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Simulation Metamaterial Based FSS with Internal Boundary Split Ring

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Abstract: Frequency selective surface (FSS) is a periodic surface with identical two-dimensional arrays of elements arranged on a dielectric substrate. An incoming plane wave will either be transmitted (passband) or reflected back (stopband), completely or partially, depending on the nature of array element. This occurs when the frequency of electromagnetic (EM) wave matches with the resonant frequency of the FSS elements. Set of simulation optimization were carried out with single split FSS, split with internal boundary and dual split FSS with internal boundary. Metamaterial based substrate with perfect electric conductor (PEC) layer was used to make the FSS design. It was observed from the results that with internal boundary and dual split ring based FSS has higher resonance frequency.

Keywords: FSS, S-parameter, resonance, planar.

I. INTRODUCTION

A frequency selective surface (FSS) is formed by periodic arrays of usually metallic elements on a dielectric substrate. The geometry of the surface in one period (array element) determines the frequency response of an FSS. Various responses can be achieved by using different traditional FSS element shapes. The FSS often displays selectivity not only on the frequency, but also on the angle and polarisation of the incident wave. FSS can be constructed by using identical elements arranged in a one or two-dimensional infinite array. If an aperture type FSS is created from a patch type FSS in such a way that the metal portions of the former are replaced by aperture portions of the latter, then the two FSS are said to be duals of one another. The FSSs can be classified as the bandstop patch type and the bandpass mesh type. If the metal plates are not connected, it is called a capacitive surface, and it reflects high frequencies whilst transmitting low frequencies. On the other hand, its complementary structure is called an 'inductive surface', which reflects low frequencies whilst transmitting high frequencies. Babinet's principle can be applied to prove that the transmission coefficient for the complementary structure of one array is equal to the reflection coefficient for the array [1, 2]. The frequency response of the transmitted signal of the complementary FSS is not exactly the dual of the reflected signal of the FSS due to the loss in the dielectric substrate. A perfectly dual behaviour for the complementary screen of the proposed filter is expected if the loss of the dielectric substrate, as well as the effects of the metal thickness, are neglected [2]. Hence, Babinet's principle can be employed to produce bandpass FSS from bandstop FSS, low pass FSS from high pass and vice versa. Different characteristics can also be obtained by cascading or combining individual filters. For instance, a bandstop filter could be formed by combining a number of bandpass filters. The equivalent circuits for a bandstop FSS or a bandpass FSS are the combination of LC in series or in parallel, respectively [1, 3]. Traditionally, many different shapes have been used to construct an FSS. However, the equivalent FSS circuit is directly related to the array element size, shape and the polarisation. Equivalent circuits and analysis of some of the traditional structures are provided in [3, 4]. FSSs have been most commonly used in microwave and optical frequency regions of the electromagnetic spectrum and for applications such as antennas, radomes, radio frequency absorbers, wireless securities to electromagnetic (EM) shielding applications and metamaterials [3, 7-13]. Decreasing loss in antennas and improving the radiated power are successfully realised by using these structures [13, 14]. They are designed to reflect, transmit or absorb electromagnetic radiation at different frequencies [1, 15, 16]. The use of dual-reflector antennas in space missions such as Galileo, Cassini, Cassegrain and Voyager, sharing the main reflector among different frequency bands, has been made possible by using an FSS, [19-22]. The choice of selecting the proper element may be of most importance when designing either a bandpass or band-stop FSS. Some elements are inherently more narrow-band or more broadband than others, while some can be varied considerably by design. Different FSS types can be chosen based on the application requirements. These requirements usually include a level of dependence on the polarisation and incidence angle of the incoming wave and bandwidth. However, it is worth mentioning that in general, at least for mechanical and miniaturisation reasons, all FSS must eventually be supported by a substantial assembly of dielectric slabs. This has a strong effect on the bandwidth variation with angle of incidence and the element size. The most common element types available to FSS designers. The elements can be arranged into three groups. The first group is the loop FSSs, such as the hexagonal rings, the circular ring, the square rings, the three and four-legged loaded elements. The second group is the centre connected FSSs, such as the square spiral elements, the

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four-legged elements, the Jerusalem cross and the three-legged elements. The third one is patch FSSs, such as square, circular paths and hexagonal patches. The mechanism of operation in traditional FSSs is based on the resonant elements. The idea is that a plane-wave illuminates an array element. This will excite electric current on the element. The amplitude of the generated electric current depends on the strength of the coupling of energy between the element and the incident wave. At the fundamental frequency where the length of the element is λ/2, the coupling reaches its highest. As a result, the elements are formed so that they are resonant near the frequency of operation. The current itself can act as an electromagnetic source depending on its distribution. It produces a scattered field. The scattered field added to the incident field forms the total field in the space surrounding the FSS. The scattered field can be controlled through the design of the elements.

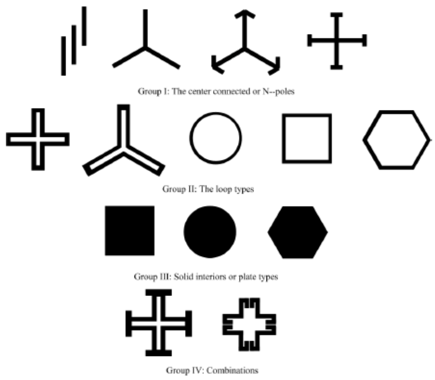

Fig.1 Typical FSS Elements classified in four major groups based on their shapes.

II. SIMULATION PROCESS FLOW

The modeling procedure is controlled through the Model Builder window, which is essentially a model tree with all the functionality and operations for building and solving models and displaying the results. During solid modeling, geometry is formed as a combination of solid objects using Boolean operations like union, intersection, and difference. Objects formed by combining a collection of existing solids using Boolean operations are known as composite solid objects. Following geometry creation is steps are taken for design the FSS. A block (box), on the 3D Geometry toolbar, is created. This operation can be used to convert a 2D geometry in a work plane into a 3D object. The *Extrude* operation enables you to extrude objects from a work plane or planar face to create 3D objects (Figure 2). Final shape of the designed geometry is shown in Fig. 3

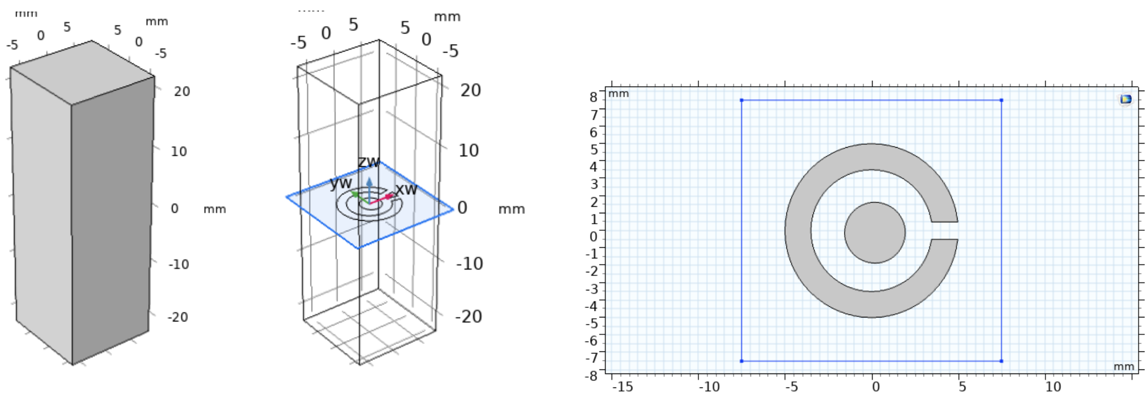

Fig. 2 Geometry design.

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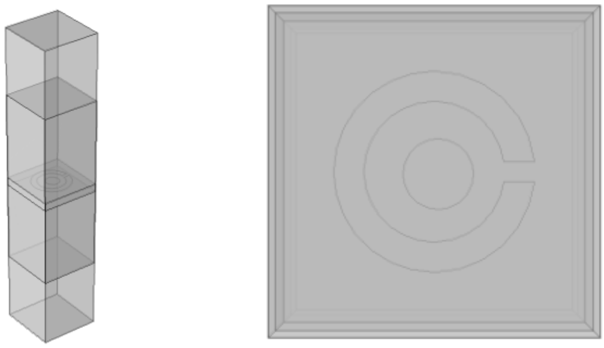

Fig. 3 FSS device with dual split resonator.

III. RESULTS AND DISCUSSION

A split ring slot is patterned on a geometrically thin copper layer that sits on a polymer substrate. The copper layer is much thicker than the skin depth in the simulated frequency range, so it is modeled as a perfect electric conductor (PEC). The rest of the simulation domain is filled with air. Floquet-periodic boundary conditions are used on four sides of the unit cell to simulate the infinite 2D array. Perfectly matched layers (PMLs) on the top and bottom of the unit cell absorb the excited mode from the source port and any higher order modes generated by the periodic structure. The PMLs attenuate the wave as it propagates in the direction perpendicular to the PML boundary. Since the model is solved for a range of incident angles. The Port boundary conditions automatically determine the reflection and transmission characteristics in terms of S-parameters. The interior port boundaries with PML backing require the slit condition. The port orientation is specified to define the inward direction for the S-parameter calculation shown in Fig. 4. It can be observed from the figure that the resonance occurs at 4.125 GHz with S_{11} value of -30 dB.

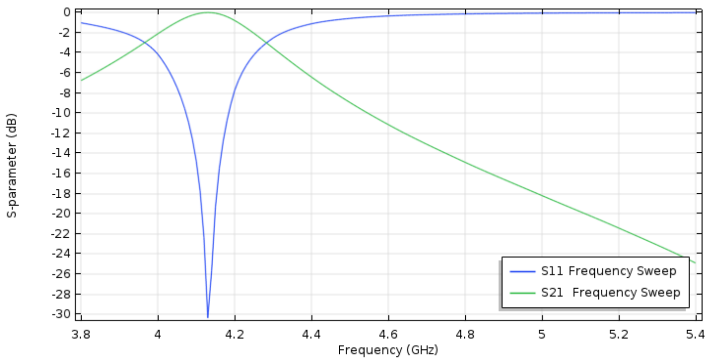

Fig. 4 S-parameter plot for single split FSS with internal boundary.

Figure 5 and Figure 6 shows the electric and magnetic field interaction with the designed FSS at split corners a flat band is seen in the resonance frequency domain. The maximum electric field displacement observed is $11x10^3$ V/m and magnetic field of 600 A/m. Figure 7 3D plot of electric field interaction with the FSS single split with internal boundary at various frequencies.

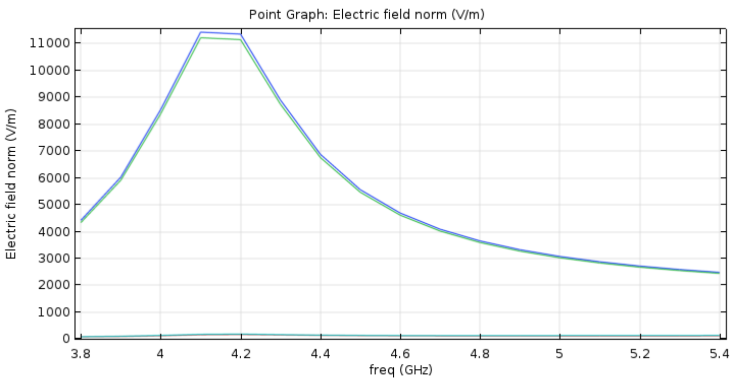

Fig.5.7 Electric filed vs frequency for single split FSS with internal boundary.

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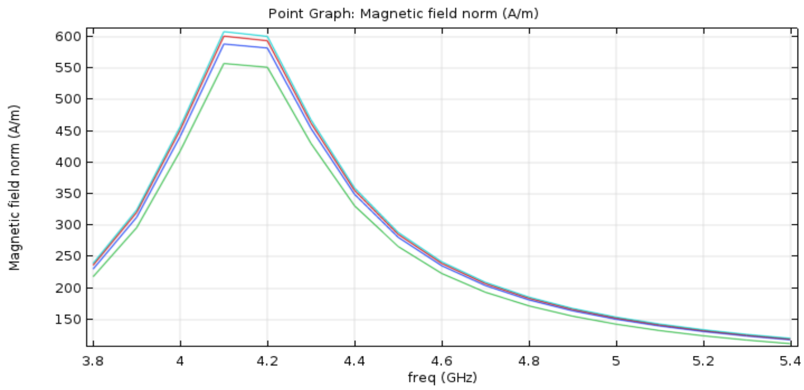
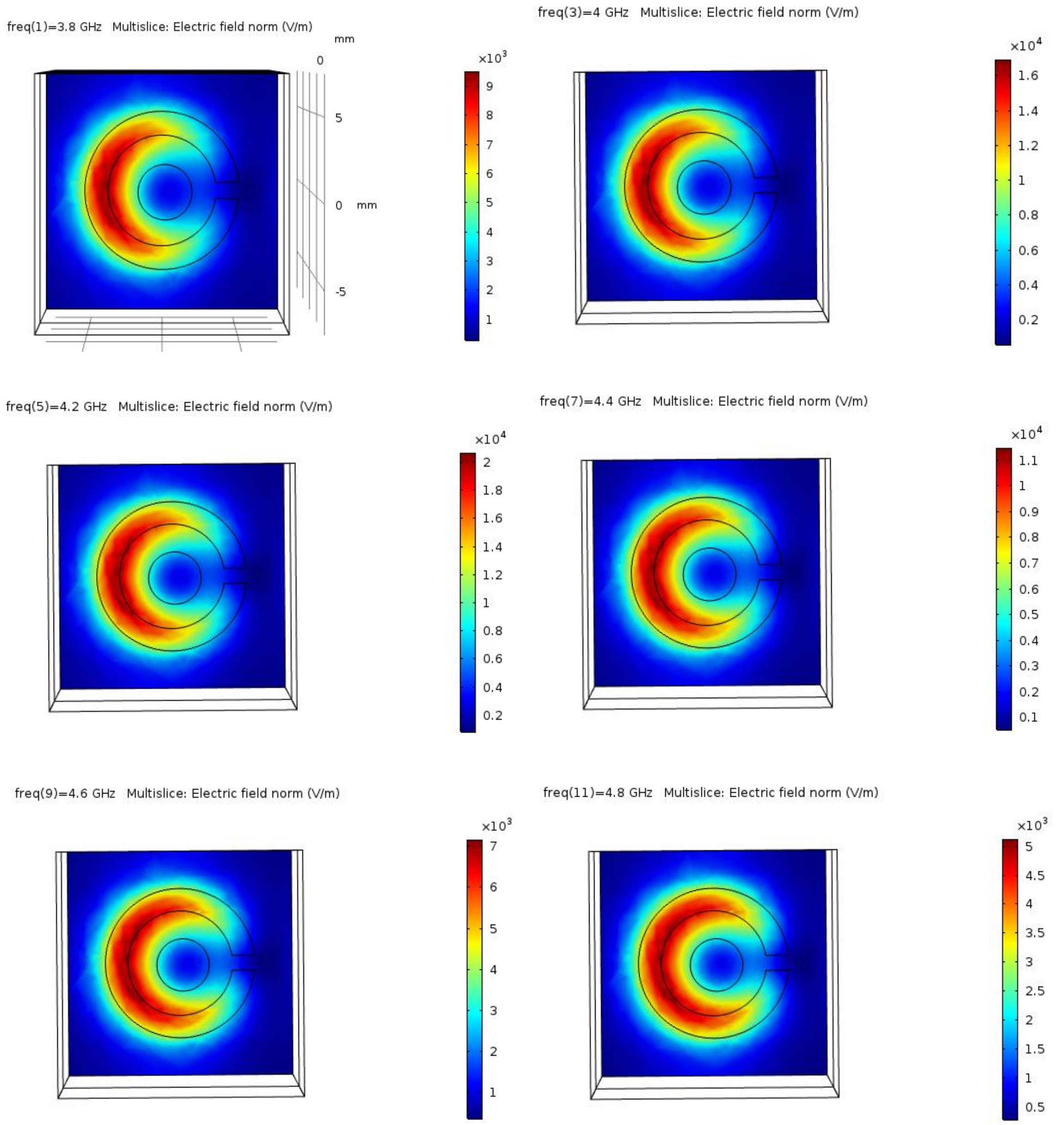


Fig. 5.8 Magnetic field vs frequency for dual split FSS with internal boundary.



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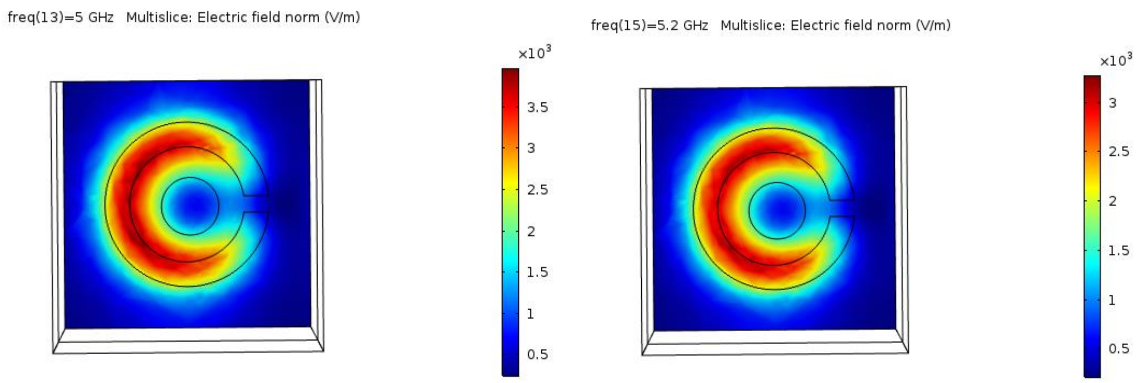

Fig. 5.9 Single split FSS device with internal boundary mlutisplice 3D plot for electric filed displacement at frequency ranging from 3.8 GHz to 5.2 GHz with step size of 0.2GHz.

IV. CONCLUSION

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. To improve the filtering effect, the metal with high conductivity is always adopted in the classical FSS fabrication process, such as copper, aluminum or silver. Experiment consists on internal boundary in the FSS with split ring. Single split ring with internal boundary showed highest value S_{11} and S_{21} at 4.125 GHz resonance frequency.

REFERENCES

[1] S. B. Glybovski,Tretyakov, S.A.; Belov, P.A.; Kivshar, Y.S.; Simovski, C.R. Metasurfaces: From microwaves to visible. Phys. Rep. 2016, 634, 1–72.

[2] Munk, B.A. Frequency Selective Surfaces: Theory and Design; Wiley Online Library: Hoboken, NJ, USA, 2000; Volume 29.

[3] Vardaxoglou, J.C. Frequency Selective Surfaces: Analysis and Design; Research Studies Press: Boston, MA, USA, 1997.

[4] Costa, F.; Monorchio, A.; Manara, G. An overview of equivalent circuit modeling techniques of frequency selective surfaces and metasurfaces. Appl. Comput. Electromagn. Soc. J. 2014, 29, 960–976.

[5] Arnaud, J.; Pelow, F. Resonant-grid quasi-optical diplexers. Bell Syst. Tech. J. 1975, 54, 263–283.

[6] Lee, S.-W. Scattering by dielectric-loaded screen. IEEE Trans. Antennas Propag. 1971, 19, 656–665.

[7] Pelton, E.; Munk, B. A streamlined metallic radome. IEEE Trans. Antennas Propag. 1974, 22, 799–803.

[8] Agahi,S.;Mittra,R.Designofacascadedfrequencyselectivesurfaceasadichroicsubreflector. InProceedings of the Antennas and Propagation Society International Symposium: AP-S Merging Technologies for the 90' (Digest), Dallas, TX, USA, 7–11 May 1990; pp. 88–91.

[9] Costa, F.; Genovesi, S.; Monorchio, A.; Manara, G. A robust differential-amplitude codification for chipless RFID. IEEE Microw. Wirel. Compon. Lett. 2015, 25, 832–834.

[10] Pozar, D. Flat lens antenna concept using aperture coupled microstrip patches. Electron. Lett. 1996, 32, 2109–2111.

[11] Li, D.; Li, T.-W.; Li, E.-P.; Zhang, Y.-J. A 2.5-D Angularly Stable Frequency Selective Surface Using Via-Based Structure for 5G EMI Shielding. IEEE Trans. Electromagn. Compat. 2018, 60, 768–775.

[12] Chiu,C.-N.;Chang,K.-P.Anovelminiaturizedelementfrequencyselectivesurfacehavingastableresonance. IEEE Antennas Wirel. Propag. Lett. 2009, 8, 1175–1177.

[13] Martinez-Lopez, L.; Rodriguez-Cuevas, J.; Martinez-Lopez, J.I.; Martynyuk, A.E. A multilayer circular polarizer based on bisected split-ring frequency selective surfaces. IEEEAntennasWirel. Propag. Lett. 2014, 13, 153–156.

[14] Abdelrahman, A.H.; Elsherbeni, A.Z.; Yang, F. Transmission phase limit of multilayer frequency-selective surfaces for transmitarray designs. IEEE Trans. Antennas Propag. 2014, 62, 690–697.

[15] Abadi, S.M.A.M.H.; Li, M.; Behdad, N. Harmonic-suppressed miniaturized-element frequency selective surfaceswithhigherorderbandpassresponses. IEEETrans. AntennasPropag. 2014,62,2562–2571.

[16] S.S.Princy, B. S.Sreeja, E.Manikandan and S.Radha, “"Design of polarisation-dependent multiband terahertz frequency-selective surface using two resonators”,*Indian Academy of Sciences*, pp. 1-5, 2019.

[17] C. Jin, Q. Lv, and R. Mittra, “Dual-polarized frequency selective surface with two transmission zeros based on cascaded ground apertured annular ring resonators",IEEE*Transactionon Antennas And Propagation* , pp.1-9, 2018.

[18] R. Banerjee, B.Rana and S. K.Parui," Performance modifications of a dielectric ring resonator loaded monopole using a composite frequency selective surface", pp. 1-6, 2017.

[19] G.Saha, C.Kumar and V. V. Srinivasan,"Frequency Selective Surface with Improvised Ring-Resonator for Flexible Design", *In Electromagnetics Research* C, vol.56, pp.137-1-144-8, 2015.

[20] A. A.Dewani, S. G.O .Keefe, D. V.Thiel and R. Galehdar,"Optically transparent frequency selective surfaces on flexible thin plastic substrates ",*Aip Advances*,vol. 5, pp. 02710701-02710710, 2015.