence

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Abstract

In this paper, a dual-band band-stop Frequency Selective Surface (FSS) is presented. The proposed FSS structure consists of symmetric F-type resonators placed on opposite sides of dielectric substrate. The aim of this structure is to block two different frequency bands which are close together, while allowing the remaining band in the 12-20 GHz frequency range to pass. The effects of the design parameters on the FSS structure and the response of the design against the incidence waves with different angles of arrivals have been examined in details and simulated using CST Microwave Studio. From the results, The design of the FSS operating at 14.8/16.5 GHz respectively has stable performance as a band-stop filter at oblique angle variations between 0° to 60° in the transverse electric (TE) and the transverse magnetic (TM) polarizations.

1. Introduction

Basic characteristics of electromagnetic waves such as transmission and reflection characteristics may be controlled using Frequency Selective Surfaces (FSSs) and FSSs are suitable to be used as filters for an incident plane wave [1]. Since FSSs performance are considerably effective, they have widely been used in antenna and radome design in addition to the design and realization of radar and communication systems as well as electromagnetic shields in millimeter-wave regime. Moreover, it has taken into consideration by whom realizing the possibility of fabricating an invisible device such as an electromagnetic cloak and potential of producing interesting electromagnetic occurrences [2].

Both in military and civilian applications, the quality of service (i.e. QoS) is demanding need for users. Once the electromagnetic spectrum's intensity is considered, there may be a lot of intended and unintended interference that must be cancelled. In the light of developing technology both in design and production techniques, in recent years, many forms and procedures are presented that using FSSs in various kind of applications such as reducing the RF signature in low-observable platforms and shielding sensitive electronic devices from unwanted interference and jamming signals. Especially the issues that studies focus on are as follows; the stability of the resonance frequency with angle of incidence and miniaturization of unit cell for use in compact structures [3][4], multiband filtering characteristics up to five resonance peaks used in filters, absorbers, couplers, and sensors [5], tunability and reconfigurability for multifunctional and multistandard communication systems by using different materials such as ferrite substrate, liquid crystals [6] and using different components such as micro-electromechanical (MEMS) switches or capacitors [7], varactors and PIN diodes [8].

In this study, a dual-band FSS structure that blocks the 14-15.3 GHz and 16-17 GHz frequency bands as a band stop filter has been presented. An F-type design is made as the main resonance element of the frequency selective surface. These F-type elements are placed opposite and symmetrically on both surfaces of the dielectric substrate for the purpose of filtering two different frequency bands. Moreover, the proposed structure shows angularly stable performance (up to 60°) for both TE and TM modes. The organization of the study is as follows: In Section II, parametric studies and geometry modification which are applied to improve the FSS design is addressed. In Section III, simulation results and parametric analysis of the proposed structure are presented and finally, the conclusions are given in the last section.

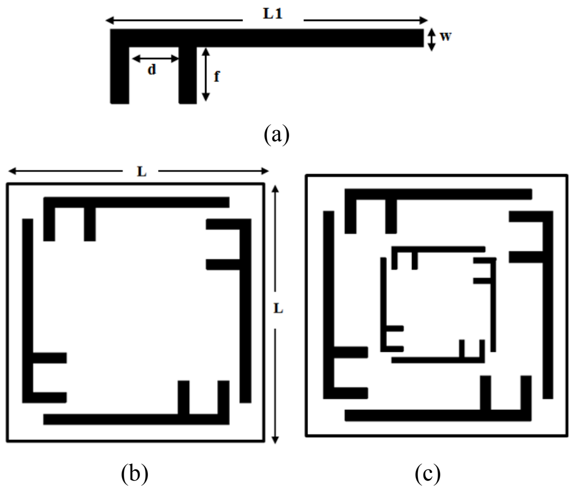
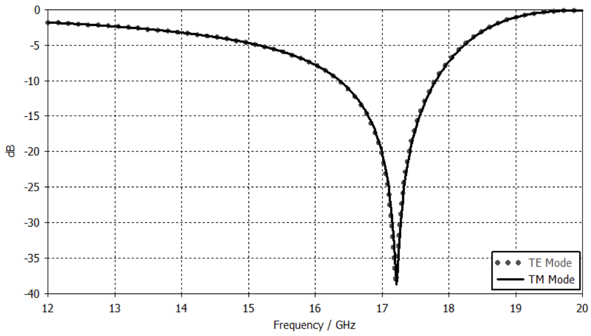


Fig. 1. (a) The basic geometry of element (b) Rotated element design (RED) (c) Scaled-element added design (SEAD)

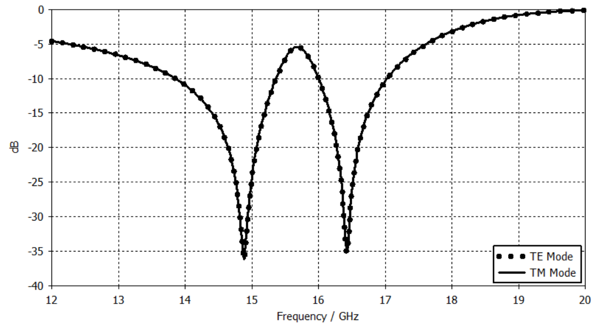
2. Design and Analysis of FSS Structure

The main resonance element resembling F letter of the FSS structure is depicted in Fig. 1(a). The method detailed in the [9] is used to create the rotated element design (RED) and the scaled-element added design (SEAD) shown in Fig. 1(b) and (c) respectively.

In the first step, F-type element is rotated 90° symmetrically according to the origin to create three more new pieces and placed on the dielectric substrate to form the RED. The next step is to add a new scaled element to the same surface to form the SEAD. By the method applied in this step, the operating frequency of the FSS structure is reduced without changing the dimensions of the structure. It is observed from Fig. 2(a) that the SEAD FSS structure resonates at 17.2 GHz, which means filtering the frequency band between 16.3 and 17.8 GHz. Final step of composing the dual-band FSS structure, the reverse symmetry of the F-type copper conductors formed on the front face of the dielectric substrate is placed on the back side of the substrate as shown in Fig. 3. The mirrored placement of the resonators enables that the geometry resonates at two different frequency bands which are close to each other that are 14.8 and 16.5 GHz respectively as it can be seen in Fig. 2(b).



(a)



(b)

Fig. 2. Simulated S-parameters (S11) of (a) the SEAD FSS and (b) the 3D FSS design in TE and TM mode at θ=0˚

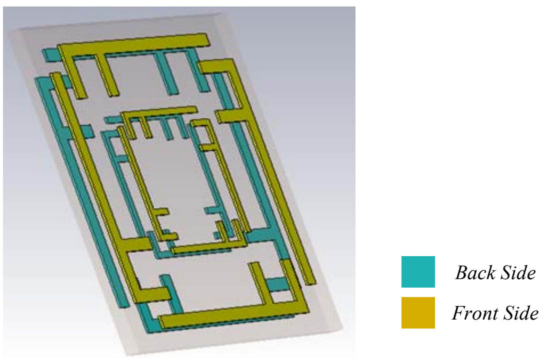


Fig. 3. 3D geometry of dual-band FSS structure

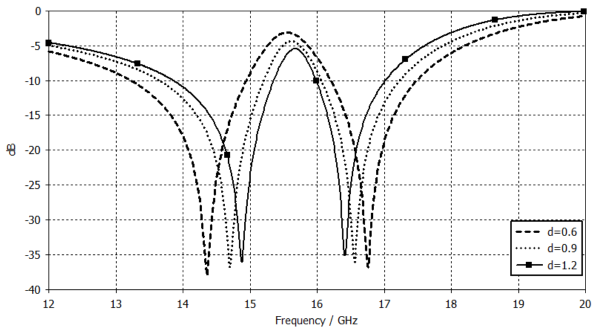
The design parameters are shown in the Table I. Both the top and bottom F-type layers are made of copper (σ = 5.8 ×107 S/m) each having thickness of 0.035 mm. Arlon AD300 with relative permittivity ε_r = 3 and loss tangent $tan\delta$ = 0.003 is used as the dielectric substrate. The total area of proposed FSS structure shown in Fig. 3 is 7.75 x 7.75 mm^2.

Table 1. Dimensions of FSS Element

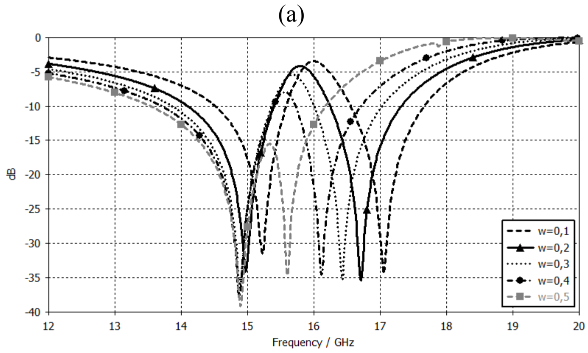
Parameters	L	L1	d	f	w	Scale Factor
	mm					
Values	7.75	5.5	1.2	1	0.3	0.5

3. Results and Discussion

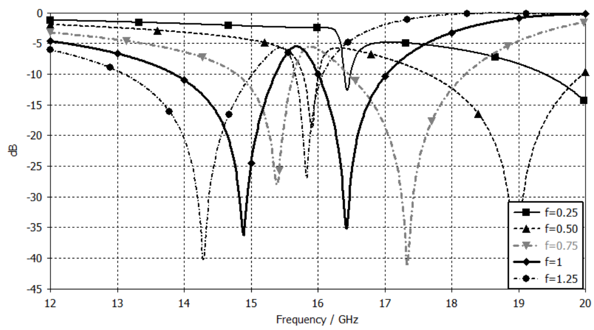
The dual-band Frequency Selective Surface design with F-type is simulated with Computer Simulation Technology Microwave Studio (CST MWS) by using unit cell boundary conditions and floquet port excitations. The aim of this structure is to block two different frequency bands which are close together, while allowing the remaining band in the 12-20 GHz frequency range to pass through. Firstly, to achieve this purpose, detailed analyzes were made on the parameters (d, w, and f) that will affect the resonance frequency of the design.



(a)



(b)



(c)

Fig. 4. Effects of parameter changes on the proposed FSS Structure (a) d-parameter (b) m-parameter (c) f-parameter

Simulation results of d-parameter expressing the distance between short bars of F-type resonator is shown in Fig. 4(a). If d increases, two different resonance frequencies approach each other, which is a desirable situation. However, as the value of d continues to increase, the FSS structure loses its ability to stop the band between two different frequency bands (d>1.2 mm, S(11)<-5dB at 15.7 GHz). It is observed from Fig. 4(b) that as the parameter w value increases, the first resonance frequency remains almost constant, while the other approaches the first. However, as the value of w is equal to about 0.5 mm, the dual band property is lost (- 15 dB at 15.2 GHz), just like in the d parameter. Unlike other parameters, the f parameter has more deterministic properties. As shown in Fig. 4(c), f=1 mm is best solution for the proposed FSS structure.

The transmission characteristics of proposed structure for different angle of incidence wave are depicted in Fig. 5(a) and (b). It can be observed from these figures that the stability of the resonance frequency with angle of incidence is provided between 0˚ to 60˚. Furthermore, it is founded that for TE mode, the -10 dB bandwidth remains constant at the first resonance frequency and shifts slightly upward at the second resonance frequency with the increase of the incident angles; however, for the TM mode the -10 dB bandwidth narrows in the given circumstance and some distortions occur between 15.7 and 15.9 GHz while theta is at 30˚ and 60˚. The low resonance frequency is 14.8 GHz and bandwidth is about 1.3 GHz; the high resonance frequency is 16.5 GHz and bandwidth is about 1.1 GHz for the normal incidence case.

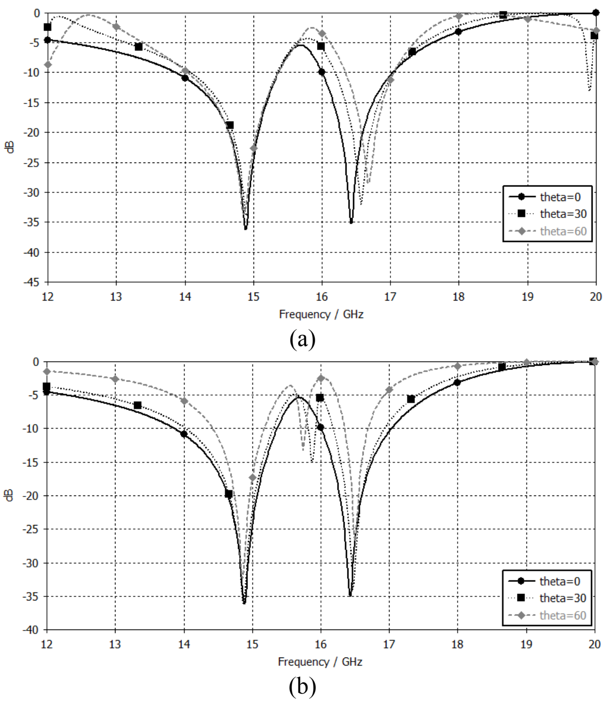


Fig. 5. Transmission Coefficient of the proposed FSS structure with different angle of incidence in (a) TE mode (b) TM mode

4. Conclusions

In this study, a dual-band and angular stable band-stop FSS structure has been presented. The reverse symmetric F-type resonators are placed on the both side of the dielectric substrate to block two different frequency bands which are close together, while allowing the remaining band in the 12-20 GHz frequency range to pass unaffected. The design of the FSS has stable performance at oblique angle variations between 0˚ to 60˚ in the transverse electric and the transverse magnetic modes. Moreover, it is appraised that by changing the design parameters, the proposed FSS structure can be used to in shielding of electronic devices to reduce the interference effect of Wi-Fi or GSM systems.

5. References

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