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PHASE SHIFT OF THE TRANSMISSION COEFFICIENTS FOR FREQUENCY SELECTIVE SURFACES

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Abstract

Frequency selective surface (FSS) is used to block multiband frequencies and allow only certain frequency signal pass through. The basic shapes of FSS such as circle, hexagon and rectangular have been designed and simulated. The basic shapes of FSS are designed and simulated using CST Microwave Studio software at 1.8 GHz and 2.4 GHz. There is a variation of phase shift when the simulation is with or without the dielectric substrate and diecletric substrate with FSS.

Keywords - Frequency selective surface (FSS), multiband, transmission, phase shift, substrate.

1 INTRODUCTION

FSS is a surface which is exhibits different reflection and transmission properties as a function of frequency. A surface which is not frequency selective surface is a flat perfectly conducting sheet. The surface is assembled with identical patch or aperture conducting elements repeating periodically in either a one or two dimensional array. The array of slots acts as a bandpass filter, passing waves at the resonant frequency of the slots but rejecting them at higher and lower frequencies. FSS is a periodic metallic patches or aperture elements within one or more metallic screens backed by dieletric slabs. One characteristic of the FSS is that the size of the resonant elements and their spacing are comparable to half a wavelength or more at the operating frequency which indicates that the designed FSS has a large periodicity, thickness and weight [1-5].

Over the years, FSS has been widely used, composed of filters, laser cavity output couplers, polarization diplexers, spectral diplexers, and many more. Their frequency selective characteristics are determined by the shape and periodic spacing of conducting patches [6]. The frequency response of the FSS can be achieve by adjusting some of the parameters such as the dimensions of periodicity, element shape, dielectric thickness and constant, and number of periodic screens [7]. The effect of various parameters on the transmission characteristics of the FSS such as width and length of patch, thickness of the substrate have done on the previous work [8

FSS is a periodic resonant arrays where the surfaces are periodic resonant arrays offering reflection coefficients and transmission coefficients with not only frequency dependent amplitude but also the frequency dependent phase in the microwave applications [9]. Phase shift is due to the incident wave. Corresponding to the phase front of the wave, these elements have a certain phase delay. Depending on the direction of illumination (incidence angle), the phase of the incident wave may vary from element to element. The phase variations, however, are linear along the elements and can be easily included in the boundary conditions. By analogy with circuit theory, the phase response can be smoothened out by introducing some loss in the FSS structure. Phase shift is any change that occurs in the phase of one quantity, or in the phase difference between two or more quantities. This is a general property of waves. If the waves are reflecting off a clamped point, the waves get phase inverted. The reason is the principle of superposition and the condition that the amplitude at the clamped point is zero. The sum of the reflected and transmitted wave must be the amplitude of oscillation at all points, so that the reflected wave must be phase inverted to cancel the incoming wave [10].]. In this paper, the basic shapes FSS are designed and simulated by using CST Microwave Studio software. The phase shift of the transmission is investigated at 1.8 GHz and 2.4 GHz.

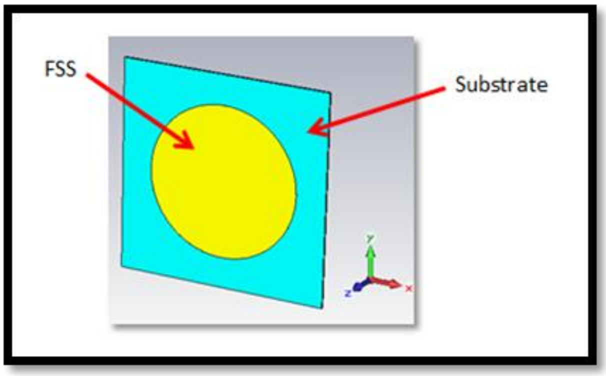
2 FREQUENCY SELECTIVE SURFACE (FSS) DESIGN

The basic structure of the FSS is shown in Fig. 1. Fig. 1 (b) shows the simulation setup for FSS structure with waveguide port. Waveguide ports are used to feed the calculation domain with power and to absorb the returning power. For each waveguide port, S–parameters (and time signals for time domain simulations) will be recorded during a solver run. In practice, the port can be substituted by a longitudinal homogenous waveguide connected to the structure. The distance between the substrate and also port 1 and 2 are constant which is 30 mm.

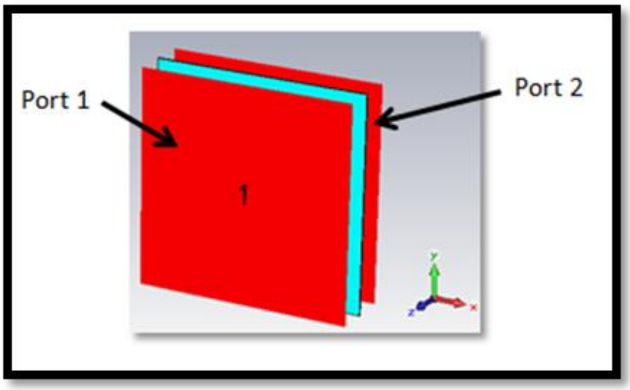
The basic structure of FSS as shown in Fig. 1 (a) consists of 2 layers that are patch and dielectric substrate. The top layer is patch or FSS structure. Then, the second layer is dielectric substrate. The material for dielectric substrate is FR4 board. Table 1 show the components and materials that have been used for the dielectric substrate and FSS. Unit cell of each FSS shape are shown in Fig. 2. The basic shapes that have been designed and simulated are circle, hexagon and rectangular.

Table 1. Components and materials that have been used

Components	Materials
Substrate	FR4 $\mu = 1$ $\varepsilon_r = 4.4$ $\tan\delta = 0.019$
Patch (FSS)	Copper (annealed) $\mu = 1$



(a)



(b)

Fig. 1. FSS structure from perspective view (a) FSS with substrate (b) FSS with substrate and port

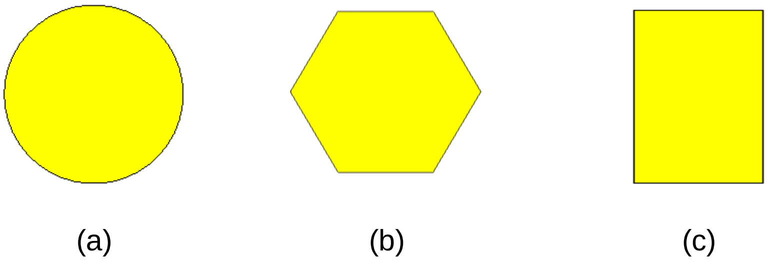


Fig. 2. Shapes of FSS (a) Circle (b) Hexagon (c) Rectangular

3 RESULTS AND DISCUSSION

In this paper, the investigations on the phase shift of the transmission coefficients (S21) are done. The phase shift investigation is done to observe the magnitude of the change in phase of a field quantity at the output .Firstly, the simulation is run with port only. Then the simulation is continued by adding a dielectric substrate. Then lastly the simulation is run by adding a FSS on the dielectric substrate. The results of the phase shift of the transmission coefficients are observed. There are phase shift when adding components to the simulation. The phase is high variation at frequency ranges of 1.2 GHz to 1.4 GHz for circle, hexagon and rectangular shapes.

A. Circle shape

For circle shape, at 1.8 GHz when simulated with port alone the phase is -130.22°, when adding dielectric substrate the phase is shift to -136.28° and lastly by adding a FSS on dielectric substrate the phase is more shifted to -82.39°. At 2.4 GHz, the phase is shift from -174.20° to 177.60° when adding a dielectric substrate. Then when adding a FSS on dielectric substrate the phase is shift to -173.52°. The phase is most likely when simulate with port only and when simulate by adding a FSS. Fig. 3 is shown the phase shift of the transmission coefficients for circle shape.

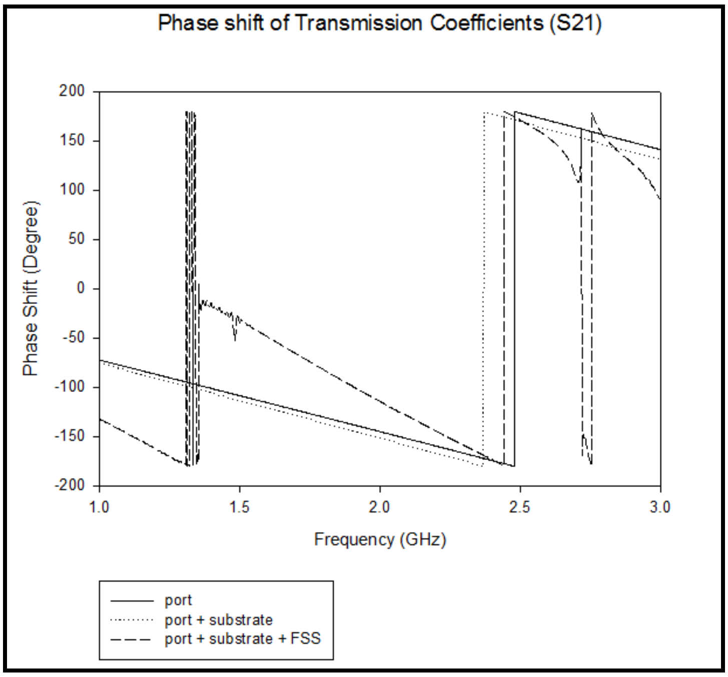


Fig. 3 Phase Shift of transmission coefficients for circle shape

B. Hexagon shape

For hexagon shape, at 1.8 GHz the phase is -130.22° when simulated with port only. The phase is shifted to -136.28° when adding a dielectric substrate as a component. After that a FSS is added on the dielectric substrate, the phase shift then shifted to -86.09°. While at 2.4 GHz, the phase is -174.20°, then after adding dielectric substrate the phase is shifted to 177.60°. Then the phase is shifted to -173.44° when adding a FSS on the dielectric substrate. Fig. 4 is shown the phase shift of the transmission coefficients for hexagon shape.

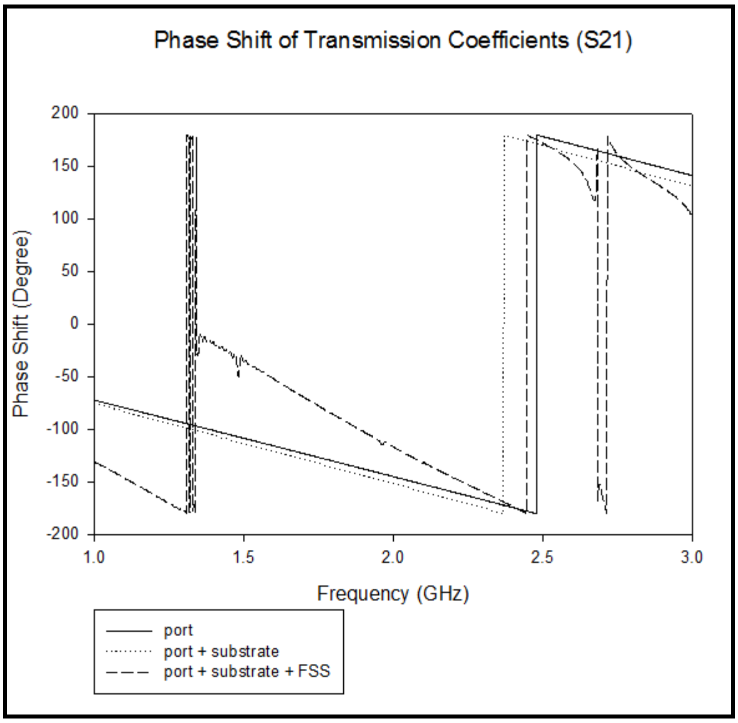


Fig. 4 Phase Shift of transmission coefficients for hexagon shape

C. Rectangular shape

For rectangular shape, at 1.8 GHz when simulated with port only the phase is -130.22°, when adding dielectric substrate the phase is shift to -136.28° and lastly by adding a FSS on dielectric substrate the phase is more shifted to -82.39°. The result is then observed at 2.4 GHz, the phase is shifted from -174.20° to 177.60° when simulated with port only then by adding a dielectric substrate. Then the phase is shifted when adding a FSS on the dielectric substrate which is -173.56°.

The phase is little bit shifted when adding a FSS on the dielectric substrate. The phase is almost the same as the simulation is run with port only with the simulation that runs by adding a dielectric substrate and also a FSS on the dielectric substrate. Fig. 5 is shown the phase shift of the transmission coefficients for rectangular shape. There is variation of phase at frequency ranges of 1.2 GHz to 1.4 GHz when simulated by adding a FSS on the dielectric substrate.

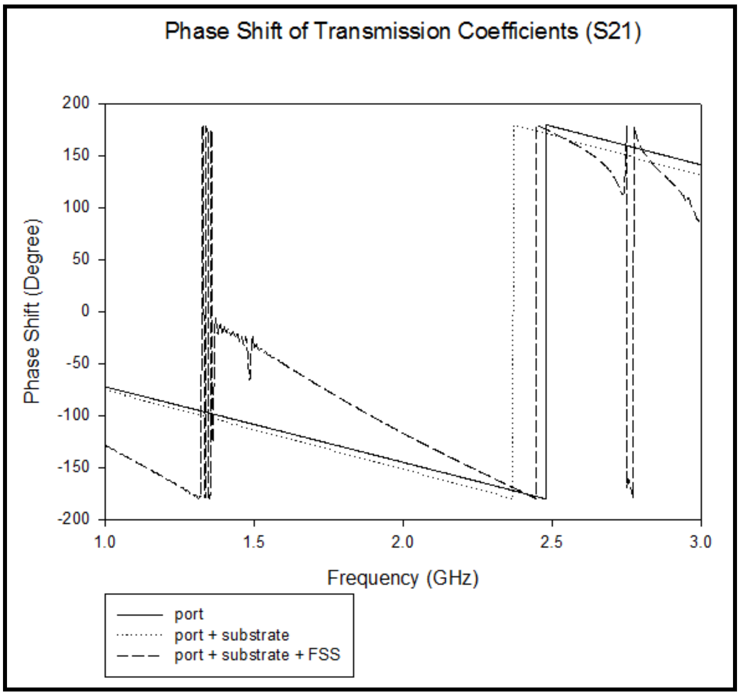


Fig. 5. Phase Shift of transmission coefficients for rectangular shape

There is a variation of phase shift when the simulation is run only with port 1 and port 2 compare with the simulation that run with dielectric substrate and dielectric substrate with FSS. There is only a little bit difference comparing the phase shift different between different shapes of FSS. There are only a little bit different of the phase shift between the circle, hexagon and rectangular shapes which are -173.52°, -173.44° and -173.56°. There are only smaller different between those shapes of the phase shift about 10% different. There are variation of phase at the frequency ranges of 1.2 GHz to 1.4 GHz. Fig. 6 is show the phase different between the circle, hexagon and rectangular.

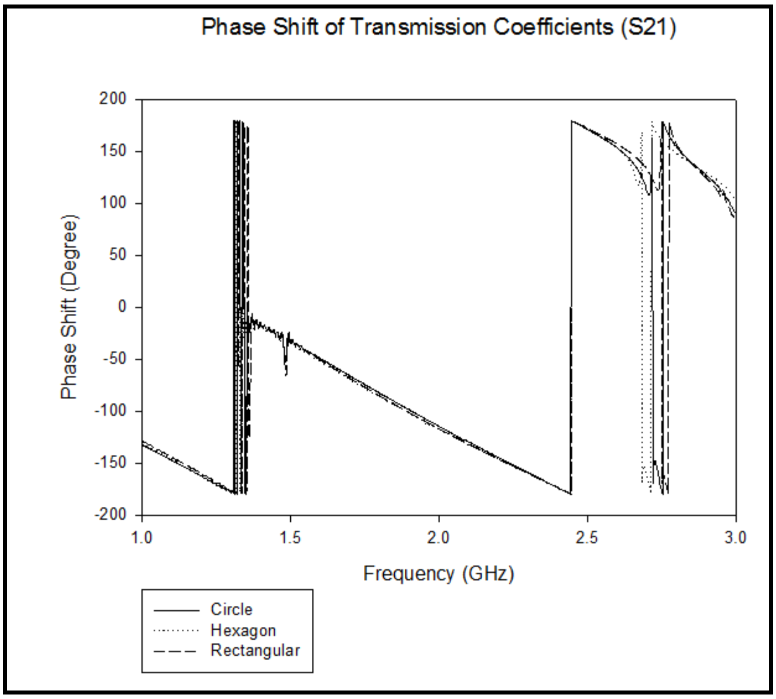


Fig. 6 Phase Shift of transmission coefficients for different shapes of FSS

4 CONCLUSION

In this paper, the basic shapes of FSS have been designed and simulated at 1.8 GHz and 2.4 GHz. The investigation is about the phase shift of the transmission coefficicents (S21). There are only little bit difference of phase shift between circle, hexagon and rectangular shapes of FSS. The shapes gave little effect to the phase shift. There are huge different of phase shift when adding the dielectric substrate. The dielectric susbtrate wih the FSS can maintain the phase of the signal same with the phase of the signal while simulated with port only. Futher investigation is needed to investigate the effect to the phase when adding two or more dielectric substrate and also when adding two or more FSS on the dielectric substrate.

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