Design and Electrical Characterization of Metamaterial Based FSS Resonators

Reeta Saini, Parbhjot Kour

Abstract—**Frequency selective surface (FSS) is well known devices for use at microwave frequencies in various applications. Usually they consist of a periodic array of resonant metallic elements or apertures on a metallic screen. According to diffraction theory, for secondary-grating lobe suppression the size and periodicity of the resonant elements should be smaller than the wavelength of the incident radiation. FSS has been extensively studied due to its potential applications in antenna reflectors, high-impedance surfaces and absorbers. In this research work double slit ring resonator FSS structure is modelled and simulated using FEM based method.**

***Index Terms*—Split rings, FSS, frequency domain, Electromagnetic wave.**

I. INTRODUCTION

Frequency selective surfaces (FSSs) resonating structures with periodicity in two dimensions have important applications in electromagnetic wave based devices. These are metasurfaces that merely demonstrates an electric response. The frequency selective surface tailoring in terms of transmission/reflection characteristics maybe done on the basis of electrical polarization parameter. Planar and periodic arrays of metallic patches or strips with different shapes are made based on the theory of antenna and microwave engineering. The metallic patch is of small thickness and of larger enough in contrast to the metal's skin depth as compared to the wavelength. Consequently, such a structure can perfectly be estimated as a microscopic thin array of perfect conducting resonant elements. FSS is a extensively studied topic of electromagnetic science, which are two-dimensional array structures having planar metallic elements (such as patch or apertures) on a dielectric substrate, showing transmission and reflection at certain resonant frequency [1-5]. The array element design play an important role in interaction with incoming plane wave which will be either transmitted or reflected, completely or partially. The process of transmission/reflection happens only when the frequency of the plane wave matches the resonance frequency of the FSS elements. Therefore, an FSS can transmit or block the EM waves with certain frequencies in free space [6].

A periodic surface is formed when identical elements are arranged in an infinite array of one or two-dimensions. The periodic array are excited using incident plane wave (known as passive array type excitation) or by the attached generators to individual element (known as active array type excitation). In passive type, the incoming plane wave (*Ei*) will partially be transmitted (*Et*) in the forward direction and in part reflects (*Er*). When t he resonance condition occurs without grating lobes, the amplitude of the reflected wave *Er* which may be equal to incident wave *Ei*, and the transmitted signal *Et* is equal to zero. The specular reflection coefficient (Γ) can be defined by

$$\Gamma = \frac{E_r}{E_i}$$

Similarly, the transmission coefficient (T) can be defined by

$$T = \frac{E_t}{E_i}$$

In a periodic surface the active array the voltage generators must have same amplitude and linear phase variation through whole active array elements so that it may be regarded as a periodic surface [8-9]. Dipole and slot arrays with a similar shape of elements constitute complementary arrays so that when both of these arrays are positioned on top of one another (cascaded), a perfect conducting plane is created. The transmission coefficient of single array is equal to the reflection coefficient of its complementary array which is given by Babinet's principle [10-15].

Frequency selective surface (FSS) consists of two-dimensional array of metallic patches or apertures in a thin conducting film and has been widely used as a filter in microwave and millimeter wave band. The classical FSS fabrication process utilizes the metal with high conductivity such as copper, aluminum or silver to improve its performance. However, the use of the metallic layer raises a problem that the FSS has a low transmittance in the optical band (from ultraviolet to infrared), which limits its applications in several fields, e.g., the energy saving window panels, the wall for securing indoor wireless networks5 and the dome on the aircrafts [16-18]. Especially for the application on the dome, the FSS should have a high transmittance in the infrared band of 3–5 μm for imaging sensor and also a band-pass filtering effect in high frequency (26–40 GHz) for receiving radar signals [19-20].

In this research work double slit ring resonator based frequency selective surface is simulated. Frequency domain analysis of the designed device is carried out using FEM method.

II. SIMULATION AND DESIGN PROCEDURE

Polytetrafluoroethylene (PTFE) metamaterial based frequency selective surface resonator is designed and simulated using finite element method (FEM) tool. Simulation process flow comprises of geometry design and electromagnetic physics application over the structure in frequency domain. Structure is simulated to estimate the range of electromagnetic wave that can be trapped using the structure. The designed resonator structure is sown in Fig. 1. A split ring with a circular dot in the center is designed for the FSS structure. The structure is extruded on metamaterial substrate is shown in Fig.2. The irradiation of the structure via electromagnetic wave is employed on the top of the structure through port 1 shown in Fig. 3.

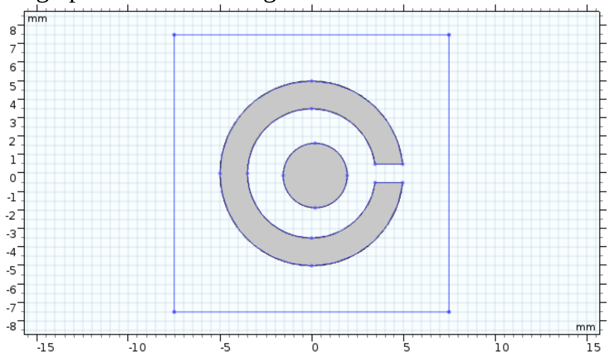

Fig. 1. Split ring resinantor with circular dot as FSS.

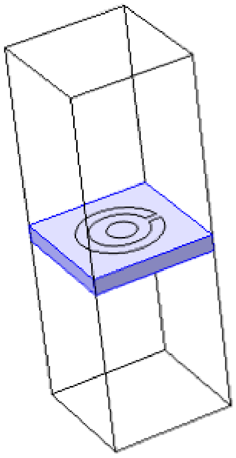

Fig. 2. Extruded geometry over metamaterial substrate.

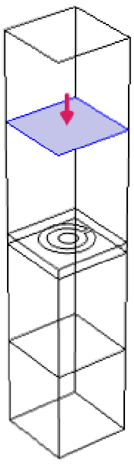

Fig. 3. Irradiation port for FSS.

III. Results and Discussion

Designed structure was meshed using physics controlled meshing with extremely fine size. Complete structure was meshed using triangular and rectangular meshing. Meshed structure of FSS is shown in Fig. 4. Frequency domain analysis of the FSS device was carried out from 3.8 GHz to 5.4 GHz with step size of 0.1 GHz. S-parameters i.e. S_{11} and S_{21} are observed and plotted in Fig. 5. From the results it is observed that the resonant frequency occurs around 4.15 GHz. Figure 6 shows the contour smith chart of computed S-parameter. Electric field variation computed for frequency ranging from 3.8 GHz to 5.4 GHz.

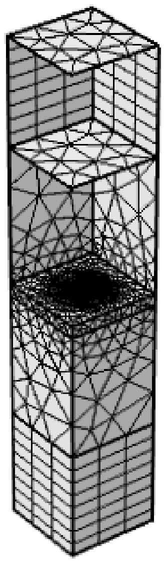

Fig. 4. Physics controlled meshing of the structre.

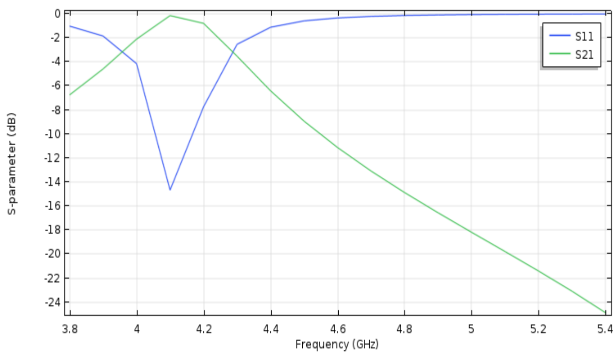

Fig. 5. S-parameters of FSS structure.

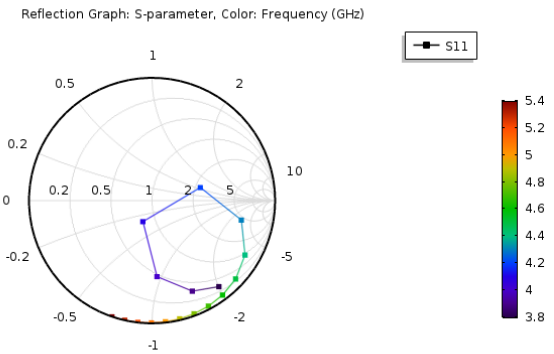

Fig. 6. Contour smith plot of S-parameter.

Table 1 Computed electric field per meter with respect to frequecny.

S. No.	Frequency	Electric field V/m
1	3.8	$9x10^3$
2	3.9	$1.2x10^4$
3	4	$1.6x10^4$
4	4.1	$2x10^4$
5	4.2	$2x10^4$
6	4.3	$1.4x10^4$
7	4.4	$1.1x10^4$
8	4.5	$8x10^3$
9	4.6	$7x10^3$
10	4.7	$5x10^3$
11	4.8	$5x10^3$
12	4.9	$4x10^3$
13	5	$3.5x10^3$
14	5.1	$3.5x10^3$
15	5.2	$3x10x^3$
16	5.3	$3x10^3$
17	5.4	$2.5x10^3$

IV. Conclusion

The research work is carried out to demonstrate the capability of metamaterial based FSS. Poly tetra fluoro ethylene (PTFE) based substrate having dimensions 15 mm width, 15 mm length and 2 mm thickness. FSS structure with prefect electric conductor property is designed and simulated over the metamaterial substrate. A circular dot surrounded with split ring resonator is modeled and analyze in frequency domain. The resonant frequency is observed around 4.15 GHz approximately. Electric filed distribution over the structure is also analyzed. Metatmaterial based FSS shows good quality of response in frequency domain.

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