Development of a Novel Three Dimensional Frequency Selective Surface Using Polyurethane Foam for Communication Bands

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***Abstract*—The focus of this paper is to develop a low cost, light weight three dimensional (3D) frequency selective surface (FSS) with reduced fabrication complexity over 2D FSSs and can be used in the communication field. Nowadays, 3D FSS is taking too much attention because it provides high degree of freedom in controlling transmission/reflection response. Therefore, in this paper, a 3D FSS has been attempted by inserting three concentric conductive cylindrical rings in to a polyurethane foam. The proposed concentric triple cylindrical ring 3D FSS aims to work as a band stop in the GSM-900, UMTS-1800 and LTE-2300 frequencies. CST software is used to simulate and optimize the dimensions of FSS. After that, measurement of developed concentric triple cylindrical ring 3D FSS is carried out in free space. Measurement results are in good agreement with simulation results. To shield the communication band in the secure places, this type of low cost structure may be quite useful.**

Keywords— 3D FSS; communication frequency band; polyurethane foam; transmission response

I. INTRODUCTION

Conductive periodic structures that also called as frequency selective surfaces (FSSs) works as a filter for microwave and optical frequencies have been of great potential application in the communication field [1-2]. These FSS structures provides shielding to some frequencies bands, to avoid any kind of undesirable communication for the secure places like prison and security offices [3-4]. Thus, it is desirable to design a structure that would be capable to perform shielding operation simultaneously at multiple frequency bands.

Various structures of 2D FSS has been used in this field and the transmission response is controlled by varying the dimensions such as periodicity, length, and width of 2D FSS [3-4]. But in 3D FSS it has been observed that controlling of transmission response is easy as compared to 2D FSS [5-6]. It is evident from the available reports that realization of 3D FSS which is light weight, low cost and having simple fabrication is still need to be implemented. Therefore, in this paper, an attempt has been made to design the 3D FSS to fulfill the aforementioned requirement.

Rest of the paper is arranged as design, fabrication and measurement of the proposed concentric triple cylindrical ring 3D FSS. section III discusses the results of fabricated design and then conclusion.

II. DESIGN, FABRICATION AND MEASUREMENT METHOD

To design the 3D FSS, some particular steps has been followed and these are given as:

A. Dielectric measurement of polyurethane foam:

The dielectric properties of the polyurethane foam used in the fabrication of 3D FSS is measured before starting the simulation process. To measure the dielectric of polyurethane foam, free space technique is used as shown in Fig. 3 (b). Sample of polyurethane foam with the size 360×360×10 mm^3 is placed in the far-field region [7]. The dielectric of polyurethane foam is approximately 1.058 all over from 0.8 GHz to 3.0 GHz. Similar dielectric properties of triple concentric cylindrical ring 3D FSS has been reported in reference [8].

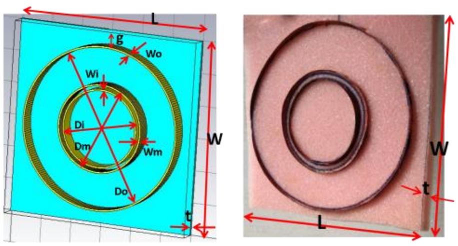
B. Simulation of concentric triple cylindrical ring 3D FSS

The geometry of 3D FSS has been defined as given in Fig. 1 (a). The dielectric properties of polyurethane foam obtained in above section has been fetched into the CST software to define the polyurethane foam. To optimize the transmission response at all the considered communication bands, parametric analysis has been carried out using CST software and optimized dimensions has been summarized in Table I. Detail of E-field distribution and parametric analysis is given in our previous paper [6]. Simulated result of transmission coefficient < -10 dB for all the considered communication band is obtained as shown in Fig. 2. The transmission response attained the -10 dB bandwidth (BW) of 64, 0, 60 (in MHz) which correspond to GSM, UMTS, and LTE band, respectively. The behavior of BW is immediate which may be due to its thickness (t). Because, single cylindrical ring FSS is defined with the simple tank LC circuit when its 't' is zero and a series inductor is added to the circuitry when H come into existence i.e., t>0. Thus, inductance is responsible to control the BW [5], [9].

For the fabrication of 3D FSS, concentric rings of defined radius (Di/2, Dm/2, and Do/2) are printed on polyurethane foam and cylindrical rings are fitted into the polyurethane foam as shown in Fig. 1 (b).

TABLE 1-DIMENSIONS OF UNIT CELL (IN MM)

Parameter	values	Parameter	values
Length/ Width of unit cell (L=W)	120.0	Diameter of inner cylindrical ring (Di)	47.0
Thickness of cylindrical rings and polyurethane foam (t)	10.0	Diameter of middle cylindrical ring (Dm)	50.4
Width of cylindrical rings (w1=w2=w3)	1.0	Diameter of outer cylindrical ring (Do)	98.0



(a) (b)

Fig. 1. Unit cell of (a) concentric triple cylindrical 3D FSS using polyurethane foam (b) fabricated 3D FSS with polyurethane foam.

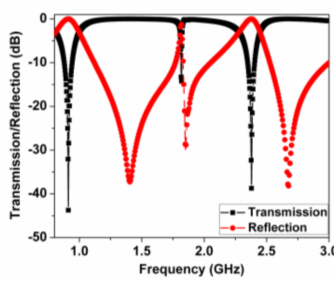
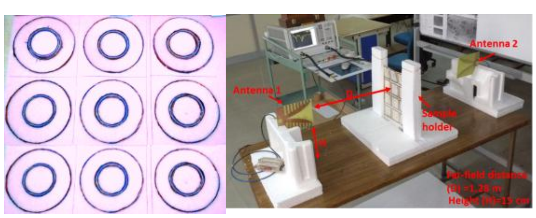


Fig. 2. Transmission and reflection response (in dB) of concentric triple cylindrical ring 3D FSS [6].

C. Measurement of fabricated 3D FSS

The 3D FSS of size 360×360×10 mm^3 has been fabricated (Fig. 3 (a)) and transmission response is measured using free space method (Fig. 3 (b)) and the obtained result is shown in Fig 4.



(a) (b)

Fig. 3. (a) Fabricated sample (b) Free space measurement technique.

III. RESULT AND DISCUSSION

As shown in Fig. 4, the transmission response below -10 dB is obtained from 0.992 to 0.886 GHz, 1.76 to 1.808 GHz and 2.24 to 2.432 GHz and little aberration in the measured result from simulated one may be due to fabrication.

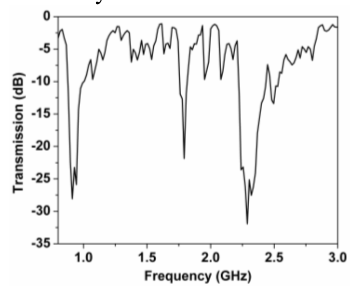


Fig. 4. Measured transmission response (in dB) of concentric triple cylindrical 3D FSS.

IV. CONCLUSION

In this work, a concentric triple cylindrical 3D FSS is simulated, fabricated and measured using free space technology. Fabricated design is flexible, simple and easy to design. It is giving absorption at GSM, UMTS, and LTE band. The polyurethane foam with the FSS gives support to the conductive cylindrical ring and aids the mechanical strength to the structure. This unique structure can find applications in future communication purpose.

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