A Miniaturized Frequency Selective Surface by Using Vias to Connect Spiral Lines and Square Patches

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***Abstract*—In this paper, a new miniaturized frequency selective surface (FSS) structure is proposed. Compared with previous FSSs, the proposed structure has promising miniaturization features. The array element is implemented by using vias to connect structures on two surface layers. The dimensions of the proposed array element are only 0.035λ×0.035λ. The top layer is constructed by four spiral-shaped structures; the bottom is made of four square-shaped patches. They are connected in series by vias. In so doing, the values of the resonant component values are increased; thus the resonant frequency is shifted downwards. The frequency response is insensitive to the oblique incidence angle. Also the proposed design is symmetric around the xy plane and can be applied for circular polarization applications.**

Keywords— FSS, frequency selective surfaces, Spatial filter

I. INTRODUCTION

Frequency selective surface (FSS), as a kind of spatial filter, is a planar or curved surface composed of scattering array elements arranged periodically, correspondingly with a passband or stopband. Traditionally, an FSS is usually constructed from slots, patches, or arbitrary geometrical structures within a metallic screen. In the past few decades, FSSs have been widely used in a variety of microwave applications, ranging from antenna reflectors, filters, absorbers, aircraft radomes, wireless securities to electromagnetic (EM) shielding applications. The use of dual-reflector antennas in space missions such as Galileo, Voyager and Cassini, sharing the main reflector among different frequency bands, has been made possible by using an FSS[1, 2]. The miniaturization of FSS elements is needed to produce an array with sufficient number of elements approaching the infinity. Miniaturizing an element is mainly achieved by enhancing the equivalent component values of resonant elements. One way to realize element miniaturization is to connect structures in different layers using vias. Metal vias are used with a planar tapered meandering line and to miniaturize the FSS array element to 0.049λ × 0.049λ in [3]. Two pairs of split square rings (one pair on the top and the other pair on the bottom of the substrate) are connected in series by vias to miniaturize the element to 0.062λ × 0.062λ in [4]. Four planar meandering lines and vertical metallic via-holes are used to design miniaturized FSS, with element size 0.039λ × 0.039λ in [5].

In this paper, the vias are used to miniaturize the element of a bandstop FSS by connecting the spiral layer (inductive) in series with a patch layer (capacitive). The polarization independence can be achieved by the symmetric arrangement of the proposed unit structure. The stable performance against the oblique incidence angle can be realized by the miniaturized unit structure and using via between top and bottom surfaces. To verify the proposed structure, numerical analysis of the proposed element was performed by using CST Microwave Studio, using array element boundary conditions to provide periodicity along the x and y axes. The FSS is excited by an EM wave with the propagation vector (**K**) in the direction of the z-axis, magnetic field vector (**H**) in the direction of the x–axis and electric field vector (**E**) in the direction of the y-axis direction.

II. CIRCUIT DESIGN

In this paper, a novel miniaturised FSS is proposed based on connecting two different layers using vias to increase the electrical length. In the FSS array element, four spiral lines are connected to the centre point as a unit on the top layer. Four square patches surfaces are printed on the bottom of the dielectric substrate. The four spiral lines are connected with the four patches by four metal vias. Compared with the traditional FSS ones, the proposed FSS element has a much lower resonant frequency due to its longer electrical length. The performance of the FSS using the proposed structure is also stable at various polarisations and incident angles. The main design variables and the layout of the proposed element are shown in Fig 1. The proposed FSS with 2×2 array elements is shown Fig. 2 shows. To confirm the stable frequency response of the designed miniaturized FSS, a simulation of the structure has been carried out. The resonator is designed on a 1.6 mm thick FR4 substrate with a relative dielectric constant of 4.3. The periodic constant of the array is 6 mm. The area of the square patch is 2.8 × 2.8 mm^2. The slot width between patches, S, is 0.2 mm. The spiral strip widths are: w_1 = 0.3 mm, w_2 = 0.5 mm and w_3 = 0.2 mm. The space between these strips, g, is 0.2 mm. Vias with a radius of 0.2 mm were used to connect the spiral lines and patches between the two layers. Fig. 3 shows the simulated transmission characteristics of the FSS for the TE and TM modes, with variable incident angles of 0º, 15º, 30º, 45º, and 60°. The resonant frequency is 1.746 GHz with an up to 45 % fractional bandwidth. The size of the proposed element was substantially reduced to 0.035λ × 0.035λ, where λ is the wavelength in free space at the resonant frequency. The resonant frequency remains stable for both polarizations, even though the incident angle is up to 60º.

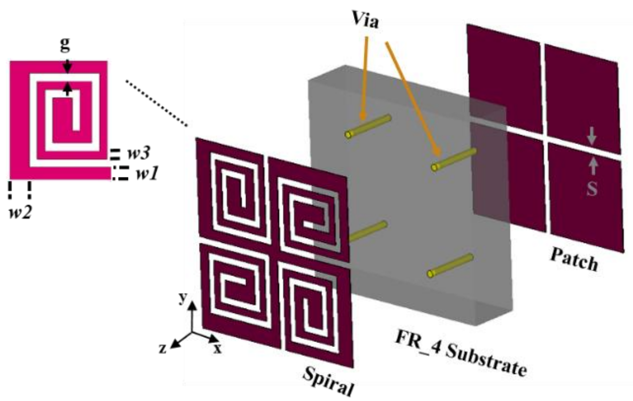


Fig. 1. An array element of the proposed FSS.

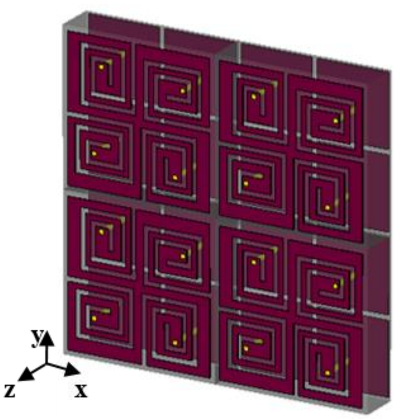
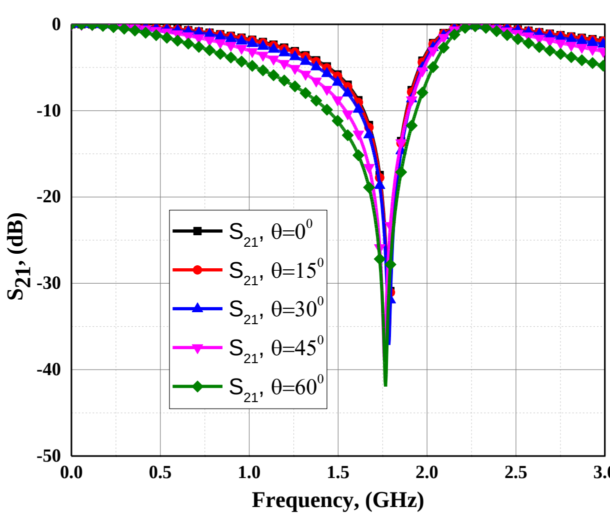
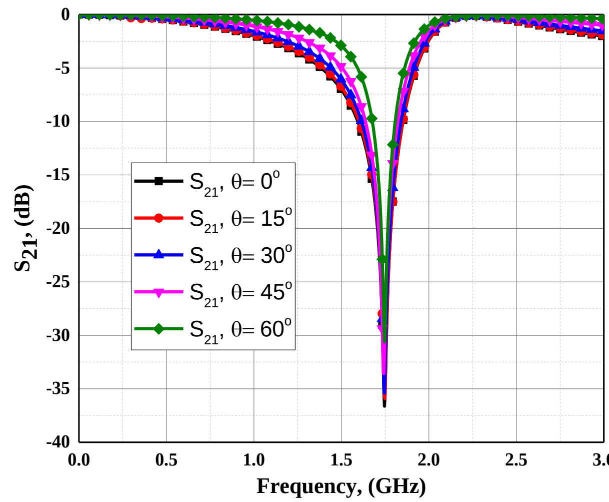


Fig. 2. An FSS using 2×2 array element of the proposed structure.



(a)



(b)

Fig. 3. The transmission coefficient of the proposed FSS as a function of incident angles (a) for the TE Mode, (b) for the TM mode.

III. CONCLUSION

In this paper, a new mainiturized FSS structure with simple configuration has been proposed. As a comparison with previous work which used vias for miniaturization as listed in the literature, the element size is only 0.035λ × 0.035λ. In addition, it can be easily fabricated by using low cost PCB technology. The proposed structure is tested under different incident angles by simulation. It was verified that the response is insensitive to the incident angle for both the TE and TM modes. The structure displays a very stable resonant frequency with an incident angle of up to 60°.

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