Experiment Results of the Microstrip Fractal Antenna in Stacked Patch Structure for Wireless Communication Applications

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Abstract—In this study, we investigate the multi band characteristics of the Microstrip fractal antenna in a stacked patch method. Hexagonal shaped patch antenna is stacked with circular shaped meandered patch in first stage. The simulation results are recorded. As a second stage, fractal is made on the hexagonal shaped patch and it is stacked to meandered antenna. This fractal is implemented to give wide bandwidth property. The simulated results of the proposed fractal antenna are provided. It is measured by means of vector network analyzer. The measured results were given. Both the simulated and measured results give high correlation ability in performance. The novelty of the work is using meandered patch as a bottom layer in stacked method. This antenna would be used in wireless communication equipments.

Keyword-Broadband antennas, Fractal antennas, Microstrip antennas, Multifrequency antennas, Patch antennas.

I. INTRODUCTION

Antenna works as an important tool in wireless communication systems. These systems require little size and multi band performances. Bandwidth is necessary parameter in the above said systems. For achieving multi band other than narrow band is a challenge in those systems. The fractal antennas research leads to analysis and design of fractal radiating elements to construct multi band characteristic of antennas [1]-[2]. Stacked method of fractals with patch antenna gives much more results. The importance of this study is getting multi bandwidth. This model is using meandered antenna patch for the bottom layer of the stacked arrangement. By this novel method of arrangement the less fringe effect is the result.

Fractal antenna is formed by using hexagonal [15]-[28] shaped patch antenna in four iterations, various length slots are cut as meander in circular patch. These circular patch and fractal patch are stacked together. In this research, radiation characteristics [29] of the stacked fractal circular patch antenna are investigated. Previous research survey, analysis and design of the proposed antenna, simulation measurement results and concluding the paper are the next sections in sequence.

II. PREVIOUS RESEARCH SURVEY

Fractal Patch antennas were presented with stacked array in research papers by this year [1]. Multi band characteristics are the need of the hour and achieved in monopole antenna with a cheap cost substrates [2]. Also, stacked arrays are introduced in microstrip antenna by using fractal patches [3]. Broadband antennas were proposed for high gain characteristics [4]. Further the size of the antenna has been reduced by using slots in antenna [5]. The idea of using slits is proposed in stacked microstrip antennas [6]. The beam is formed for array of Non-isotropic antennas [7]. Monopole antennas are proposed with enhanced bandwidth [8]. Antenna with fractal hexagonal iterations is used in broadband applications [9]-[15]. The fractal antennas are developed in arrays for Satellite Networks [10]. Circular polarization is achieved by stacked microstrip antennas [11]. Fractal antennas for wideband are studied to give good responses [12]. Meandered design is used for microstrip antenna patch as a novelty [13]. Fractals are used in radiating patch microstrip antenna to give dual bands [16]. So far, fractals in stacked patch for broadband are not arrived. In this paper, the idea of using fractal hexagonal designs on the stacked microstrip antennas to achieve broadband is taken here as radiating patch and meandered circular patch is used as feeding patch.

III.DESIGN SPECIFICATION

FR4 substrate is used for circular patch with a permittivity constant of 4.4, thicknesses 3.2 mm, for the hexagonal patch with same dielectric constant, thickness1.6 mm and the loss tangent of the substrate for both the patches 0.018. The design is simulated using the electromagnetic simulator IE3D[30] after all the dimensional values are calculated in order to get the required return loss, voltage standing wave ratio(VSWR) and radiation characteristics[25]. SMA female connector is used to attach with the feed end at the bottom of the patch. For the hexagonal patch, the design specifications are given below.

A. Hexagonal Design

The number of sides is six; the hexagonal shape is arrived by closing all the six sides. The sum of interior angles is 720° and each angle is 120°. The Sum of interior angles is calculated as follows.

$$
\begin{aligned}
(n-2) \times 180^\circ &= (6-2) \times 180^\circ \\
&= 4 \times 180^\circ \\
&= 720^\circ
\end{aligned}
$$

$$angle = (n-2)\times\frac{180^\circ}{n} \tag{1}$$

$$hence, \frac{720^\circ}{6} = 120^\circ$$

The area of a regular hexagon of side length‘t’ given by

$$A = \frac{3\sqrt{3}}{2}t^2 \tag{2}$$

$$A = 2.59t^2$$

To investigate the designs for hexagonal arrays we consider the six element circular generating sub-array of d=λ/2. According to hexagonal properties interior angle is 120° and the exterior angle is 60°.

$$\cos\left(\frac{120^\circ}{2}\right) = \frac{\frac{d}{2}}{r} \rightarrow r = 0.25\frac{\lambda}{2} \tag{3}$$

The each side length of the hexagonal patch is 30 mm to the centre frequency of 3 GHz, in between 0.5-6 GHz.

IV. ANALYSIS OF PROPOSED DESIGN

When we do stacking of the patch, multi band [17] characteristics is achieved due to the increase of the dielectric thickness and the self similarity nature of the fractal structure. Circular patch with radius 47.6 mm is taken and slots are made on the circular patch as meandered. This circular meander patch is used as feeding patch for the proposed design. Hexagonal patch with side 30 mm is taken and fractal iterations are made on that patch to make radiation patch. These two circular and hexagonal patches are stacked [18]-[21] together by the dielectric constant $\varepsilon_{r1} = \varepsilon_{r2} = 4.4$. The distance between the patches are h1=3.2 mm and h2=1.6 mm. SMA connector is attached to the feeding patch through the ground [8]-[9]. The stacked arrangement is shown in the Fig. 1.

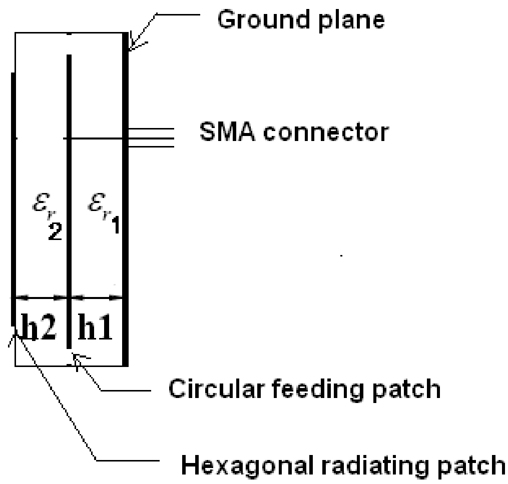

Fig. 1. Stacked structure of the patch antenna side view

On the ground dimension of 200 sq. mm, circular patch with five slots are etched with the thickness of h_1=3.2 mm with the ground.

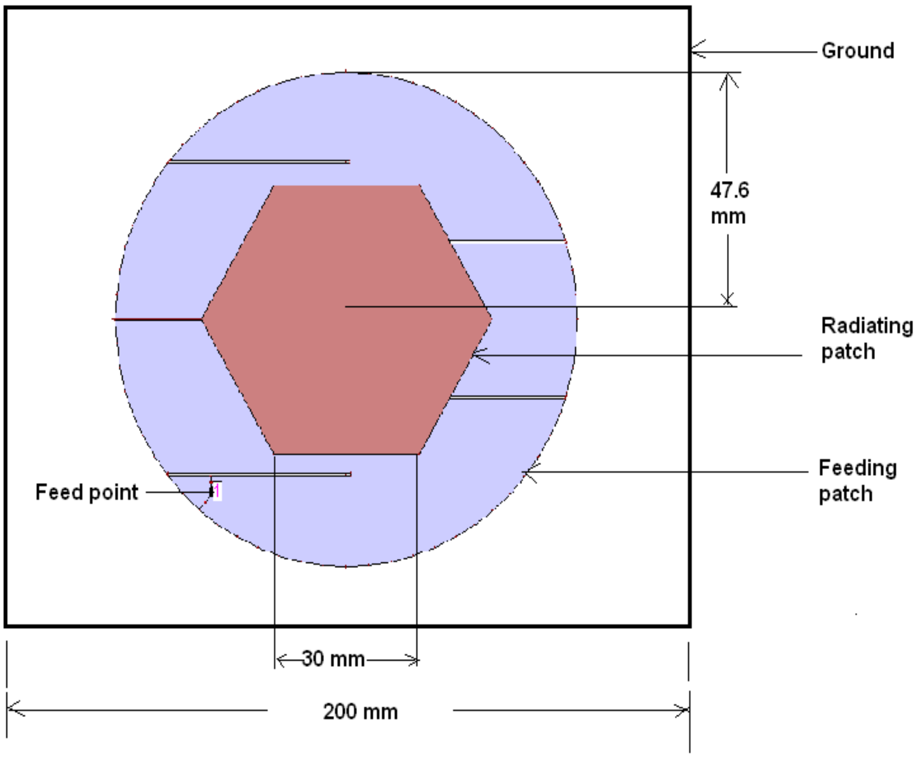

Fig. 2. The geometry of hexagonal radiating patch on circular meander feeding patch

Above the circular patch, hexagonal patch is etched with the thickness of h2=1.6 mm. In Fig. 2, plain hexagonal patch without any fractal [22]-[24] is designed. The fractal design is made on the plain hexagonal patch and it is shown in the Fig. 3. This fractal patch itself gives the results of resonant frequencies at 1.945 GHz, 2.54 GHz, 3 GHz, 4.45 GHz and 5.35 to 5.65 GHz only.

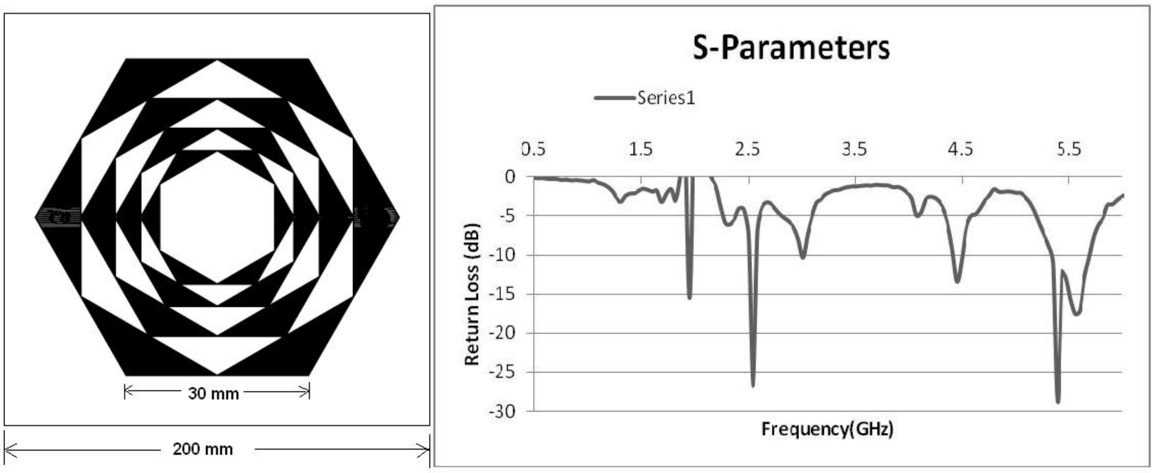

Fig. 3. Hexagonal Fractal Patch and its S-Parameter

This hexagonal shaped fractal patch is radiating patch, stacked with circular meander patch to form as proposed patch. It is shown in Fig.4.

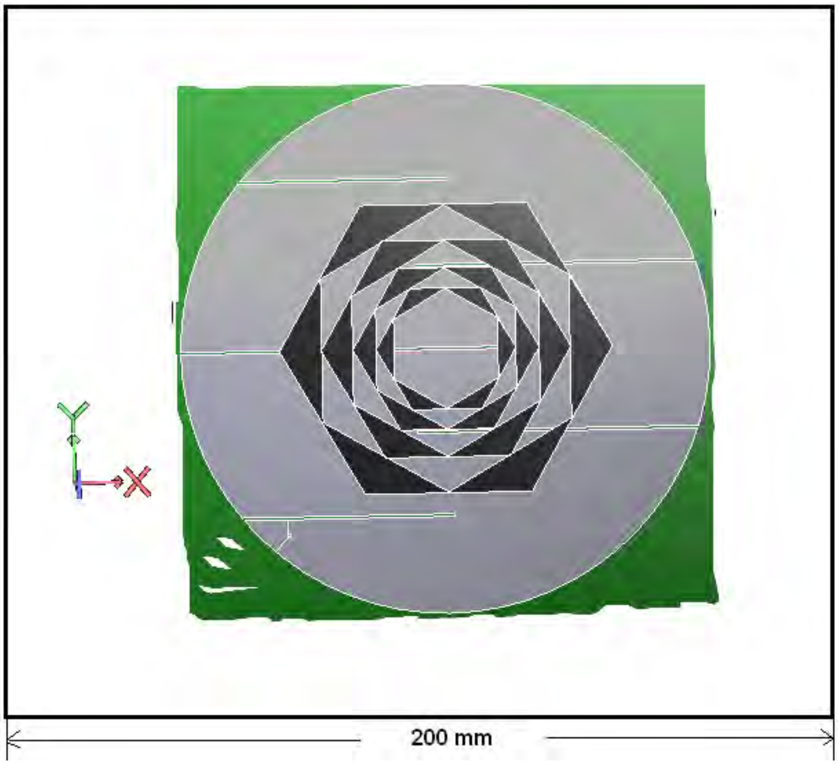

Fig. 4. Proposed Fractal Antenna

The proposed design is simulated by the electromagnetic simulator. The simulated results are furnished in the following section. The design is then fabricated using FR4 substrate and SMA connector is attached to it [26]-[28]. Using vector network analyzer, the fabricated antenna is measured. The measured results are given in the following section. Fig. 5 shows the fabricated antenna upper layer (top) and ground layer (bottom).

Figure 5. Radiating Upper layer and Lower Ground layer of fabricated antenna

Meandered circular patch and hexagonal fractal patch are stacked over the ground patch is displayed in this fig.5.

V. RESULTS AND DISCUSSION

The Simulation results of plain hexagonal circular meander patch and proposed fractals on hexagonal stacked antenna are furnished in this section. Also, measurement results of the proposed antenna are shown. Fig.6 illustrates the s-parameter display of plain hexagonal on the stack arrangement. From the graph, multi band [14] performance is known. Resonant frequencies 1.5 GHz, 4-5 GHz, 5.5-5.75 GHz are seen in the graphs. The frequencies below 1.5 GHz and after up to 4GHz are to be achieved.

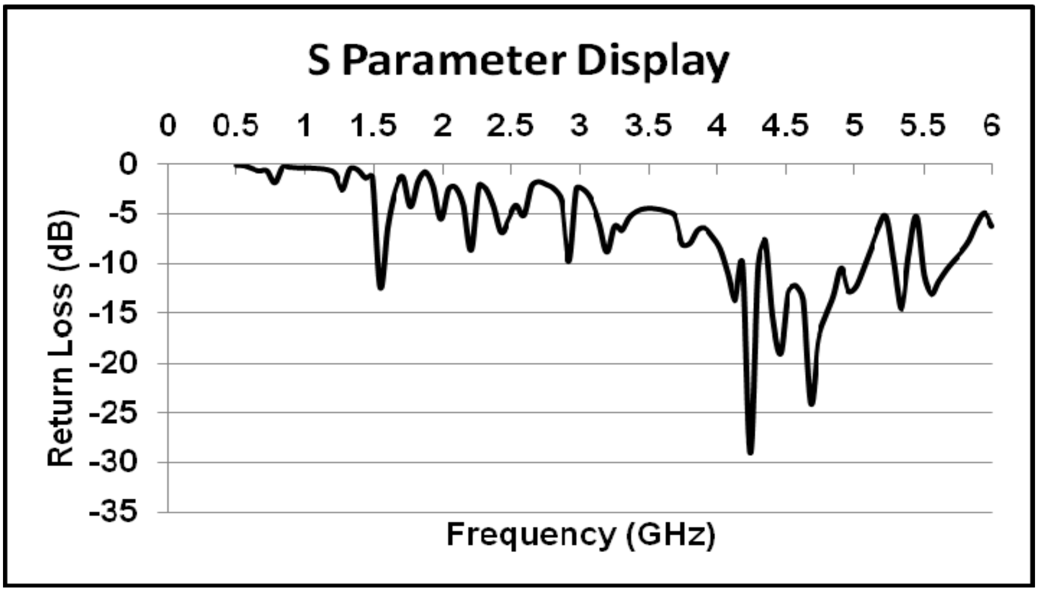

Fig. 6. The reflection coefficient curve of plain hexagonal radiating patch on circular meander patch antenna

In proposed fractal antenna, the graph shown in Fig. 7 illustrates the following multi band resonant frequencies at 0.775 GHz, 0.88 GHz, 1.60GHz, 1.65 GHz, 1.71 GHz, 2.01 GHz, 2.64 GHz, 2.97 GHz, 3.30 GHz, 3.41 GHz, 4.18 GHz, 4.40 GHz, 5.12 GHz, 5.34 GHz, 5.50 GHz, 6.0 GHz.

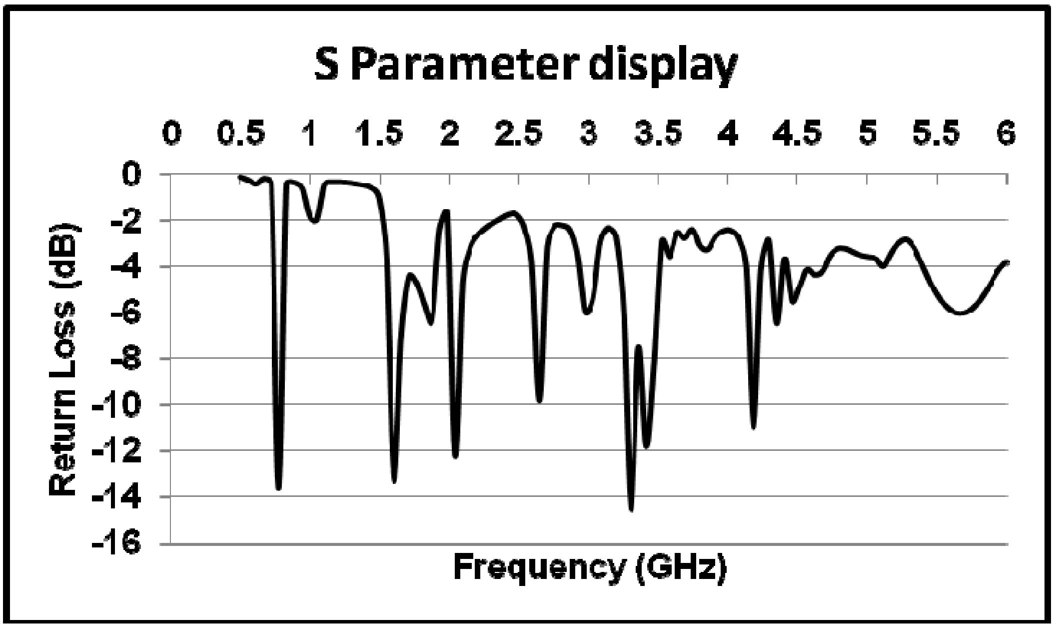

Fig. 7. The Reflection Coefficient Curve Simulation Result of Proposed Fractal Stacked Antenna

The simulated result parameters are tabulated in Table I as radiation pattern properties. In that table, radiation efficiency, gain and directivity values corresponding to the resonant frequencies are furnished.

TABLE I
The Radiation Pattern Properties

requency (GHz)	Radiation Efficiency (%)	Gain (dBi)	Directivity (dBi)
0.77	48.54	2.92	6.25
0.88	53.13	-7.54	6.17
1.60	41.74	2.88	6.88
1.65	62.81	4.34	7.31
1.71	76.45	4.03	7.13
2.04	49.89	4.23	5.52
2.64	42.85	3.90	8.05
2.97	53.63	5.70	9.66
3.30	33.89	3.12	7.97
3.41	37.29	5.03	9.61
4.18	36.01	6.91	11.71
4.40	29.36	2.49	10.26
5.12	22.39	0.81	7.84
5.34	22.13	0.31	9.67
5.50	25.99	2.96	10.18
6.00	22.24	0.03	9.32

For the proposed fractal antenna stacked structure, VSWR, return loss, and impedances are given in the Table II. Fig. 8 shows the VSWR display of the proposed antenna simulation result.

In that, 5-6 GHz frequencies are getting values more than 2 [15]-[17] and it is undesired properties shown in the Table II.

TABLE III
VSWR Return Loss Impedance at Resonant Frequencies

Resonant Frequency (GHz)	VSWR	Return Loss (dBi)	Impedance (ohms)
0.775	1.52	-13.60	33.8-j6.9
1.60	1.55	-13.26	32.1-j0.7
2.04	1.64	-12.21	71.5-j21.2
2.64	1.95	-09.93	38.4+j27.5
3.30	1.46	-14.51	71.7+j7.1
3.41	1.68	-11.82	31.3+j9.7
4.18	1.78	-10.98	61.6+j30.5
5.06	4.82	-03.65	69.4+j0.7
5.61	3.03	-05.90	151+j1.9
6.00	4.63	-03.80	189+j8.7
6.00	22.24	0.03	9.32

Fig. 9 shows the impedance parameter graph, known as Z-parameter. In that graph, frequencies 5.6 and 6 GHz are at high impedances are tabulated in Table II. It shows the less radiation effect in those frequencies [18]-[20].

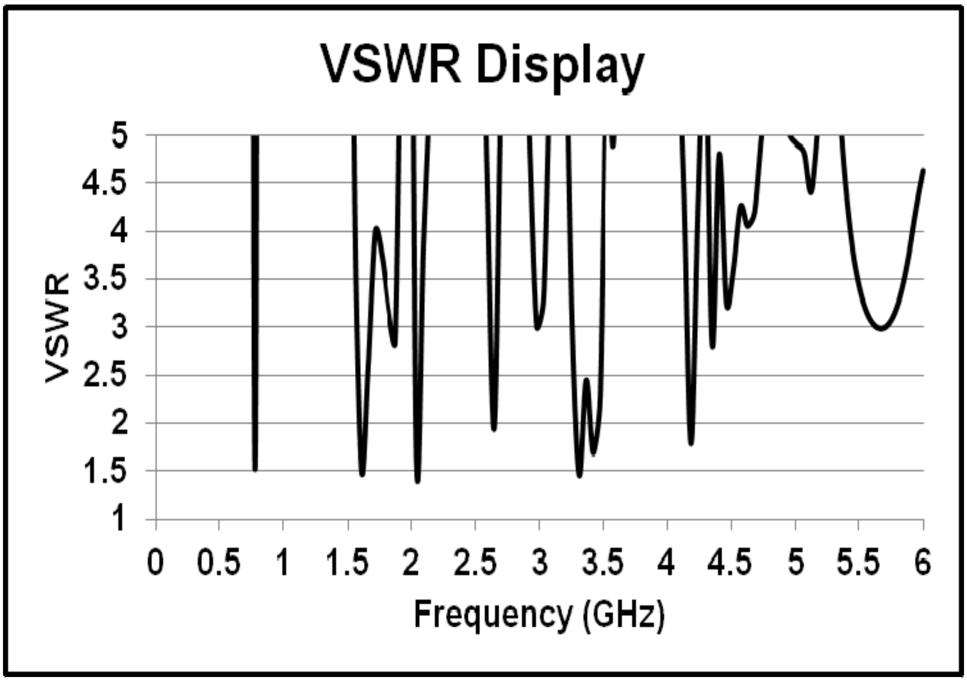

Fig. 8. VSWR Display of the Proposed Antenna

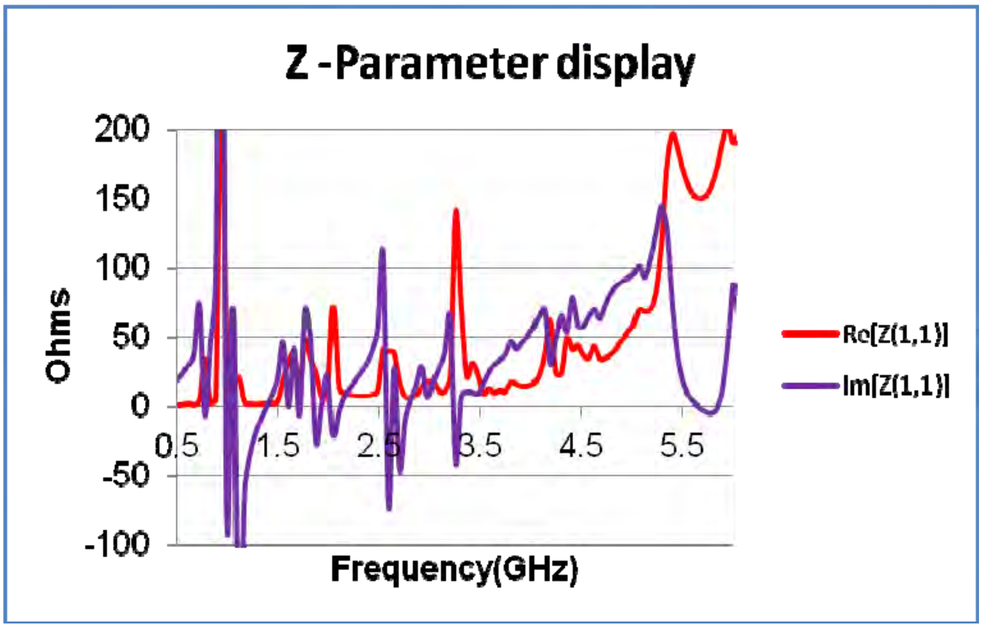

Fig. 9. Z -Parameter of the Proposed Antenna

Fig. 10 is displayed with the measured result data of the proposed antenna after fabrication. The measurement result shows the various frequencies resonating less than -10 dB to achieve the radiation making a useful multi band antenna in the areas of L-band of microwave (1.65 -1.71 GHz), S-band (2-2.9 GHz), Wimax band (3.3-3.7 GHz), downlink frequencies (4.18 -4.40GHz)

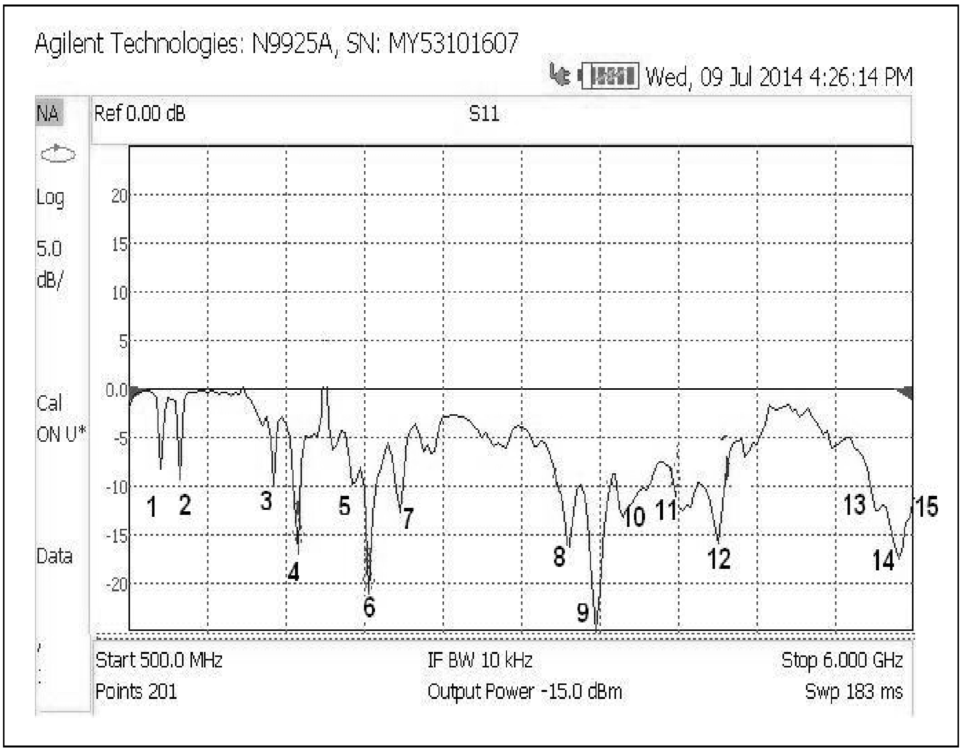

Fig. 10. Measured Results of Proposed Antenna

In the Table III, both simulation result and measurement results were tabulated as a comparison purpose [21]-[22].

TABLE IIIII
Comparison of Simulation and Measurement Results

S.No.	Frequency (GHz)	Simulated Return Loss (dBi)	Measured Return Loss (dBi)
1	0.50	00.00	00.00
2	0.77	-13.60	-08.83
3	0.90	-02.00	-09.82
4	1.30	-01.00	-10.00
5	1.60	-13.26	-16.32
6	1.90	-02.00	-10.00
7	2.04	-12.21	-21.05
8	2.40	-02.10	-12.50
9	2.64	-09.93	-10.00
10	3.30	-14.51	-16.53
11	4.18	-11.82	-25.00
12	4.50	-06.00	-13.00
13	4.70	-04.00	-12.50
14	5.06	-03.98	-16.50
15	5.40	-06.00	-10.00
16	5.80	-06.00	-17.50
17	6.00	-04.00	-11.00

The maximum radiation is occurring at some frequencies [23]-[26]. Comparison of simulation and tested results are given in fig 11.

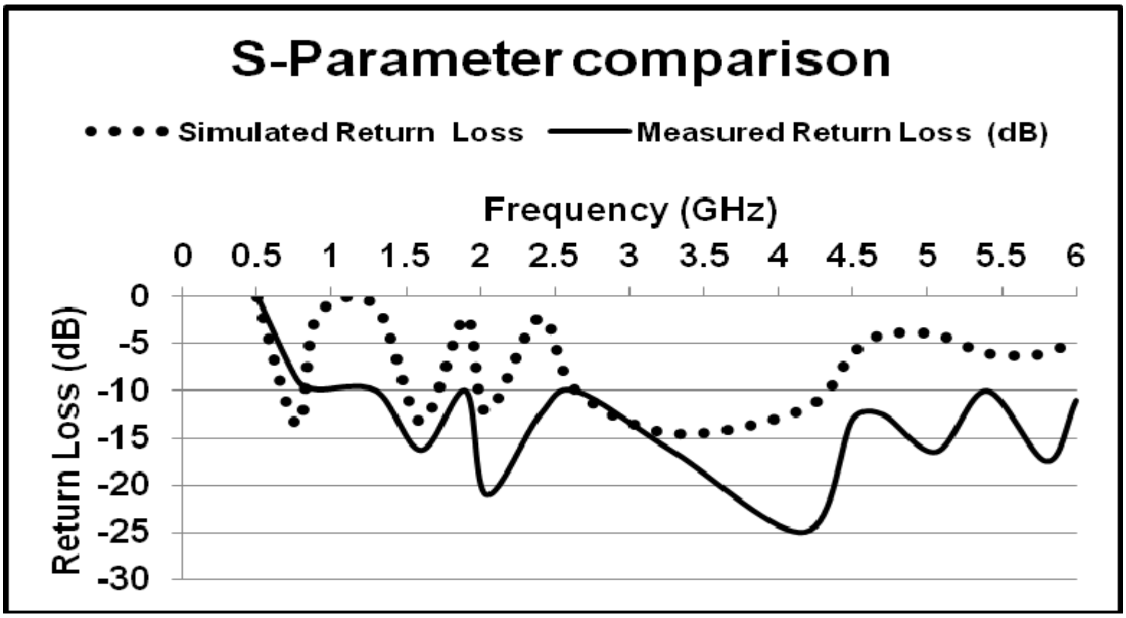

Fig. 11. Comparison of Simulated and Measured Return Loss of Proposed Fractal Stacked Antenna.

This comparison figure shows the high correlation between the two simulation and measurement data. The Elevation and Azimuthal radiation pattern diagrams for the frequencies 0.775, 3.30 and 4.185 GHz are shown in Fig. 12-17.

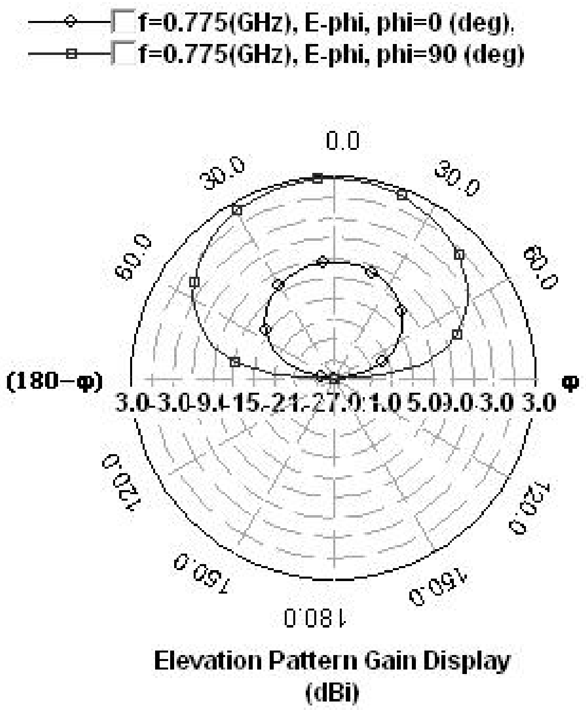

Fig. 12. Elevation Radiation Pattern at 0.775 GHz

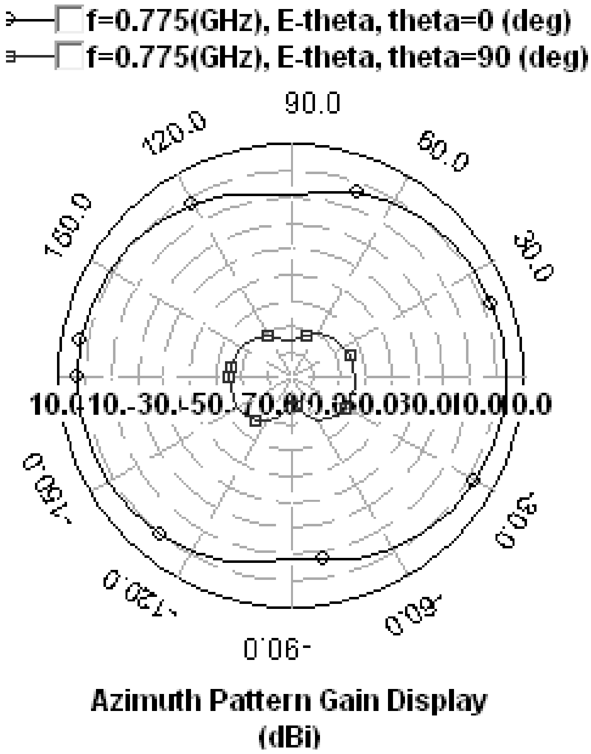

Fig. 13. Azimuthal Radiation Pattern at 0.775 GHz

From the f=0.775 GHz Elevation diagram, pattern forms in upper hemisphere. In azimuthal direction, it forms in full area as circular shape.

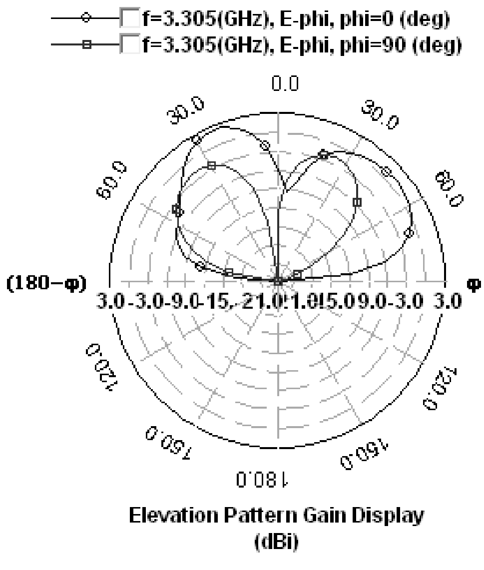

Fig. 14. Elevation Radiation Pattern at 3.30 GHz

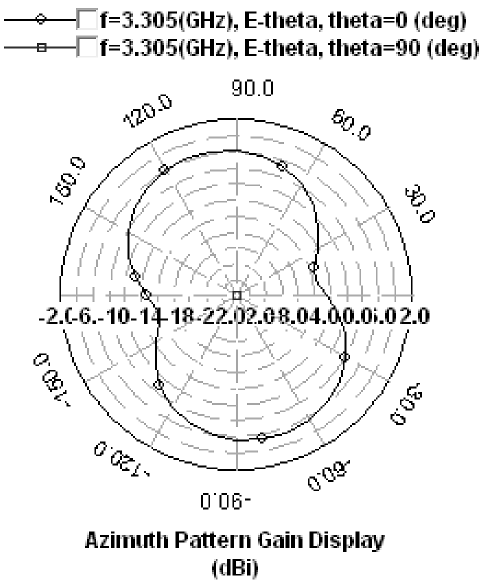

Fig. 15. Azimuth Radiation Pattern at 3.30 GHz

For the the resonant frequency 0.775 GHz Elevation diagram, pattern shrinks in upper hemisphere. In azimuthal direction, it forms in area as octet shape.

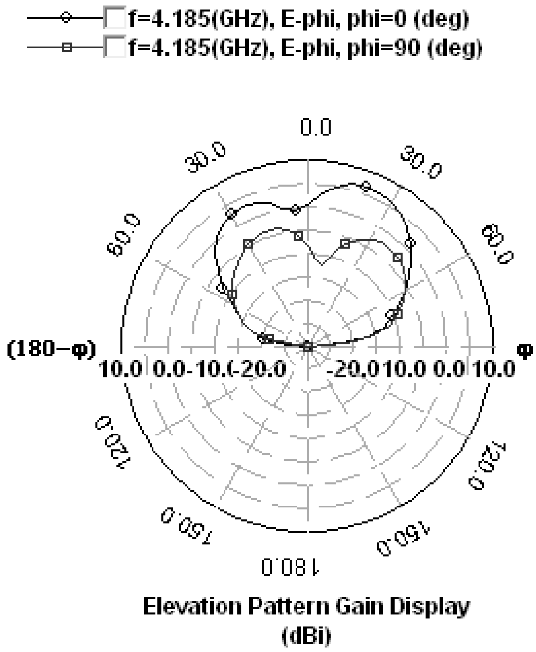

Fig. 16. Elevation Radiation Pattern at 4.185 GHz

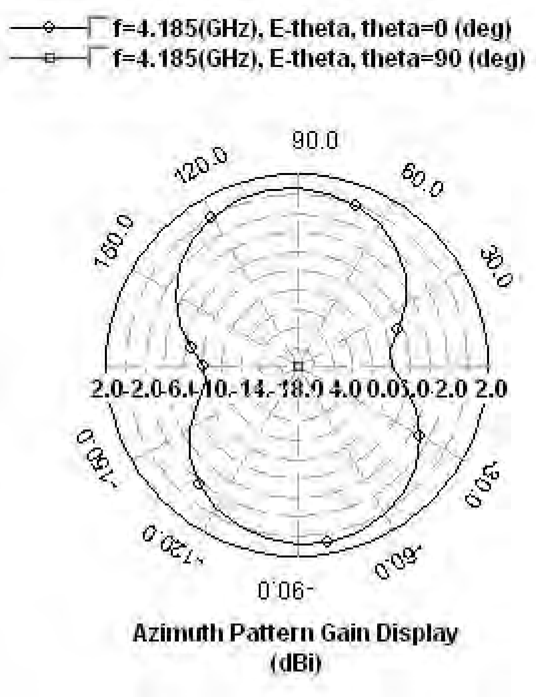

Fig. 17. Azimuthal Radiation Pattern at 4.185 GHz

From the frequency f=4.185 GHz Elevation diagram, pattern forms in top upper hemisphere. In azimuthal direction, it forms in area as octet circular shape.

VI. Conclusion

Microstrip fractal in stacked structure has been proposed on low cost FR4 substrate. The proposed stacked antenna is simulated and its performances are measured. The simulated reflection coefficient values, VSWR and directivity are acceptable in between the range of 0.5 GHz and 6 GHz frequencies. The proposed design is compared with the same design without any fractal. The results of this research show that the bandwidth is improved as a useful antenna for multi band applications. Multi band performance is the presented outcome from this research work. This work may be useful in wireless communication applications. Even though many multi band structures are already presented by the researchers, this work gives high directivity of 11.71 dBi and low fringe effect.

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