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NOVEL COMPACT UWB FREQUENCY SELECTIVE SURFACE FOR ANGULAR AND POLARIZATION INDEPENDENT OPERATION

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Abstract—This paper deals with a novel miniaturized FSS with wide stop band characteristics for UWB applications. The proposed FSS consists of garland like design printed on either side of the dielectric substrate. The design provides a bandwidth equal to 3.5 GHz at −20 dB reference level of insertion loss which lies within the UWB range. The design delivers stable response for various angular incidences. In addition to this, the symmetrical nature of the FSS holds identical response for both TE and TM Mode of polarization. The proposed geometry is fabricated and its simulated results are validated with measurements. A comprehensive analysis is made by adjusting various parameters associated with the proposed design.

1. INTRODUCTION

Frequency Selective Surfaces are periodic structures providing either a band pass or a band stop response according to its geometrical nature. FSS's are exploited for many applications as discussed in [1, 2]. Advent of new technologies in communication ultimately leads to soaring crave for bandwidth. Contemporary applications exploit the Ultra Wide Band which ranges between 3.1 GHz to 10.6 GHz to quench the thirst for bandwidth. Frequency Selective Surfaces are no exception from this, hence many techniques are followed to widen the band stop/band pass characteristics of the frequency selective surfaces.

A comprehensive study on Frequency Selective Surfaces is done in [3]. The erstwhile contributions from FSS designed for wide band application consists of stacked layers [4] to enhance their bandwidth of

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operation. The stacked layers make the structure bulkier and also the unit cell of size 17 mm × 17 mm is reported. A novel design described in [5] provides better response, but it is polarization selective due to lack of symmetry. Yet another geometry embraced in [6] for UWB application is polarization independent with its compact unit cell dimension of 8.4 mm × 8.4 mm at the cost of their bandwidth. The double layer FSS's reported in [5, 6] are simpler in design providing wide band operation. Major breakthrough in size reduction with comparatively larger bandwidth using fractals is reported in [7]. Intricate design with compact size makes the use of fractals in FSS a challenging task. Use of Sierpinski space-filling curve (SSG) for wide stop band operation is explored in [8]. Similar to fractals, SSG's are also complex in nature from the design perspective. A simple compact FSS geometry along with the symmetrical nature is the need of the hour to address the aforementioned issues.

In this paper, a novel FSS geometry with wide stop band characteristics is proposed. The novelty is attributed to its unique unit cell geometry similar to circle but convoluted along its periphery resulting in a garland like structure. The proposed design is compact and shows angular and polarization independency as well. The proposed geometry can be tuned to span the entire UWB range and deserves wide application in antennas and radars.

Section 2 of this paper deals with the design and analysis of the proposed FSS. Various parameters and their effect on the FSS performances are dealt with in Section 3. Section 4 throws light on the measurement setup and the results obtained.

2. FSS DESIGN AND ANALYSIS

The unit cell geometry of the proposed FSS is illustrated in Fig. 1. It resembles the shape of the garland printed on either side of the dielectric substrate. The side view of the proposed unit cell design is given in Fig. 2. The dielectric substrate used is FR4 with dielectric constant, $\varepsilon_r = 4.3$ and dielectric loss tangent of 0.025. The dimensions are detailed in Table 1.

The proposed garland design is derived from the circular ring geometry which provides stable response for various angles compared to other geometries as [12, 13]. The design also favours polarization independent operation.

The simulation is done using CST Microwave studio commercial software which utilizes Finite Element Method to determine the electromagnetic behaviour of the structure. Floquet's ports are used to determine the reflection and transmission coefficients of the proposed

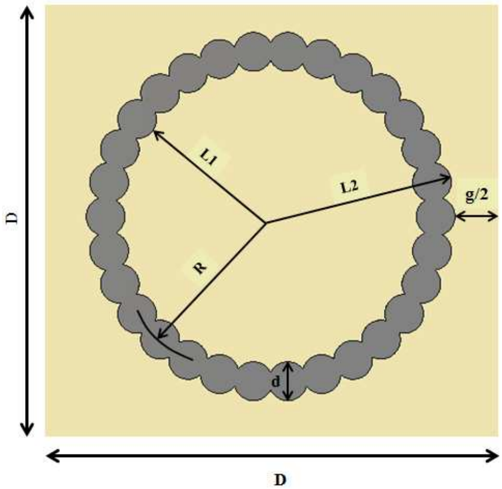

Figure 1. Unit cell geometry of the proposed FSS.

Table 1. Unit cell dimensions.

Parameters	**Dimension (mm)**
Unit Cell Dimension, D	8
Patch thickness, t	0.035
Substrate height, h	1.6
Width, d	0.6
Inner Distance, L_1	3.25
Outer Distance, L_2	3.85
Radius, R	3.55
Inter cell Gap, g	0.3

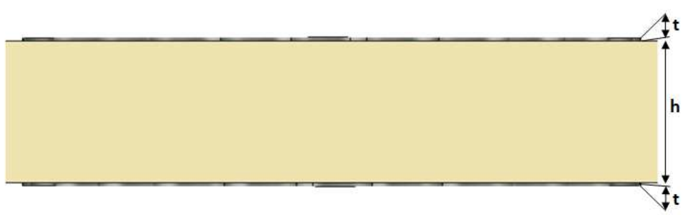

Figure 2. Side view of the proposed FSS.

FSS unit cell. The simulated results are portrayed in Fig. 3 which gives the transmission characteristics (S_{21}) of the proposed FSS. It is observed that the design provides stop band characteristics for a broad band of 3.5 GHz with its start and stop band frequencies lying at 7.04 GHz and 10.55 GHz respectively for −20 dB reference level of insertion loss. The design provides a relative band width of 39.89% centered around 8.8 GHz. The wide band response is due to the double layer FSS adopted in the design which comes under the cascading principle discussed in [8–11]. In addition, the proposed design gives identical response for both TE and TM mode of polarization with its symmetrical nature making it feasible for polarization independent operation.

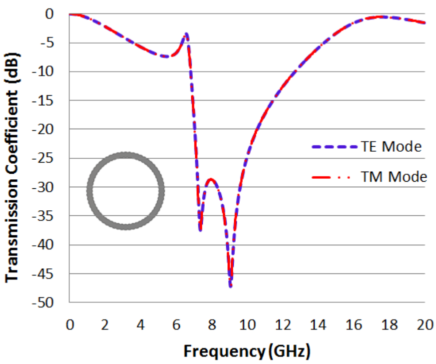

Figure 3. TE and TM mode transmission characteristics.

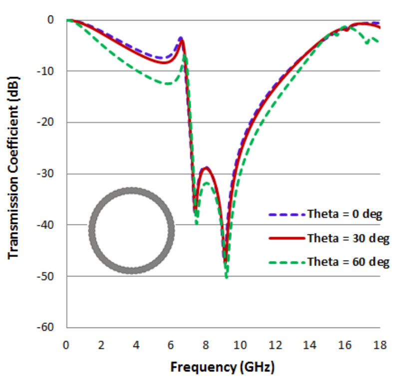

Figure 4. TE mode characteristics.

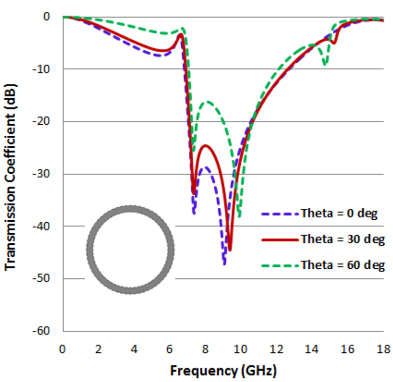

Figure 5. TM mode characteristics.

The angular independent operation of the FSS for TE and TM modes of polarization is depicted in Fig. 4 and Fig. 5, respectively, in which transmission characteristics (S_{21}) for varying angle of incidence is substantiated. The results implicitly mean that the proposed design holds highly stable response for oblique angular incidence for both TE and TM mode of polarization. This property is the figure of merit for any FSS as demonstrated in [12] and [13].

3. PARAMETRIC STUDY

3.1. Inner Distance L_1

The Transmission Characteristics (S_{21}) of the proposed cell geometry obtained by varying distance L_1 while maintaining other parameters undisturbed are given in Fig. 6. The stop band range shifts from 7.04 GHz–10.55 GHz to 7.34 GHz–11.97 GHz and to 7.85 GHz–14.70 GHz for varying distance L_1 of 3.25 mm, 3.0 mm and 2.6 mm respectively. It is evident from the results that the change in distance L_1 eventually affects the width (d) of the design ultimately shifting the curve to the right covering the higher frequencies.

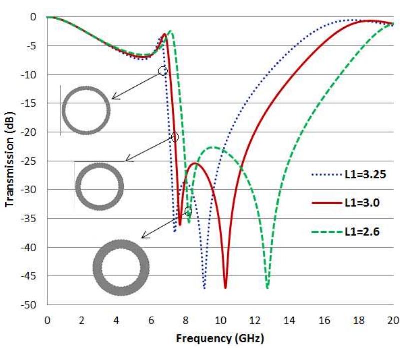

Figure 6. Transmission characteristics of the FSS for varying L_1.

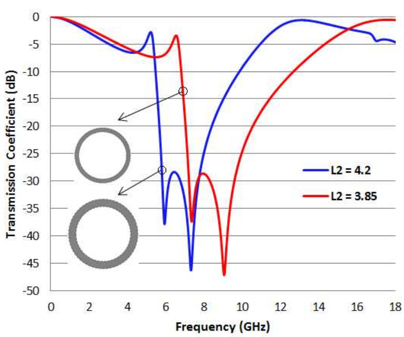

Figure 7. Transmission characteristics of the FSS for varying L_2.

3.2. Outer Distance L_2

Keeping all other parameters constant, outer distance L_2 is varied, and its simulated results are illustrated in Fig. 7. It is observed that by varying the L_2 from 3.85 mm to 4.2 mm the curve gets shifted towards left, indicating that the value of the inductance increases thereby decreasing the frequency of operation. It is to be noted that increasing distance L_2 ultimately increases the unit cell size.

3.3. Radius *R*

It is apparent from the transmission characteristics reported in Fig. 8 that the entire UWB range can be covered by varying the radius R. The change in radius R either increases or decreases the unit cell dimension. It is illustrated in Table 2 that range of frequencies covered varies with varying R ultimately affecting the unit cell size and the bandwidth performance.

Table 2. Effect of distance R on unit cell dimensions.

Unit Cell Area (mm^2)	Distance R (mm)	Frequency Range at −20 dB (GHz)
8×8	3.55	7.04–10.55
10×10	4.55	5.80–9.54
20×20	9.55	2.71–6.60

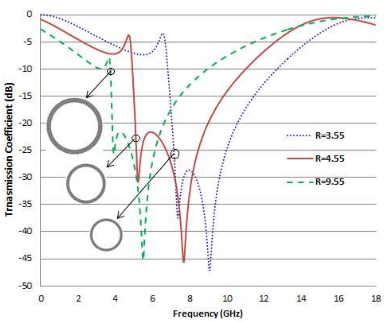

Figure 8. Transmission characteristics of the FSS for varying R.

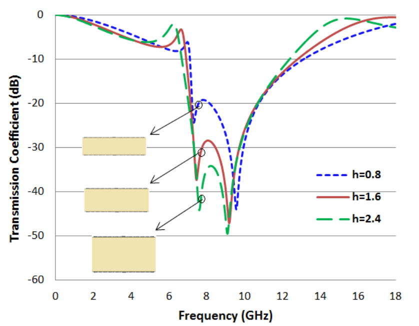

Figure 9. Transmission characteristics of the FSS for varying h.

3.4. Substrate Height *h*

The Transmission Characteristics (S_{21}) obtained by varying the substrate height are given in Fig. 9. Height of the substrate plays a dominant role in deciding the gain performance of the FSS. More the gain better the performance is.

4. MEASUREMENT SETUP

The proposed FSS is fabricated on an FR4 substrate consisting of 35×35 elements measuring up to $33\,\text{cm} \times 31.2\,\text{cm}$ is shown in Fig. 10.

Figure 10. Fabricated prototype.

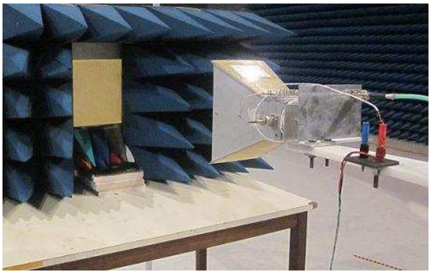

Figure 11. Measurement setup.

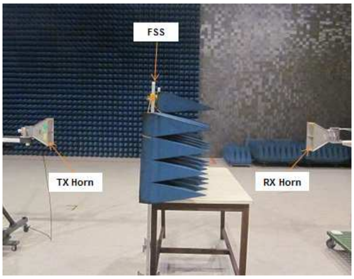

Figure 12. Transmitting and receiving horn antennas.

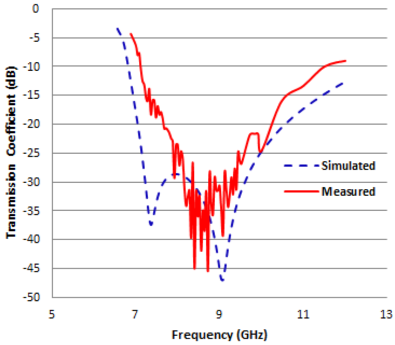

Figure 13. Comparison of the measured and simulated results.

The fabricated prototype has the dimensions $h = 1.6\,\text{mm}$, $L_1 = 3.25\,\text{mm}$, $L_2 = 3.85\,\text{mm}$, $R = 3.55\,\text{mm}$ and $d = 0.6\,\text{mm}$. Care has been taken to ensure that the fabricated prototype is the exact replica of the designed FSS with much attention to its material properties. The prototype is placed in an anechoic chamber for measuring the Transmission characteristics. The measurement setup is shown in

Fig. 11 where a horn antenna is placed facing the FSS surrounded by the absorbers. The measurement is made by placing horn antennas on either side of the FSS configuring them as Transmitting and Receiving antennas as shown in Fig. 12.

The measured transmission characteristic (S_{21}) of the fabricated prototype for incident angle, theta = 0 degree, is compared with the simulated result in Fig. 13. It is observed that the measured result shows good agreement with those of the simulated one. However, the inconsistency between the simulated and measured results may be due to the lossy FR4 dielectric used for fabricating the prototype.

5. CONCLUSION

A novel frequency selective surface with wide stop band characteristics is discussed in this paper. The proposed design provides a wide stop band of 3.5 GHz at −20 dB reference level of insertion loss with its simple and easy to fabricate geometry. The proposed FSS proves to be the potential candidate for UWB applications. The compactness along with the angle and polarization independency attracts wide usage in antennas and radars. Comprehensive study of the various parameters associated with the design is done for thorough analysis. The future scope of this paper will be the modification of this structure for a reconfigurable operation.

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