Investigating the Dual-passbands Frequency Selective Surface with Complementary Structure

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Abstract— A dual-band frequency selective surface (FSS) is presented. The complementary hexagonal loop resonators are used in each FSS unit cell to obtain this ability. We designed three styles FSS composed of circle loop squared loop and hexagonal loop arranged in a 2-D periodic lattice. These FSSs are engineered a hybrid of three layers closely coupled FSS. The outer layers of elements and a middle layer of complementary elements are etched either side of a dielectric substrate. The proposed FSS structure is independent of incident polarization and angle because of centrosymmetric of the unit cell. We investigate the frequency responses of such periodic structures induced field distribution. It is demonstrated that transmission zeros occur in passbands formed by the mode of aperture resonance and aperture coupled patch resonance. By simulating their transmission and reflection coefficients under normal and oblique TE and TM incidences, show that it has a stable frequency response at different oblique incident angles and the advantages of high selectivity.

1. INTRODUCTION

The frequency selective surface (FSS) has found widespread applications, such as antennas and radomes for aircraft and communication fields [1, 2]. With the development of radome's performance and the improvement of communication devices, the requirements of multi-frequency communication become more and more significant. For those applications, the multi-band FSS have been used especially when multiple independent transmission bands are required. Therefore the multi-band FSS designs have been investigated extensively [3, 4]. In the past, several techniques have been used to design multi-band FSS, include cascading multi-layer different unit cell to obtain multi-resonance [5] and single-layer FSS with the fractal structures [6]. Recently, in substrate-integrated waveguide technology, dual-band FSS was constructed to obtain a large band separation, band-reject response [7–12].

In this letter, we present a complementary structure of FSS, comprising loop elements with complementary loop elements connected via two layers dielectric, as shown in Figure 1. The field distribution is shown to analyse the resonant frequencies. In the end, we obtained dual-passbands frequency selective surface with excellent performances. These FSSs have advantages to high selectivity, stable performance, compact volume and easy to be fabricated by print circuit board technology.

2. DESIGN AND ANALYSIS

In this Section, we present the results of numerical simulation of the FSS models shown in Figure 1. These FSSs have a substrate with relative permittivity of $\varepsilon_r = 2.65$, loss tangent of 0.01 and

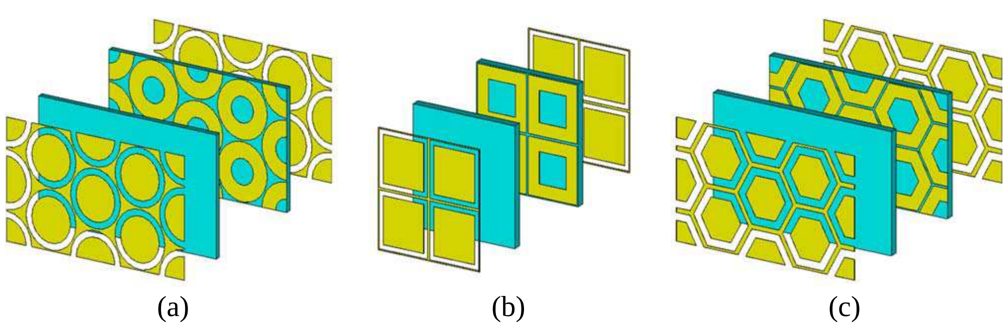


Figure 1: Geometry of 3D FSS element. (a) Circle element view. (b) Square element view. (c) Hexagonal element view.

thickness of $h_{sub} = 1\,\text{mm}$. Finite element method (FEM) was used to calculate its reflection and transmission characteristics. Assume that these FSSs is an infinite periodic structure. The four side of the unit cell are set to be periodic boundary and these FSSs are excited by the TE and TM polarizations. The S parameters of this FSS under normal incident are presented in Figure 2. It is found that the transmission property has dual-band performance.

The magnetic field distribution at first transmission zeroes are plotted in Figure 3(a). It is found that the first transmission zeroes (under TE normal incidence Circle at 5.712 GHz, Square at 5.824 GHz, Hexagonal at 6.24 GHz, respectively) corresponds to the aperture resonance, whereas the second transmission zeroes of these elements (also under TE normal incidence Circle at 11.664 GHz, Square at 12.944 GHz, Hexagonal at 15.248 GHz, respectively) exhibit the opposite direction of currents arise in top layer and middle layer were shown in Figure 3(b). So we can affirm that it is a patch-aperture resonance mode.

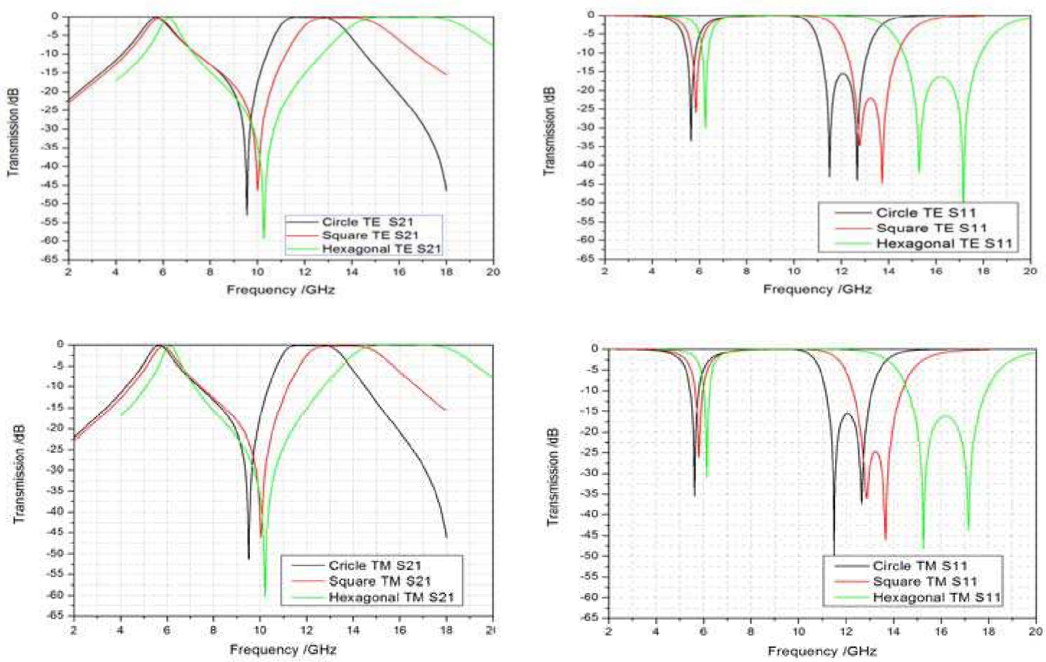
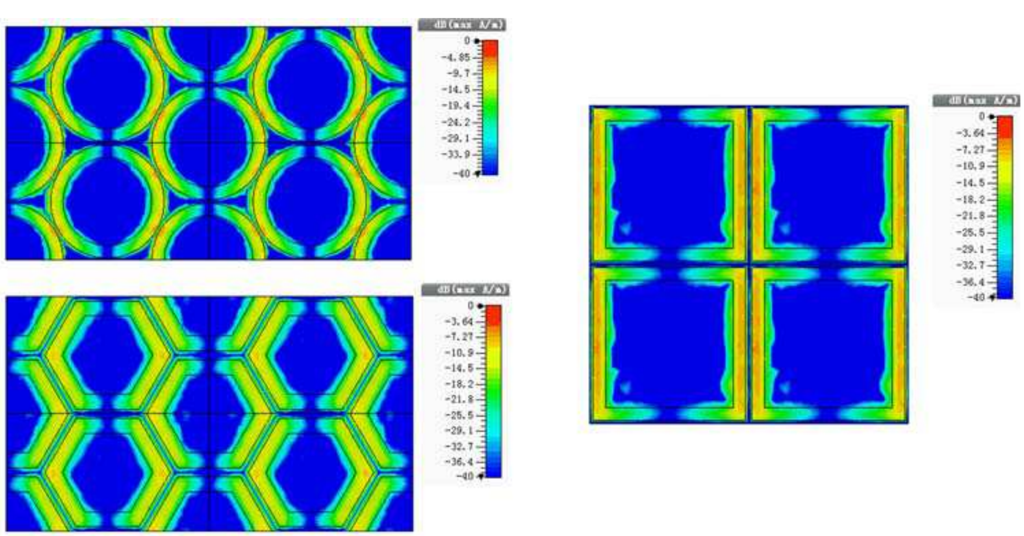
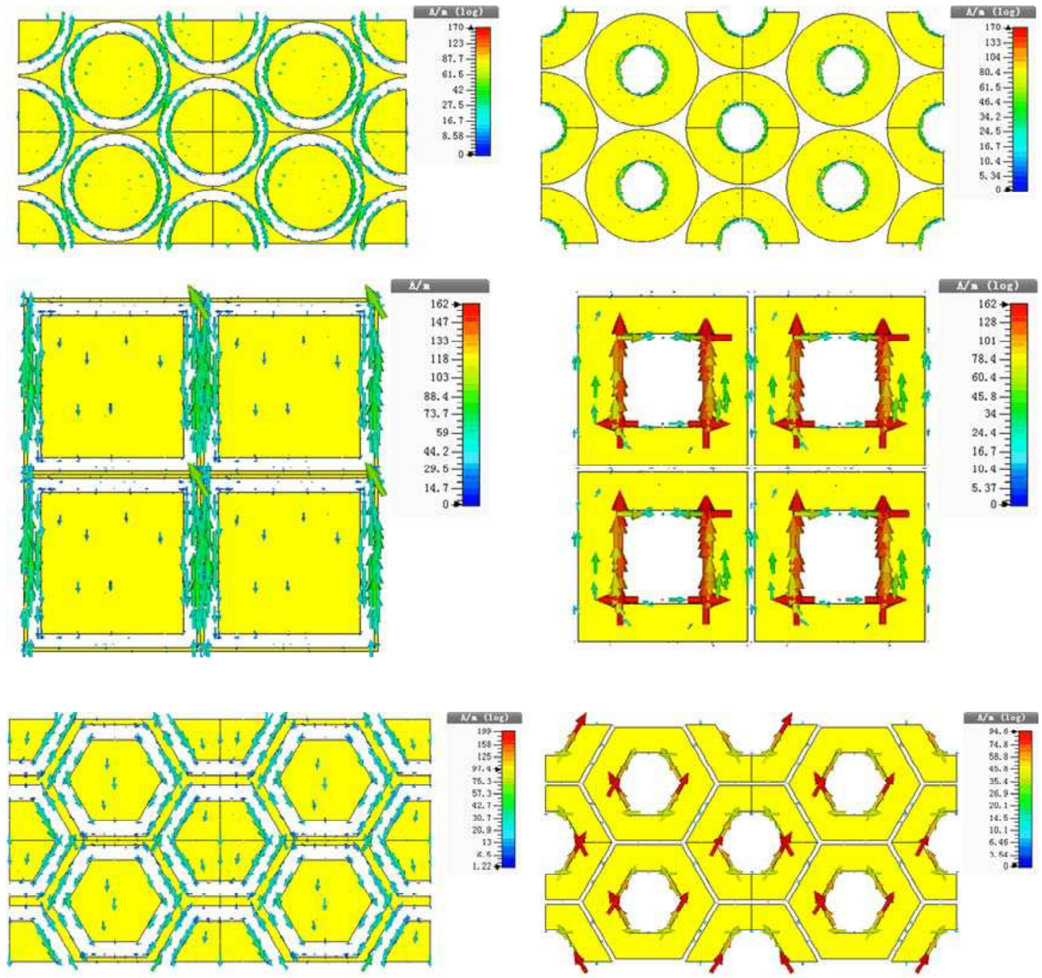


Figure 2: Frequency responses under normal incidence.



(a)



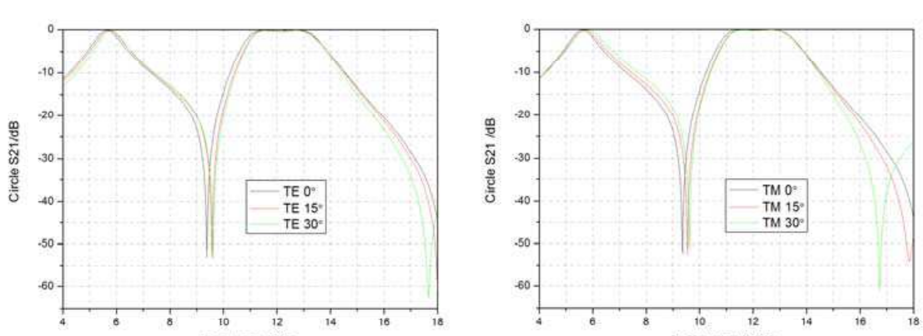
(b)

Figure 3: Current distribution at two zeroes of transmission response. (a) At first transmission zeroes. (b) At second transmission zeroes

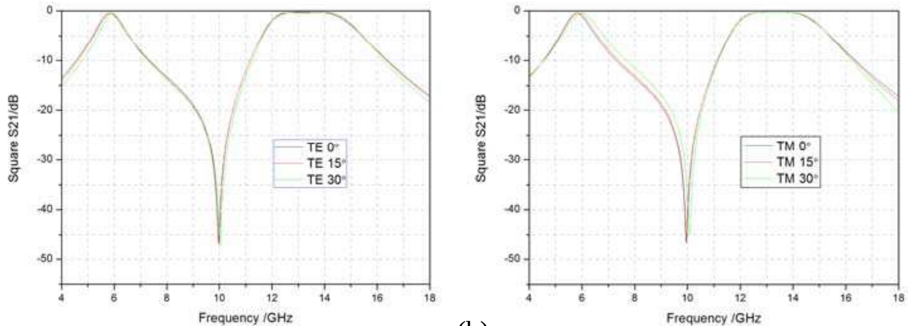
3. STABLE PERFORMANCE ANALYSIS

The excellent frequency selective surface would provide stable performance under different incidence angles and polarizations. Usually, dual-passbands FSS should have large band separation and flat passbands. A high rejection edge is also a good benefit.

Figure 4 gives these frequency selective surfaces under different incidence angles and polarizations. These frequency selective surfaces is stable under oblique incidence angles from 0° to 30° for both TE and TM polarization, its transmission is obviously dual-passbands performance. The first passband bandwidth of −3 dB reaches (circle: 1 GHz, square: 900 MHz, hexagonal: 800 MHz, respectively), and second passband relative bandwidth of −3 dB reaches (circle: 2.8 GHz, square: 3.2 GHz, hexagonal: 4.8 GHz, respectively).



(a)



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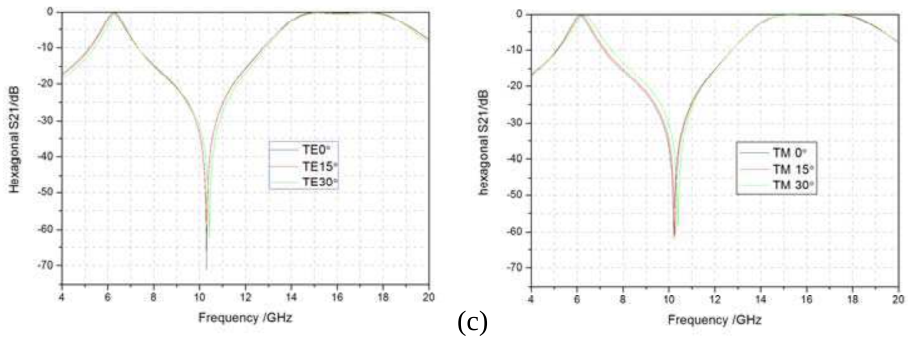

(c)

Figure 4: Frequency response of these FSS under incidence angles from0° to 30° for both TE and TM polarization. (a) Circle element. (b) Square element. (c) Hexagonal element

4. CONCLUSION AND DISCUSSION

In this paper, we proposed a dual-passbands frequency selective surface with stable performances. The complementary struct was designed for obtain advantages. The each passband has stable performance various incident angles and TE/TM polarizations. The dual-passbands frequency selective surface has advantages of high selectivity, large band separation. Such a frequency selective surface can provide practical applications in communications filed, etc.

ACKNOWLEDGMENT

The authors are grateful to the supports from the National Natural Science Foundation of China under Grant Nos. 61331005, 11204378, 11274389, 11304393, 61302023, the Aviation Science Foundation of China under Grant Nos. 20132796018, 20123196015, the National Science Foundation for Post-doctoral Scientists of China under Grant Nos. 2013M532131, 2013M532221, the Natural Science Foundation of Shaanxi Province under Grant No. 2013JM6005, and the Special Funds for Authors of Annual Excellent Doctoral Degree Dissertations of China under Grant No. 201242.

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