A Novel Miniaturized Four-Band Frequency Selective Surface

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Abstract — In this paper, a novel miniaturized four-band frequency selective surface (FSS) is presented. The multi-band and miniaturization characteristics are realized by the utilization of a novel pattern, which consists of four spiral-based elements, and each element is made up of four spiral strips coiled from a centre point. Simulation proves the novel FSS has stable miniaturization and four-band characteristics with respect to different polarizations and incident angles, and the miniaturized amount can be controlled by the outer length of the strips. A prototype of the FSS is fabricated and tested, and the measured results demonstrate the correction of the simulation results.

I. INTRODUCTION

Frequency selective surfaces (FSSs) are planar periodic arrays of scatterers exhibiting one or more pass-bands or stop-bands for impinging electromagnetic waves. They are widely used in microwave technology as, for instance, in antenna radomes and reflectors [1-2]. One of the important applications of FSS is to be used as a method to increase the capabilities of satellite communications when the requirement of data communication links over multiple frequency bands makes it necessary to design a FSS operating at multiband frequencies [3]. During the last decades, many different methods have been proposed to create a multiband FSS. Fractal elements are utilized in paper [4] to design FSS for multiband and dual-polarized applications. In paper [5] double layers of simple elements with air gap between are used to create a dual-band FSS. And FSS constructed by square loop slots etched on substrate integrated waveguide cavities to realize triband is proposed in paper [3]. However, since theoretically FSS is infinite arrays, its practical performances are usually limited by the space. Therefore design of multiband FSS with miniaturization in size is more valuable for practical application. In paper [6] the authors proposed a miniaturized dual-band FSS consists of double square loops with different capacitive loadings. And FSS with double metallic planes of complementary pattern is proposed in [7] also to realize the miniaturized dual-band characteristic.

In this paper, a novel miniaturized four-band FSS is proposed. Instead of substrate integrated waveguide (SIW) technology, multilayer structure or methods proposed in other papers, the miniaturization and four-band characteristics are realized by a simple structure of one metallic plane of the novel spiral pattern proposed. Moreover, simulation results show that the structure performs excellent stability with respect to waves of different polarizations and incident angles, and the miniaturization amount can be controlled by the length of the outer strips, which ensures practicability of the FSS. Prototype of the FSS is fabricated and tested, and measured results demonstrate the characteristics of the FSS.

II. STRUCTURE DESIGN OF FSS

The structure of a unit cell of the FSS is shown in Fig.1. A unit cell of the structure consists of a layer of metal strips, with the height t=0.2mm, and put on top of a dielectric substrate, of which the width D=6mm, height h=1.6mm and relative dielectric constant ε_r=5.5. The pattern of the metallic plane is mainly made up of four elements. Each element is formed by four strips coiled from a center point. One of the strips is extended to the center of the plane so that four elements are connected together. Another strip is extended along the edge so that both the inductance of the unit cell and the capacitance between two adjacent cells are increased. Distance between every two adjacent strips are well controlled so that the capacitance between can be increased as much as possible and at the same time avoiding the appearance of grating lobes. So in the structure proposed distance between strips in a unit cell y=0.2mm, and distance between outer strips and edge of the unit cell g=0.1mm. All the widths of metal strips are the same, and the value w=0.2mm.

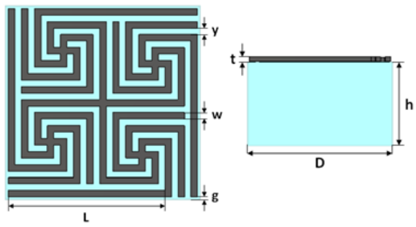


Fig.1. Top view and side view of a unit cell.

III. SIMULATIONS AND MEASUREMENTS

To investigate the transmission performances of the structure proposed, simulation by CST Microwave Studio is done and results are presented in Fig.3. It can be observed that for normal waves the FSS has four resonant frequencies in the frequency band 0-15GHz. Respect to the first resonant frequency, the size of the unit cell is only 0.072λ. Compared with the FSS consists of double square loops with different capacitive loadings with the size of 0.114λ proposed in [5] and the FSS with double metallic planes of complementary pattern with the size of 0.086λ proposed in [6], the FSS proposed in this paper has better miniaturization performance. Moreover, when illuminated by waves of different polarizations and incident angles, frequency deviation of each resonant frequency is no more than 2.5%. Therefore the structure performs great angle stability and polarization stability.

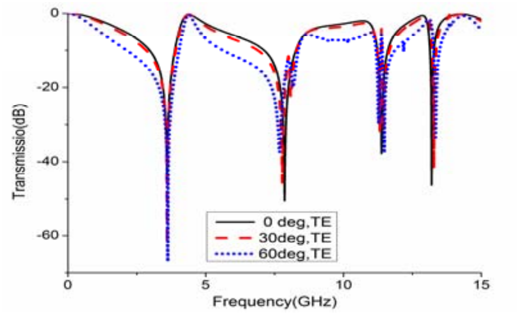


Fig.3. Transmittances of the FSS when illuminated by TE-polarized waves of different incident angles.

A prototype of the FSS with the dimension of 30cm×30cm (Fig.6 shows) is fabricated and tested in an anechoic chamber. Two horn antennas are used to transmit and receive waves, and Agilent E8363B vector network analysis instrument is also used to analyze the data received. Two measurements, transmittances with and without the FSS, are taken to ensure the precision of the test. The results are presented in Fig.7. It can be observed that for all the resonant frequencies there are good agreement between simulation and measurement, and therefore demonstrate the four-band and miniaturization characteristics of the FSS.

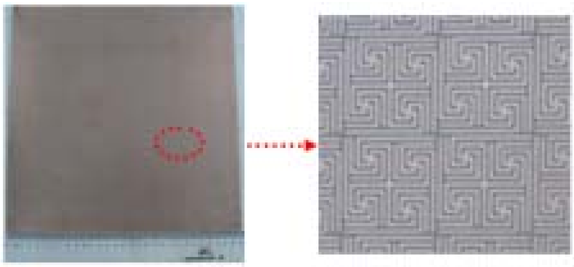
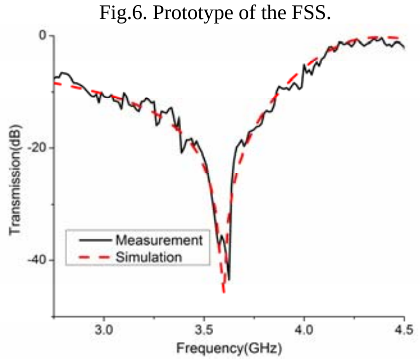
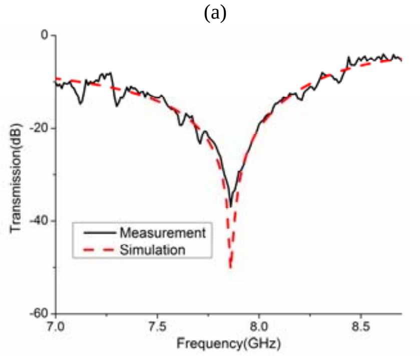


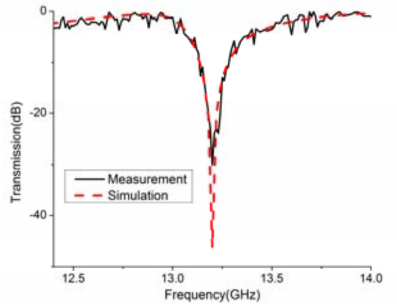
Fig.6. Prototype of the FSS.



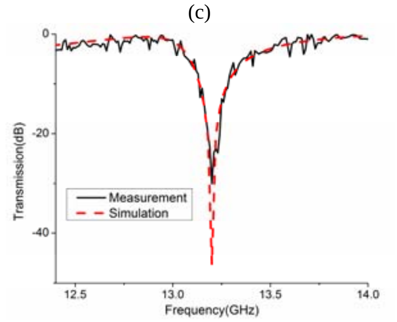
(a)



(b)



(c)



(d)

Fig.7. Measured and simulated transmittances of the FSS. (a) First resonant frequency ; (b) Second resonant frequency; (c) Third resonant frequency; (d) Fourth resonant frequency

IV. CONCLUSIONS

In summary, by utilization of a novel pattern which mainly consists of four strips-coiling elements, a novel miniaturized four-band FSS is realized. Both simulation and test results show the dimension is only 0.072λ, and the FSS has great stability with respect to different polarizations and incident angles. Thus, the FSS shows great potential for practical application.

V. REFERENCES

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