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A Comparable Simulation Study of Complementory Split Ring Frequency Selective Surface

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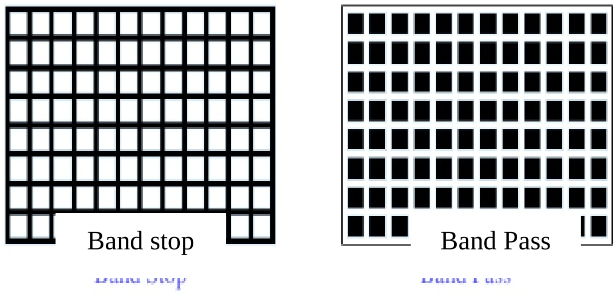
Abstract- In this paper, a common design of frequency selective surface is simulated by using two software, COMSOL Multyphysics 5.1 and CST Microwave Studio. The Various simulation results has been presented and compared using the above two tools. The proposed structure is a complimentary split ring FSS resonator design. FSS elements are much smaller than the operating wavelength. Due to symmetric configuration, the FSS element has achieved excellent resonance stability. Analysis was conducted on the proposed unit cell structure & simulation results are presented. We observed that the results are found to be in close proximity on the basis of frequency which is 4.6 GHz transmitted frequency, but return loss S_{11} parameters are having different values. Return loss is 31.62E-3 for COMSOL and 7.07E-3 for CST. The CST result has minimum return loss compare to COMSOL Multiphysics 5.1 result. FSS is a metallic screen with frequency selective properties which are used as a spatial filter through which EM energy with a specific frequency range may be propagated.

Key words - Frequency Selective Surfaces (FSSs), periodic structures, return loss

I. INTRODUCTION

FSS is a periodic array of certain type of conductive elements that are either printed on a dielectric substrate or etched out of a conductive layer [1]. FSSs are used for different applications such as spatial filtering and shielding, design of radar domes (RADOMS), wireless security, and satellite communications in order to provide large surface with tailored electromagnetic (EM) properties [2-8]. In the present days, obstructing the use of a few gadgets for others might be valuable or in office building or private urban environment, one may need to minimize the co-channel impedance from nearby Wi-Fi framework. [4-9]. FSS contribute to interference mitigation and wireless security in indoor radio environment.

FSS is of two types passive and active. One more classification of FSSs on the basis of periodic element is patch type and aperture type (slot) as shown in Fig 1. Patch type FSS work as an inductive resonant band pass filter and aperture type FSS works as a capacitive resonant band reject filter. In the present work we have taken FSS as a passive and slot type (Reason). The frequency band utilized as a part of this work is of C-band which is accessible from 4 GHz-8 GHz and wavelength is 7.5 cm-3.75 cm. A specific application of C-band is in weather radar system, Wi-Fi device, cordless telephones, and satellite communication. The transmitting bandwidth of proposed structure is 3.9 GHz to 5.1 GHz and the resonant frequency is taken as 4.6 GHz, usable at INSAT satellite ground station receiving antenna system.



Black=Metal

Fig. 1. Aperture and patch type frequency selective surface

In the following section we have presented the detailed design of FSS that we have taken into account. Further in the next section, the simulation by COMSOL Multiphysics has been presented. Preceding section presents simulation of same design model by CST microwave studio. Finally, the comparisons of results have been done by the two tools and results are found to be in good agreement. And at last section summaries the whole results.

II. PROPOSED STRUCTURE

Fig 2 shows the configuration of the complimentary split ring FSS unit cell structure. Here substrate is of dielectric material and the material used to make patch or apertures is metal. The substrate of the FSS unit cell structure is made up of polytetrafluoroethylene (PTFE) / Teflon, permittivity is 2.1. It is a single-layer structure with unit cell dimensions which is mention in table given below.

Table 1: Unit cell dimensions

Parameters of unit cell	Dimension(mm)
Substrate	15*15
Substrate height	2
Copper height	0.05
Slot outer circle	5
Slot inner circle	3.5
Rectangle patch	1*4

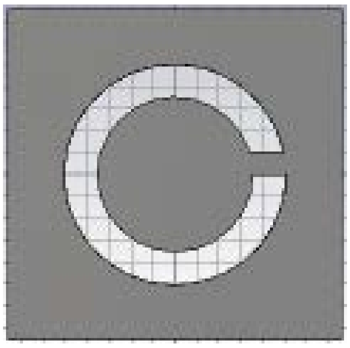


Fig 2. Unit cell design of complimentary split ring resonator

Split ring resonator equivalent circuit contains capacitance, inductance and resistance in serial fashion as shown in Fig 3. In single ring configuration, the circuit model is that of the simplest RLC resonator with resonant frequency $\Omega = \sqrt{LC}$ [5]. As indicated by the previous work, resonating notch depends on the patch which is discontinued on the circular slot [8].

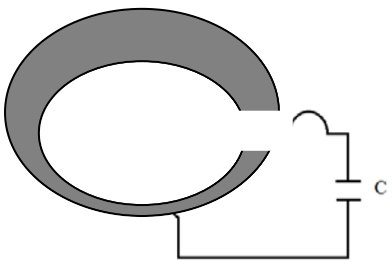


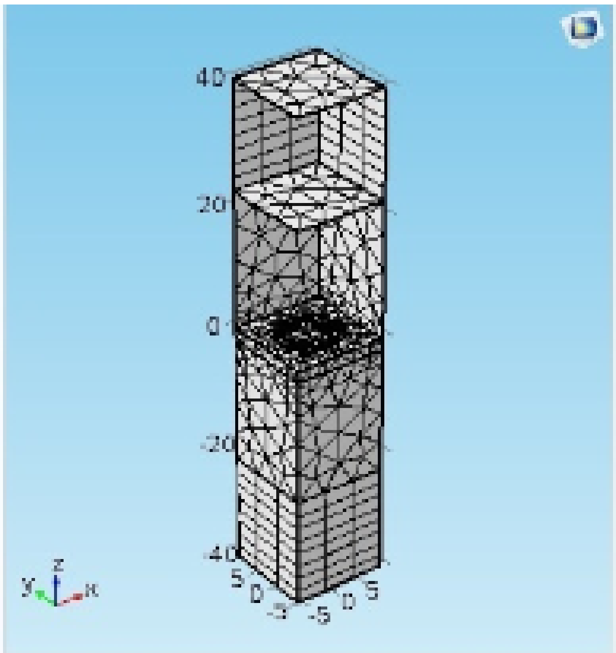
Fig.3. Electrical equivalent circuit model of split ring resonator

III. SIMULATIONS

The performance of the proposed FSS design variants was evaluated in the COMSOL Multiphysics 5.1 software and CST Microwave Studio software. The simulation results depicted in this section provide the frequency response curve for common design. Both software give same result up to some extend so Here, we try to find the limitations on the design and simulation of the any FSS structures that can be done by the method of moments (MOM), finite element method (FEM), and finite-difference time-domain (FDTD) with periodic boundary conditions. However, each technique has its own merits and demerits. The computational cost of the finite methods is higher than that of the method of moment for PEC objects. Both finite difference time domain method and finite element method follows different procedure to solve the differential equations [7].

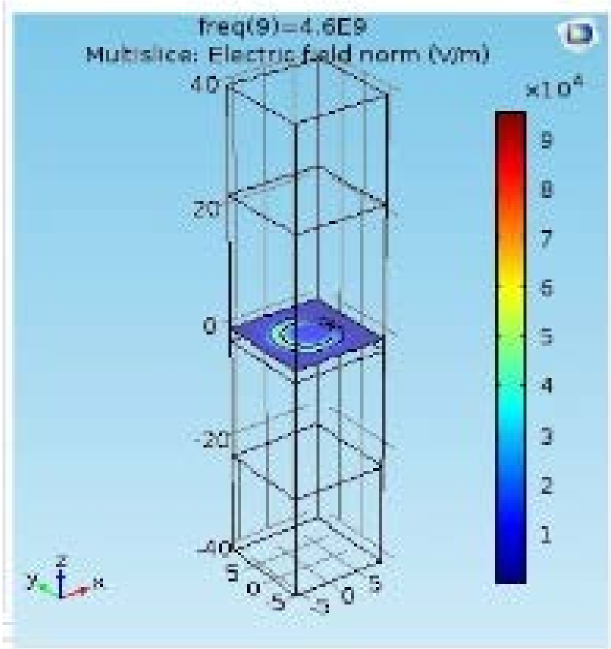
a. By Comsol Multiphysics

EM Fouquet port simulations can be done in COMSOL with either RF or Wave Optics Module, and this study uses the former physics module with a frequency domain analysis [6]. Here for simulation purposes we start with the modeling of the unit cell, in which we use Boolean function on different block of different shapes to create the model of design. After making geometry of the cell of the required dimension, material selection of the particular domain has been done. Material selection is then followed by boundary conditions.



(a)

This is then followed by meshing as shown in Fig 4 (a) and studying of the whole model and finally viewing of the results has been done. At single design we can apply multiple studies, and create multiple observational results used to understand the different aspect. In results we studied the electric field distribution shown in Fig 4 (b) and frequency response curve. The main purpose of the simulation is to find the transmission and reflection frequency graph. This is an array structure that can be of any dimensions. By using unit cell study we can find the generalized performance of the surface. This is the reason for doing single cell study.

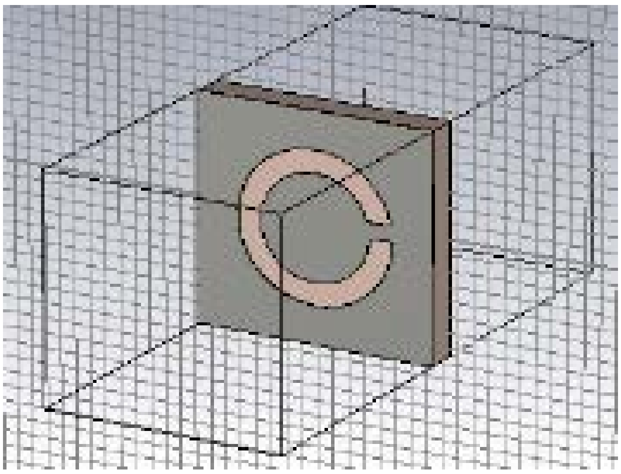


(b)

Fig. 4. Simulation showing (a) Meshing (b) Electric Field distribution

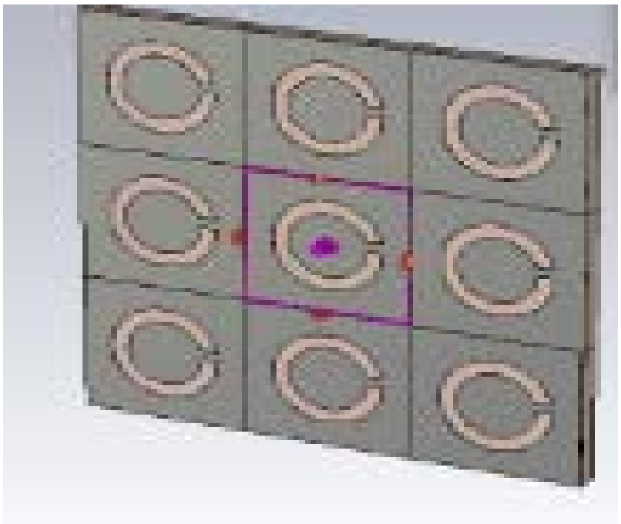
b. By Cst Microwave Studio

Periodic boundary condition method is used for simulation in CST. The whole process of making design, material assignment and meshing is likewise as COMSOL.



(a)

Fig 5 shows the port creation, boundary condition assignment to a single cell and connection of that cell with the whole array, and finally the resultant frequency response curve. Initially, the designed structure is located within a waveguide with PBC walls, after that a vertically polarized TEM wave impinges on the structure. Unit cell simulation reduces the overall simulation time [7]. CST MWS is based on the Finite Difference Time Domain Method

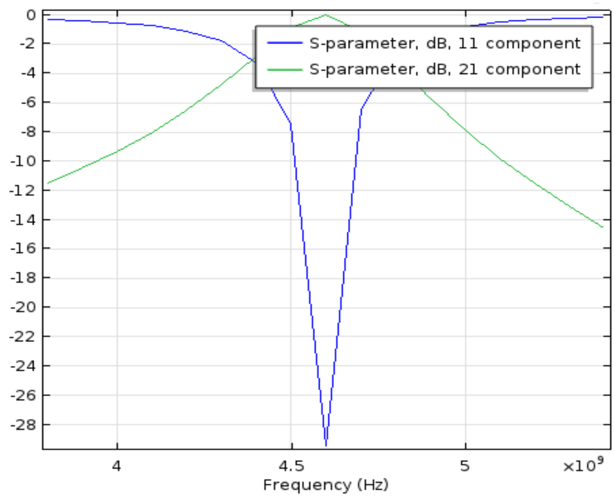


(b)

Fig. 5. Simulation shows (a) Define port and boundary (b) Interconnection between unit cells

IV. RESULTS AND DISCUSSION

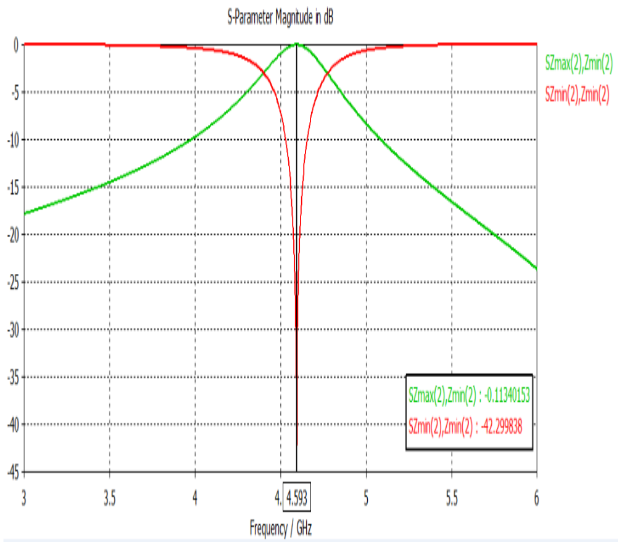
The work presented here analyzed the performance of CST and COMSOL for common frequency selective surface design.



(a)

Fig.6. Frequency response curve (a) by COMSOL

Return loss parameter study is the main focus of this work. Return loss is the loss of power in the signal returned or reflected by a discontinuity in a transmission line or optical fibre. This discontinuity can be mismatch with the terminating load or with a device inserted in the line. In the previous frequency response curve there are two parameters namely transmission curve S_{21} and return loss curve S_{11}, In dB,



(b)

Fig.6. Frequency response curve (b) by CST Microwave studio.

$$\text{Return loss} = -20\log_{10}|\Gamma|$$

Where,

Γ=reflection coefficient

The Return loss must be of small value for good matching. The design results of both resonant frequency lie on 4.6 GHz but the return loss is different.as shown in table 2

Table 2: Value of calculated parameters

S.No	Parameters	By COMSOL	BY CST
1	Resonant frequency(GHz)	4.6	4.6
2	Return loss(dB)	-30	-43
3	VSWR	9.39E-01	9.86E-01
4	Reflection Coefficient	3.16E-02	7.07E-03

From the Frequency response curve shown in Fig.6 presented, the return loss (dB) in CST is -43dB and in COMSOL is -30 dB but the normal value is 7.07e-3 for CST and 31.62e-3 for COMSOL. CST result has smaller return loss compare to COMSOL Multiphysics results. So from the above discussion we can say that FSS simulation in CST tool is a good option than COMSOL Multiphysics tool. Fig 7 shows the setup for measurement of FSS.

V. CONCLUSION

The simulation design has been done by CST and COMSL Multiphysics tool, and we concluded that FSS simulation by CST is a good option than COMSOL. For FSS simulation most significant parameter is return loss. So, on the basis of that we studied about the performance of design. This is the main reason why antenna studies or FSS studies are done by CST software mainly.

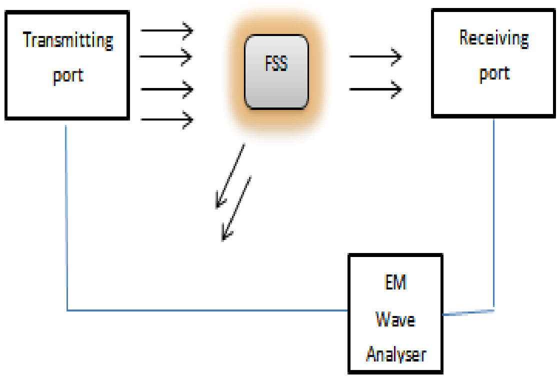


Fig. 6. The block picture of the FSS measurement principle

VI. ACKNOWLEGMENT

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VII. FUTURE SCOPE

This work will be helpful for the selection of simulator for FSS design. FSS have important applications regarding defense and health tools so the designing of FSS should be more idealized or matched. Selection of simulation tool is as important as the other aspects regarding a design.

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