International Journal of Trend in Scientific Research and Development (IJTSRD)
International Open Access Journal
ISSN No: 2456 - 6470 | www.ijtsrd.com | Volume - 2 | Issue – 1

An Analysis of Dual Band bandpass Filters using with Arbitrary Band Ratios

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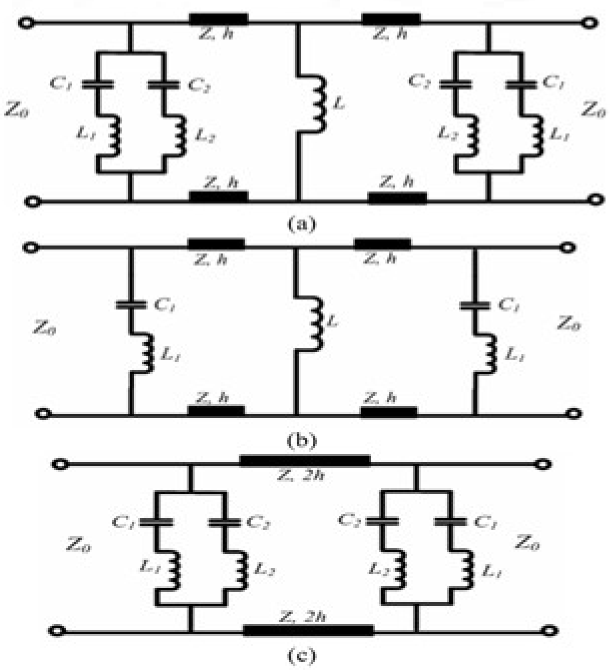
ABSTRACT

This paper proposes the variable reflection angle of metasurface composed of the double layered FSS (Frequency Selective Surface) and the ground. The meta-surface can steer the reflection direction of the incident wave by shifting the lower FSS. It is clarified that the gradient of the reflection phase in the reflection direction steering plane (*x-z* plane) are changed by the shift amount of lower FSS. A miniaturized dual-band frequency selective surface with second-order band-pass response at each operation band is presented. The design is implemented by cascading a two-dimensional periodic array of double square loops and an array of wire grids. The proposed structure composed of three metal and two dielectric layers acts as a spatial dual band microwave filter with large band separation. The predicted FSS has the merits of broadband response, excellent stability for different incident angles, and sharp roll-off at X- and Ka-band, respectively.

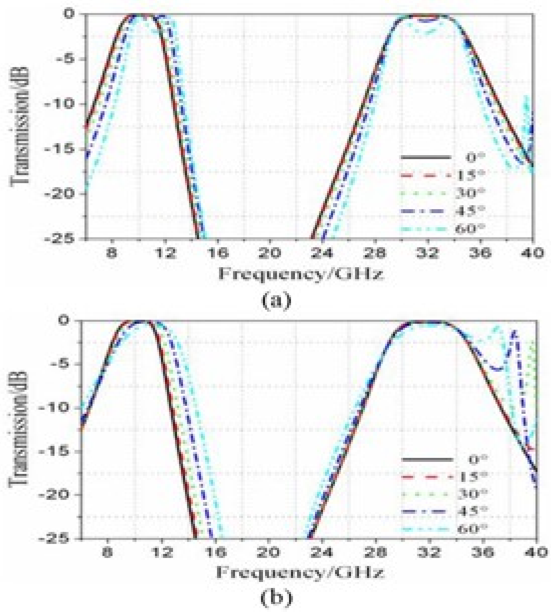
Keywords: *Dual Band, FSS, steering*

I. INTRODUCTION

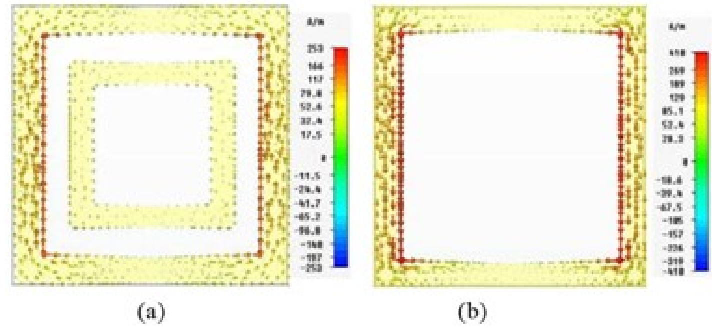
Frequency selective surfaces (FSSs) have been studied extensively for many years [1]. They are widely used in the design of various microwave systems, such as antenna reflectors, absorbers, as well as electromagnetic band gap materials [2], [3]. Therefore, the FSS has been regarded as an active research due to its various applications ranging from radomes for aircrafts, dichroic reflector antennas, electromagnetic shielding applications, artificial electromagnetic band gap materials and radiofrequency (RF) absorbers in recent years. In the application of dichroic reflector antennas, a FSS with band-pass and band stop response at each band of operation in oblique incidence is often needed. In this figure we are presenting a new design:-



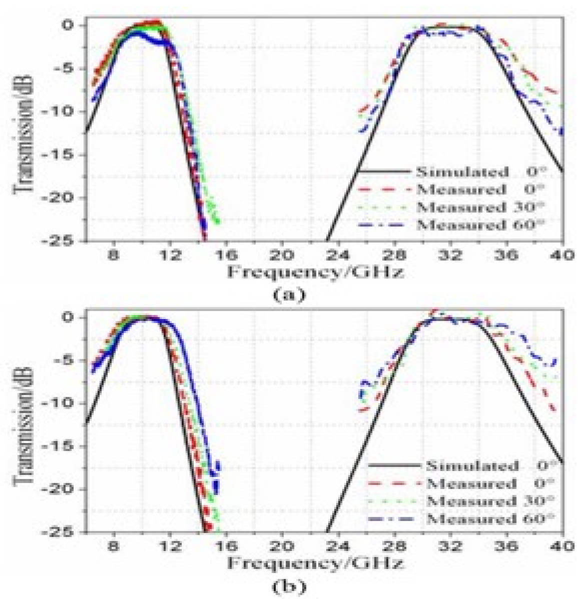
We can establish the equivalent circuit model of the proposed dual-band FSS, as shown in Fig. 6. It should be mentioned that this equivalent circuit model is modified from the one discussed in [29]. As can be seen, the free-space regions are represented by parallel-plate waveguides with characteristic impedance. The discontinuities at the interfaces of the incident regions and the FSS are denoted by capacitors and, where (or) is the discontinuity between substrate 1 (or substrate 2) and the incident region. The transmission-line sections and represent the propagation path 1, where is equivalent to the middle cavity, and is the narrow gap between the top- and middle-layer strip lines. It is the inductance of the metallic rod and via hole1 in path 1. The transmission-line section denotes the propagation path 2, is the inductance of via hole2 in path 2. The result of required designs are shown below:-



There are several techniques in designing dual- or multi-band frequency-selective surfaces in the literature, which can be summarized as: 1) multi-layered structures perturbations of a single-band FSS [11]–[13] or loading extra resonant elements [14], [15]; 3) fractal elements [16], [17]; 4) multi-resonant elements, such as double square loops and complementary patterns [18]–[23], and so on. Most of the existing designs are focused on the application of close frequency band spacing. Thus, the band ratios of their operating frequencies are usually not more than 3 in [8]–[23]. It may be true that a dual- or multi-band frequency-selective surface with a small band ratio is desirable for a lot of applications. However, it is still a challenge for the existing designs to obtain excellent dual- or multi-band responses with large band ratios because of the appearances of harmonic resonances and grating lobes. Moreover, the angular-stability of most dual- or multi-band frequency-selective surfaces will deteriorate rapidly when the frequency band ratio is large.



In this design, we only assume that the plane of incidenceis in the -plane and the electric field is parallel to the -axis, namely TE-polarization incidence. Fig. 3 provides the simulated S-parameter results of a design example by using a commercial full-wave simulator CST microwave Studio (CST-MWS). It is observed that two pass bands are obtained around (3 GHz) and (13.5 GHz), respectively. In the lower frequency band, two transmission poles are achieved at 2.82 GHz and 3.1GHz. In the higher frequency band, another two transmission poles are realized at 13.3 GHz and 13.8 GHz .The frequency band ratio is as large as 4.5. Due to the large band ratio, the maximum isolation between these two operating bands can reach 40 dB. The detailed operating principle can be explained by the electric field distributions and an equivalent circuit model in the following sections.

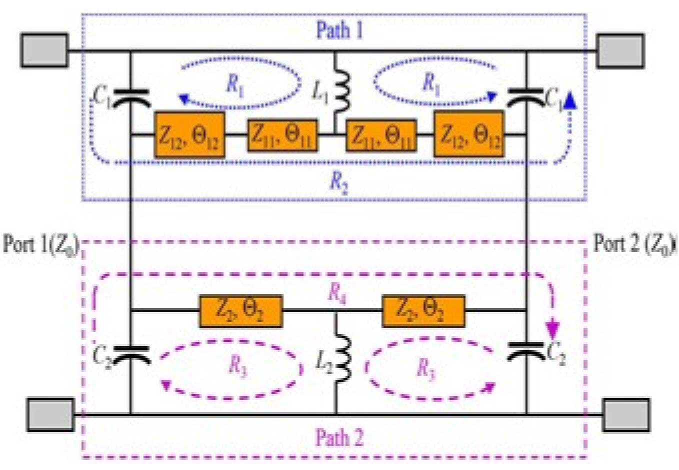


It is undesirable that there is a spurious resonance that creeps into the second band from the upper side as the incident angle increases. This is because that the second pass band is formed by the coupling between the serial resonator and serial resonators. In fact, the upper side frequency region of the second band is just the high-order resonant frequency band of serial resonator. Consequently, as the incident angle increased, the grating gradually creeps into the second band from the upper side.

II. ELECTRIC FIELD DISTRIBUTIONS AND EQUIVALENTCIRCUIT MODEL

A. Electric Field Distributions

Assuming that the left- and right-side free-space regions representing the incoming plane wave in Fig. 1 are the input port(port 1) and output port (port 2), respectively. Signals can pass through the whole structure in the two operating pass bands. Fig. 4 illustrates the electric field distributions (in the -plane) at four transmission-pole frequencies. At frequencies and the frequency response of TM mode remains stable as the angle increases. The difference above can be explained as follows. The electrical length of FSS element is different for different polarization resulting resonant frequency and the different bandwidth when the incident angle is relative large[5].The frequency response in upper reflection band under different angles and polarizations is shown in Fig. 5 and there sonant frequency is about 44 GHz. As observed, the structure of FSS demonstrates a rather stable response as a function of incidence angle in the upper frequency band for both the TE and TM mode wave. From the transmission coefficient curves in Fig. 5, it can be seen that the -30dBbandwidth is rather broad when the angle is 0° for TE and TM mode. An inevitable fact occurs that the bandwidth narrows as the angle increases.



IV. CONCLUSION

In this paper, a second-order dual-band FSS is designed. The predicted FSS has the merits of small element size, dual independent operating band at X- and Ka-band, higher selectivity and broadband response. The qualitative analysis is presented by the equivalent circuit model. In each propagation path, two resonators are constructed, thus leading two transmission poles in each operating frequency band. The operating principle has been explained by analyzing the electric field distributions and establishing the equivalent circuit model. In order to verify our concept, two design example with band ratios of 4.2and 1.95 have been fabricated and measured. The measured results show that the proposed FSS exhibits stable dual-band performance with arbitrary band spacing under a large variation of incident angle. Although the proposed FSS is limited for single polarization, the presented concept may be readily extended to realize a dual-polarized FSS, which may be the topic of a future publication.

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