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Multi-Band Second-Order Bandstop Frequency Selective Structure With Controllable Band Ratios

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***Abstract*—A multi-band second-order bandstop frequency selective structure (FSS) is proposed. The structure is based on controlling the propagating modes in a multi-mode resonator to obtain transmission and reflection zeroes. The band ratios between these multiple bands can be controlled independently. As an example, a tri-band FSS is designed with center frequencies at 10.3, 14.3 and 18.9 GHz and exhibiting fractional bandwidths of 12%, 8% and 9%, respectively. The proposed multi-band FSS has stable filtering performance under various angles of incidence due to its small unit cell size compared to the operating wavelength. The principle of operation is explained along with simulation results.**

I. INTRODUCTION

Frequency selective surface is a periodic structure composed of a single or multi-layer two-dimensional lattice that acts as spatial filter for electromagnetic waves, widely used in hybrid radomes, dichroic main reflectors, dichroic subreflectors and absorbers [1]. In the past several researchers studied multi-band frequency selective surfaces; most of them proposed structures that have dual-band first-order response [2, 3]. Few have second-order response [4] and some have tri-band first-order response with two stopbands and one passband [5] or two passbands and one stopband in between [6]. A tri-band second-order bandpass frequency selective surface was reported in [7]. Unfortunately, it suffers from two problems because its unit cell size is comparable to the operating wavelength: (1) the band spacing could not be large as grating lobes will appear at lower frequencies; (2) the insertion loss will be significant for large incident angle ($\theta > 30^o$). All of them were based on the traditional 2-D frequency selective surfaces [1]. Recently, [8] proposed a dual-band second-order FSS with large band ratio; but the structure is complicated.

To authors' knowledge no simple and good multi-band second-order bandstop or bandpass FSS has been presented in the literature. This paper proposes a multi-band second-order bandstop FSS based on the structure presented in [9]. It is simpler than structure presented in [8]. Moreover, it is multi-band, exhibiting stable performance under large angle of incidence ($\theta = 60^o$) and larger band spacing can be also achieved.

II. STRUCTURE AND SIMULATED RESULTS

Fig.1 shows the proposed tri-band second-order FSS. It is seen that each unit cell consists of three strips. Each strip with its capacitor is responsible for one band of the three bands. The strips alone are responsible for obtaining first-order response and we use capacitor loading at the center of each strip connected to ground through via to achieve wider band width, by lowering the first harmonic of each fundamental mode [10].

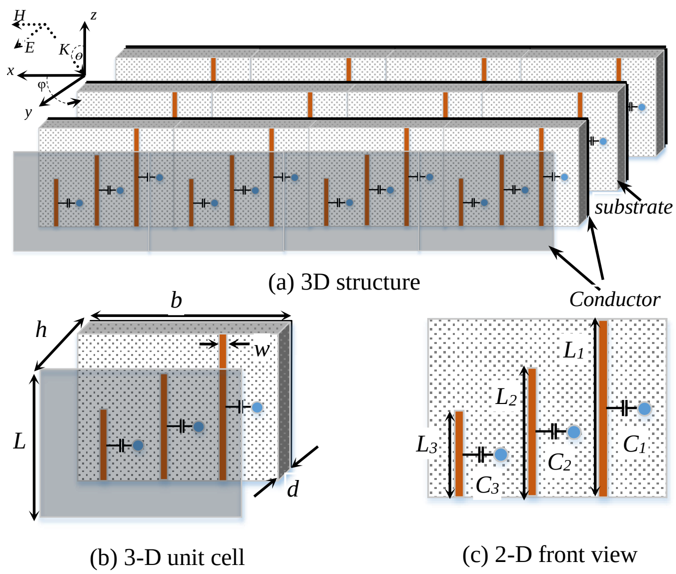

Fig. 1. Structure of the proposed multi-band FSS.

A. *Unit cell of first order multi-band FSS*

The unit cell proposed in [9] produce one transmission zero and two reflection zeroes, which can provide one band first-order bandstop FSS. As mentioned in [9], this unit cell supports propagation of two fundamental quasi-TEM modes and other higher-order modes. One of the fundamental modes propagates in air region and the other propagates in substrate region. The transmission zero is obtained when the phase difference between these two modes of equal amplitude is equal to π or they become out of phase so they cancel each other (no transmission). The two reflection zeroes (transmission poles) are produced when the propagating path of each mode is equal to $\lambda_{eff}/2$, where $\lambda_{eff} = \lambda_o/\sqrt{(\varepsilon_r + 1)/2}$ and λ_o is the free space wavelength at the center frequency. As these two modes propagate in different media, then they will have two different propagation constants meaning that they will achieve $\lambda_{eff}/2$ at two different frequencies.

One can easily obtain dual-band response by adding another transmission line (TL) of different length. As shown in

Fig. 2, we achieve dual-band bandstop FSS using two different lengths TLs. The longer TL is responsible for the lower band, while the shorter TL responsible for the upper band. The band ratio can be controlled by the TL length. One can achieve multi-band response by adding additional TLs. But this process is limited by two factors: one is the dimension *b* with respect to the width of the TL (*w*) and the other factor is the length *L* of the unit cell.

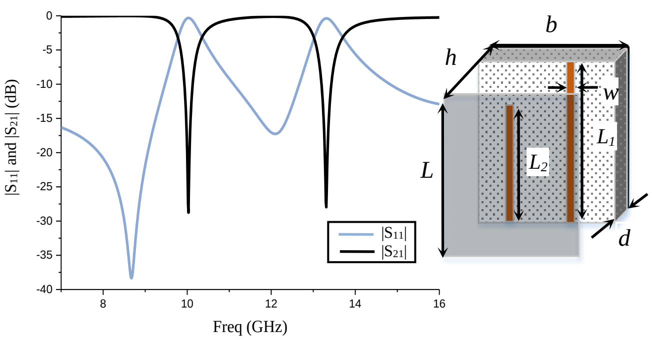

Fig. 2. Unit cell of a dual-band FSS and simulated transmission and reflection coefficients (b=6mm, h=3.524mm, L=9.5mm, d=1.524, w=0.3mm, L_1=9.5mm, L_2=6.5mm, ε_r=3.55).

B. *Unit cell of second-order tri-band bandstop FSS*

One can get wider bandwidth by lowering the first harmonic of each quasi-TEM mode, this can achieved by connecting a shunt capacitor to ground at the middle of each TL [9]. By controlling the capacitor value we can achieve the second-order response. Fig. 3 shows simulated reflection and transmission coefficients of the proposed tri-band second-order bandstop FSS. The unit cell is shown in Figs. 1 (b) and (c) with capacitance values C_1=0.21pF, C_2=0.11pF, C_3=0.045pF and a substrate of ε_r=3.55. Fig. 4 shows the simulated performance of the tri-band FSS under oblique incidence. It shows stability with a change of incident angle due to its electrically small unit cell size. Although our proposed structure supports TE mode only it can be modified to support both TE and TM modes. The idea presented here may also be applicable to bandpass FSS and absorbers to achieve multi-band operation.

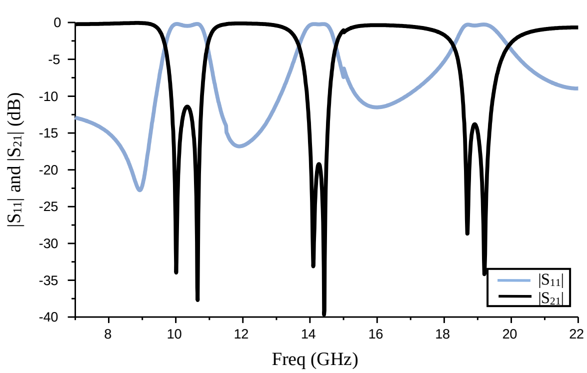

Fig. 3. Simulated transmission and reflection coefficients of a tri-band FSS (b=6mm, h=3.524mm, L=9.5mm, d=1.524, w=0.3mm, L_1=9.5mm, L_2=6.5mm, L_3=4.75mm).

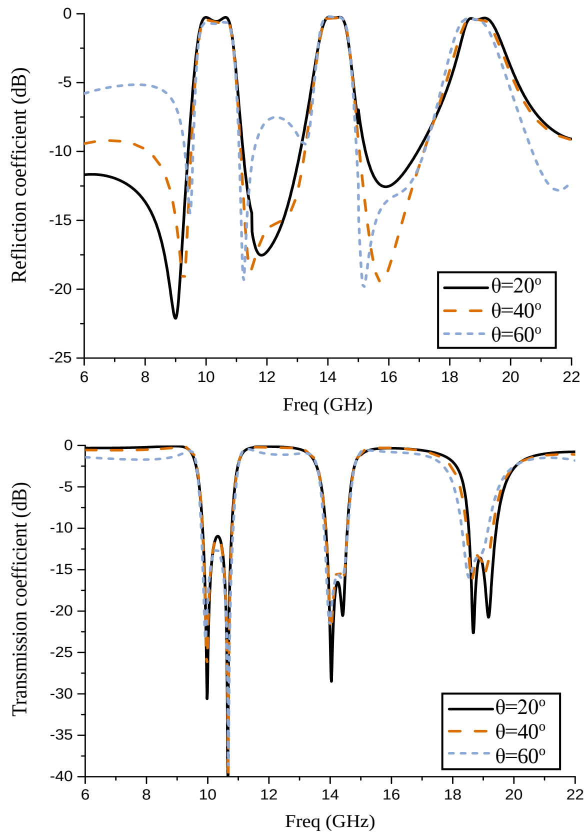

Fig. 4. Simulated transmission and reflection coefficients of a tri-band FSS with different incident angles.

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