A Closely Located Dual-Band FSS Design for X Band Applications

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***Abstract*—This study focuses on single layer dual band Frequency Selective Surface (FSS) with closely located resonant frequencies for X band applications. The designed FSS comprises of cross dipoles and fragments of broken rings printed on a single layer dielectric material to get dual band frequency response. The proposed structure offers the advantage of distinguishing two closely located frequencies such as 8.8 GHz and 11.2 GHz. The frequency ratio of the upper resonant frequency to the lower one is as small as 1.27s. Furthermore, the thickness of proposed FSS is only 0.017*λ where λ is the wavelength of the lower resonant frequency. In addition to these properties a stable frequency response is observed for different incidence.**

I. Introduction

Frequency Selective Surfaces (FSSs) are periodic structures which contain slots or metallic patches with different geometry to provide filter characteristics [1], [2]. FSSs have been extensively studied and used in various applications such as spatial filters, absorbers, polarizers, radomes, antenna reflectors, EBGs (Electromagnetic Band Gaps), AMCs (Artificial Magnetic Conductors), electro-magnetic shielding, RCS reduction controlling practice [2]-[4]. Recently, with the rapid development of electronics and communication technologies increasing demands have led to research [2]. Multiband or dual-band FSS can be practice where multiple transmission bands are required such as multi-channel systems [5],[6].

One of the considerable property of FSS design is the sensitivity to the different incidence angle of the EM wave. In [7] and [8] angular stable performance is obtained due to the symmetric geometry of the unit cell design. Also in [1] closely spaced planar dual-band FSS is studied with the feature of the 90° rotation technique for the unit cell makes available to independence of incident polarization and angle. Several methods have been investigated to achieve closely located frequency characteristics. The closely band response was achieved by reducing the mutual coupling with the redistributed maximum current densities along the unit cell in [6]. In [9] and [10] closely spaced operating bands are provided with the meander lines printed on a single layer dielectric material. In some multiband FSS studies, double square loop [11] and concentric ring [12] elements investigated to obtain closely spaced operating bands. However, well-adjusted gaps between those elements produces closely spaced bands and very small gaps have difficulties in implementation.

In this paper, we present a closely located dual-band FSS which is constructed as an ultra-thin structure. The proposed structure has the advantage of a low frequency ratio of 1.27s. Also the design shows the stable performance to the various incidence angles.

In section 2 the geometry of the proposed single layer, two surfaces FSS and design parameters have been studied in detail. In section 3 the simulation results of the transmittance and reflectance are given for both Transverse Electric (TE) and Transverse Magnetic (TM) polarizations. Also surface current distributions are given at two stop bands for both TE and TM polarizations to show resonating metallic arms of the unit cell, and finally section 4 shows the concluding views.

II. Design of FSS Structure and Performance

This section presented FSS unit cell with simple geometry is demonstrated in Fig. 2. The metallic lines, printed on the dielectric substrate are consist of two separated parts on two surfaces. Part one is composed from a small cross dipole in the center with the fragments of a broken ring on the front surface. The second part on the back surface is derived by scaling the first part by k and rotating it by 40 degrees but the fragments of a broken ring are rotating -5 degrees again. The preferred angle of rotation provides the geometry that causes the parts to be separated from each other and also contributes to achieving angular stable frequency performance. While outer diameter of the fragments of a broken big ring is named R, smaller one is r. The lengths of the big and small cross dipoles are R and r, respectively. When part two is obtained, k is used as a scale factor between R and r. The frequency ratio can be adjusted with different values of k.

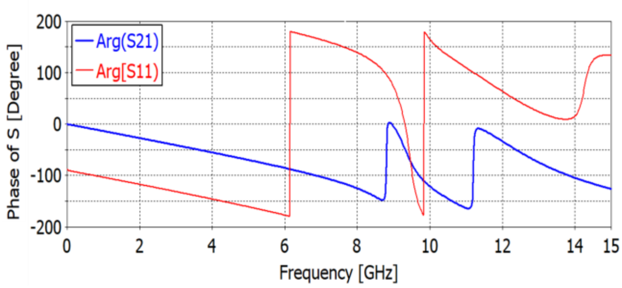

Figure 1. Simulation results of transmission and reflection phase at normal incidence

In Fig. 1, transmission and reflection coefficient phase characteristics are shown. The presented FSS has two operational frequencies (f1=8.8 GHz and f2=11.2 GHz) which is understood from Phase of transmittance curve obviously.

TABLE I.
DESIGN PARAMETERS OF THE UNIT CELL STRUCTURE

Design parameters	Dimensions (mm)
D	7
R	*k*r*
r	4.95
g1	0.22
g2	*k*g1*
h	0.508
k	13/11
m	1.65786
n	1.2899

And the design parameters of the unit cell which are shown in Fig. 2 are listed in Table 1. The unit cell designed on an Arlon AR 600 dielectric substrate with a thickness of (h) 0.508 mm, and a relative permittivity of (εr) 6. The total lengths of the unit cell are 7 x 7 mm.

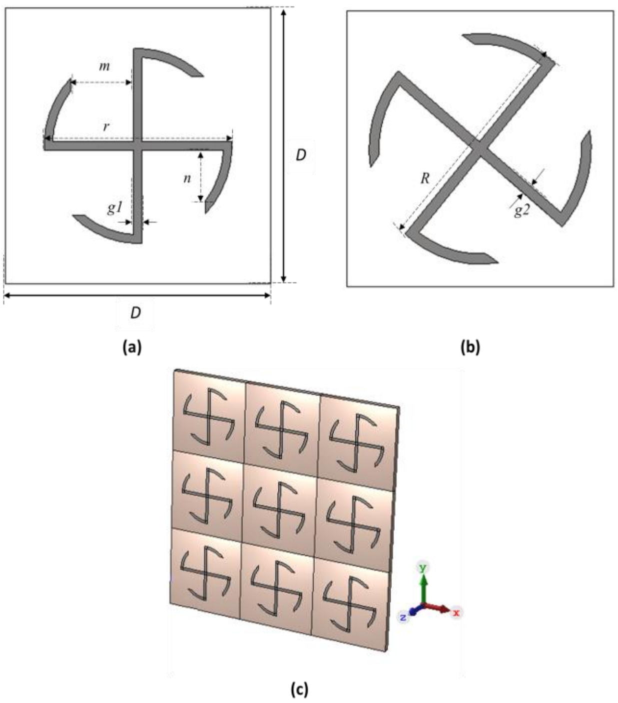

Figure 2. (a) Top view of the proposed unit cell, (b) Bottom view of the proposed unit cell, (c) Designed FSS structure

The gray region shown in Fig.2 represents the printed metallic lines and the white region represents the dielectric substrate. g1 and g2 are the width of the metallic lines which illustrated in Fig.2 (a) and (b). In Fig.2 (c) perspective view of designed FSS structure is given.

Part one causes the higher operating frequency (f2) and part two causes the lower operating frequency (f1).Thus, the band spacing can be easily reduced or increased by optimizing k which is the ratio between the parts forming the geometry.

CST Micowave Studio is used to analyze the transmission and reflection response of the examined FSS and unit cell boundary conditions are used in order to getting periodicity for both directions. The simulation results of the transmission and reflection characteristics of the designed unit cell are demonstrated in Fig. 3. Obtained frequency response shows that the designed structure exhibits band-stop characteristics in dual frequencies. The first resonant frequency is at f = 8.8 GHz, and the second resonant frequency is at f2 =11.2GHz. The lower and higher resonant frequencies can be controlled separately by adjusting the lengths and proportion of lengths.

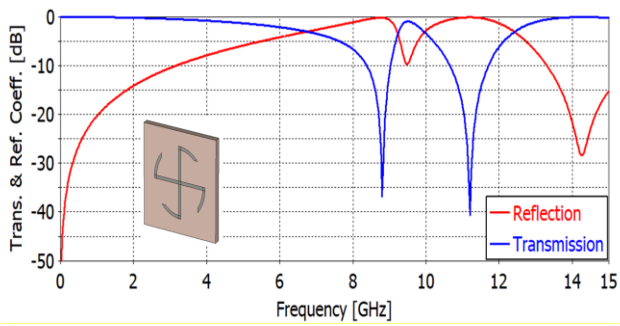

Figure 3. Transmittance and reflectance of the proposed unit cell illuminated by a normal incidence

Parametric analyzes are performed to investigate the effect of the angular variation of the metallic elements at the bottom surface on the transmission characteristic. Metallic elements at the bottom surface are positioned at 0 degree, 30 degrees and 40 degrees relative to metallic elements of the top surface. In Fig. 4, 0 degree, 30 degrees and 40 degrees configurations are demonstrated.

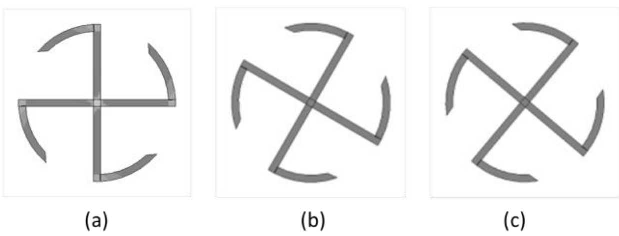

Figure 4. Angled configurations of the metallic elements at the bottom surface of the unit cells (a) 0 degree configuration, (b) 30 degrees configuration, (c) 40 degrees configuration

In Fig. 5, parametric study of simulation results of transmittance of the designed FSS at normal incidence for TE polarization is shown. It is clearly observed from the Fig. 5 that the angular configuration affects the operating frequencies and space between these frequencies.

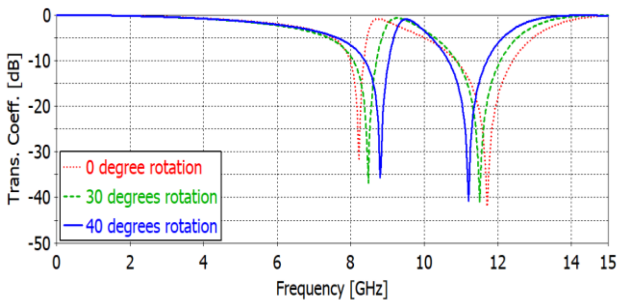

Figure 5. . Simulation results of angle-dependent transmittance of the 0 degree, 30 degrees and 40 degrees configurations of the metallic elements in the bottom surface

In Fig. 6. transmission response of the presented FSS for different incidence of EM wave. Angularly stable frequency characteristics is observed for up to θ=60 degrees of several incident angle when ***ϕ***=0 for Transverse Electric (TE) polarization.

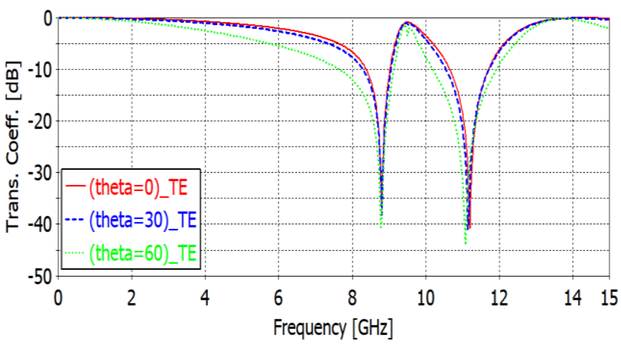

Figure 6. Simulation results of transmittance of the designed FSS illuminated by a different incidence for TE polarization

Metallic lines printed on front surface and back surface of the unit cell have four symmetrical arms. These symmetrical arms can diminish the sensitivity to the various incident angles.

The Designed structure maintains angular stability up to θ=60 degrees of several incident angle when ***ϕ***=0 for Transverse Magnetic (TM) polarization. Stable frequency performance for TM polarization is observed from the Fig. 7.

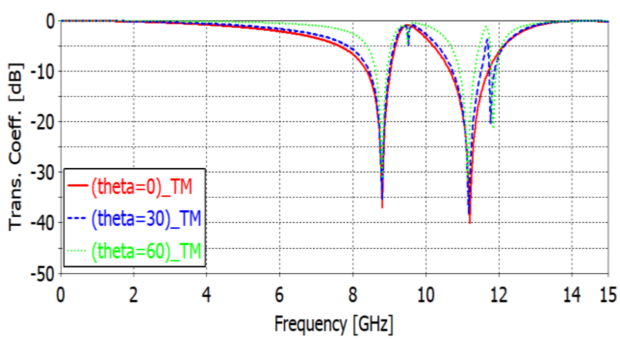

Figure 7. Simulation results of transmittance of the designed FSS illuminated by a different incidence for TM polarization

The surface current distributions of the presented unitcell at lower and higher operational frequencies for both TE and TM polarizations under normal incidence are demonstrated in Fig. 8 to express resonating parts.

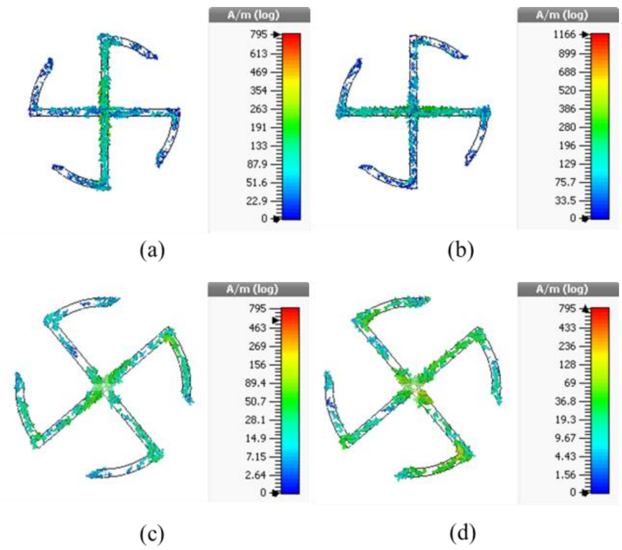

Figure 8. Surface current distributions of the designed FSS under normal incidence at (a) 8.8 GHz for TE polarization, (b) 8.8 GHz for TM polarization, (c) 11.2 GHz for TE polarization, (d) 11.2 GHz for TM polarization

III. Conclusions

A single layer closely located dual-band FSS is designed and simulated. Simulation results of the X band closely located FSS structure are obtained using CST Microwave Studio. The presented FSS is operating at 8.8 GHz and 11.2 GHz. The designed FSS with simple geometry have advantages such as low ratio of two resonating frequencies with 1.27s and ultra-thin design led to low mass. Also the presented design exhibits dual-band reject filter response. The simulation results show that the designed single layer structure provides a good frequency sensitivity up to 60 degrees of incident angles for TE polarization.

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