A Design Approach for Dual-Polarized Multiband FSS using Self-Similar Fractal Element

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ABSTRACT

In this paper, fractal FSS has been designed using recursive technology and this frequency selective surface (FSS) acts like a multi band-reject filter. The proposed design has been investigated theoretically using Ansoft Designer® software in which the reflection and transmission band has been predicted by the method known as Method of Moment.

In comparison to the reference square patched Frequency Selective Surface (FSS) without slot, this FSS with fractal design can provide size reduction up to 83.78%. Efforts have been given to achieve Size reduction, Bandwidth enhancement and multifrequency operation in a single FSS structure.

Keywords

Bandwidth (BW), Fractal, Frequency Selective Surface (FSS), Multifrequency, Resonating Frequency, Size Reduction.

1. INTRODUCTION

It has been many years since Frequency Selective Surface (FSS) was widely studied among researches due to its special property of selectivity of the frequencies and polarizations of the incident wave [1-2]. Therefore, FSS has been applied in many areas, especially in communication systems, such as radar cross section (RCS), satellite antenna, microwave, electromagnetic wave absorber [3-5].

In order to satisfy the requirements on high-effective and integration of communication devices in the recent years, FSS with multiband properties and simple structures is needed. Self-similar fractal elements contain many scales of the original geometry, each of which acts as a scaled version of the beginning. A multiband FSS that we need can be designed using iteration technology to form a fractal that resonates corresponding to each of the scales present in the structure. Except the multiband property, this application also can reduce the overall size of the periodic elements that constitute an FSS [6].

To analyse different types of FSS structures theoretically, basically three methods are used – Finite Difference Time Domain (FDTD) method, Finite Element Method (FEM) and the Method of Moment (Mom). Different softwares are available for theoretical analysis by different methods [7]. However the analysis of the proposed FSS is done using Ansoft DesignerTM software which works on the Method of Moments.

2. PROPOSED DESIGN SPECIFICATION

This fractal FSS is an iterative model of square shaped patch from which a rhombic shape is etched out as shown in Fig 1. In the proposed design, we started with a periodic array of square conducting patches with side 20 mm on a dielectric substrate. Then we etched out a rhombic slot with both of its diagonals 18mm (originally it is a square slot rotated 450 w.r.t. square patch). It is shown in Fig 1 which is taken as basic design. For the first and second iterations the dimensions are shown in Fig 2 and Fig 3. The FSS periodic arrays designed with the same periodicity values along x and y directions which is 24mm as shown in Fig 4.

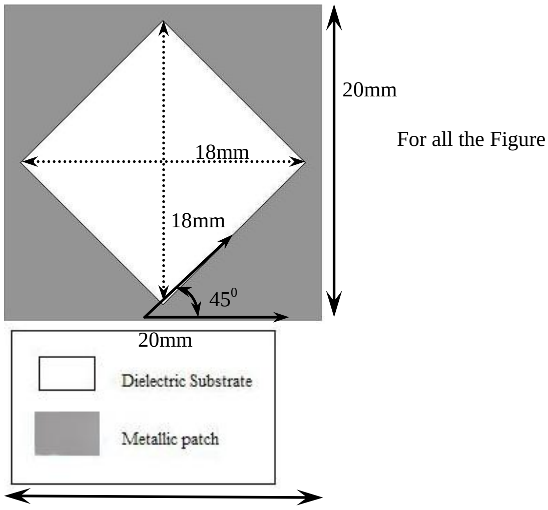

Fig 1: Basic design of the FSS Patch

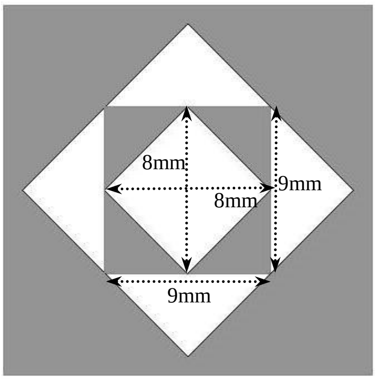

Fig 2: First iteration

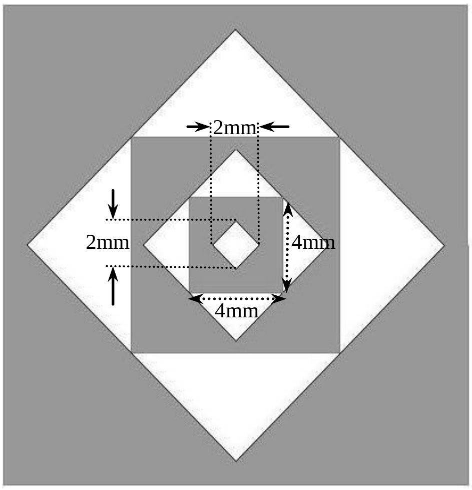

Fig 3: Second iteration

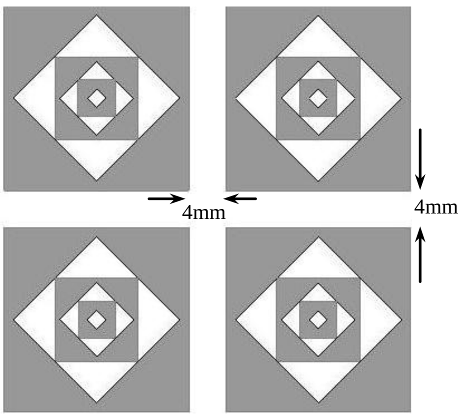

Fig4: FSS showing four patch element and Spacing between adjacent patches.

The metallic patches are considered to be present on one side of a thin dielectric slab and the copper coating on the other side of the slab is completely removed (Fig 5). In this study, Glass PTFE as the dielectric substrate having relative permittivity of 2.4 & thickness of 1.6 mm is used.

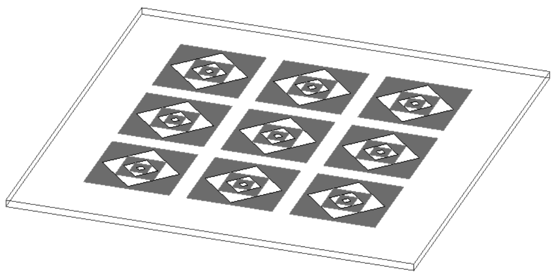

Fig 5: FSS showing two dimensional array of patch on dielectric substrate.

3. RESULTS

Transmitted electric field for the FSS structures is calculated by Ansoft Designer software in the frequency range of 1 GHz to 20 GHz.

A. Basic Design

This FSS with the basic design provides two resonating frequencies at 5.09GHz and 19.29GHz. The -10dB reflection bandwidths recorded are 1.96GHz and 3.63GHz respectively and that are equivalent to percentage bandwidth of 37.3% and 18.81%.

Resonant frequency for the square conducting patches with side 20 mm without slot is found as 11.25GHz. After etching out a rhombic slot (as shown in Fig 1), 1st resonant occurs at 5.09GHz. If we wish to design an FSS which resonate at 5.09GHz, the side of square will be 44.20 mm.

So, Size reduction achieved in this structure is 79.53% and that has been calculated as given below.

$$\frac{(44.20*44.20)\mathrm{mm}^2-(20*20)\mathrm{mm}^2}{(44.20*44.20)\mathrm{mm}^2}*100\% = 79.53\%.$$

The corresponding transmission graph is shown in Fig 6 which is for the basic design (Fig 1)

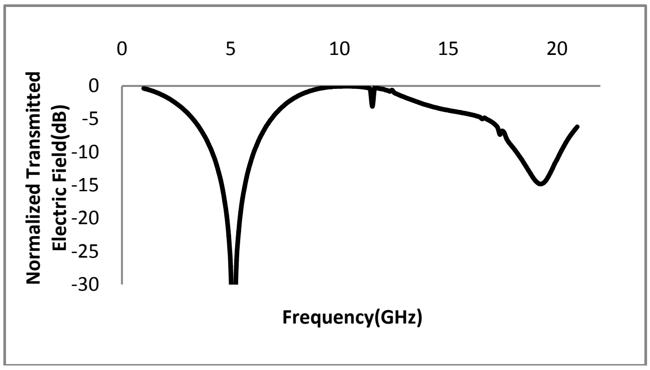

Fig 6: Normalized Transmitted Electric Field vs. Frequency

B. First Iteration

For the first iteration we are getting three wide bands at resonating frequencies 4.62GHz, 10.51GHz, 18.38GHz and one narrow band at resonating frequency 12.42. The size reduction achieved in this design is 83.12% and this has been calculated as described previously for basic design.

C. Second Iteration

In the structure of second iteration we get three bands at resonating frequencies 4.53GHz, 10.02GHz and 17.98GHz. The -10dB reflection bandwidths recorded are 2.14GHz, 1.6GHz and 2.1GHz respectively and that are equivalent to percentage bandwidth of 47.24%, 15.96% and 11.67%. The size reduction achieved in this design is 83.78%. Here again size reduction is calculated as described earlier that for basic design.

For the first and second iteration (shown in Fig 2 and 3) the transmission graph is shown in Fig 7.

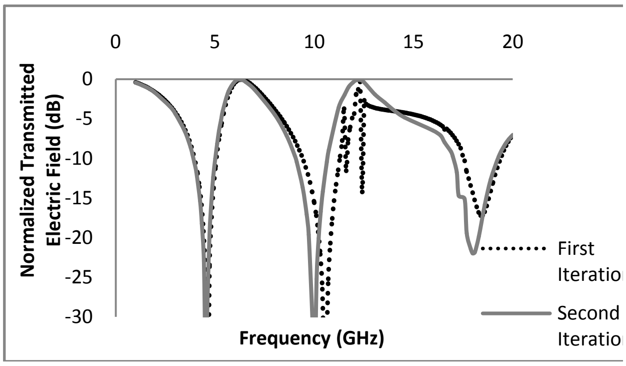

Fig 7: Normalized Transmitted Electric Field vs. Frequency

The Analyzed numerical results of various designs are summarized below in TABLE I.

TABLE I
COMPARING VARIOUS PARAMETERS OF THE THREE DESIGNS

FSS Design		1.Basic Design	2.First Iteration	3.Second Iteration
Resonating Frequencies (GHz)	F_1	5.09	4.62	4.53
	F_2	19.29	10.51	10.02
	F_3	-	12.42	17.98
	F_4	-	18.38	-
Bandwidth (GHz)	BW_1	1.96	1.12	2.14
	BW_2	3.63	1.89	1.6
	BW_3	-	0.1	2.1
	BW_4	-	1.89	-
Size Reduction (%)		79.53	83.12	83.78

4. CONCLUSIONS

Theoretical analysis shows that all the proposed FSS structures act like a Band-Reject Filter. From the simulated results and their corresponding graphs it can be inferred that to achieve Size reduction, Wide Bandwidth and multifrequency operation in a single FSS structure, iteration technology can be used to make a fractal FSS as shown in our proposed design.

In this paper FSS with basic structure acts as wide dual band reject filter.

After introducing a fractal element i.e. in first iteration we get three wide bands along with one narrow band. Further insertion of fractal element (in second iteration) all the features almost remain same as in first iteration except narrow band is removed and we get a three wideband stop filter with fairly good band ratios 1.79(f3/f2) and 2.21(f2/f1).

This fractal design can provide size reduction up to 83.78%.

5. REFERENCES

[1] B. A. Munk, *Frequency Selective Surfaces: Theory and Design*. New York: Wiley-Interscience, 2000..

[2] B. Munk, R. Kouyoumjian, and L. Peters, Jr., “Reflection properties of Periodic surfaces of loaded dipoles,” *IEEE Trans. Antennas Propag.*, vol. AP-19, pp. 612–617, Sep. 1971.

[3] N.D. Agrawal and W.A. Imbraile, Design of a dicroic Cassegrain subreflector, IEEE Trans Antennas Propagat AP-27 (1979), 466-473.

[4] S.W. Lee et al., Design for the MDRSS tri band reflector antenna, IEEE Int AP-S Symp, Ontario, Canada, 1991, pp. 666-669.

[5] Hsing-Yi Chen and Yu Tao, “Bandwidth Enhancement of a U-Slot Patch Antenna Using Dual-Band Frequency-Selective Surface With Double Rectangular Ring Elements”, *MOTL Vol. 53 No. 7, pp 1547-1553, (July 2011).*

[6] ohn P.Gianvittorio,Yahya Rahmat-Samii,"Fractal geometry in antenna system design: miniaturized-multiband element, phased array and frequency selective surfuce design," in *Proc. MMWT*, 2002, p.508-511

[7] PhD Thesis of P.P.Sarkar, “Some Studies on FSS”, Jadavpur University, 2002.