Sierpinski carpet fractal microstrip antenna for improved bandwidth using stacking technique with stripline feeding

Sudhina H. K.
Department of Electronics and Communication Engineering
REC, Hulkoti, Gadag, Karnataka, India
Ph. D Scholar at St. Peter's University, Chennai

Dr. Jagadeesha S.
Department of Electronics and Communication Engineering
S.D.M.I.T., Ujire, Karnataka (D. K.), India

Dr. N. M. Shetti
Department of Physics
S. D. M. College Ujire, Karnataka (D.K), India

Abstract - This paper outlines the design of Sierpinski carpet fractal microstrip antenna up to third iteration is proposed. Prototype antenna is designed on FR4 substrate with thickness of 1.6mm whose relative dielectric constant of 4.4 using microstrip line feeding. These antennas are optimized to operate under various specified bands between 2-14 GHz. Simulation is carried out using IE3D simulator and it is found that the simulated results are in good agreement with the experimental results. Stacking techniques are also implemented on the designed antenna using microstrip line feeding to enhance the bandwidth. Comparison is carried out with and without stacking method.

Keywords: Microstrip antennas, Sierpinski, Multiband, Iterations, Stacking

I. INTRODUCTION

Antennas determine main properties of the modern radio communication systems [1]. The term fractal was coined by Benoit Mandelbrot to describe a family of complex shapes that possess an inherent self-similarity or self-affinity in their geometrical structure and to study the patterns of nature. For instance, fractals have been successfully used to model such complex natural objects as galaxies, cloud boundaries, mounting ranges, coastlines, trees, leaves, snowflakes, ferns, and much more [2-5]. There are many different antenna applications worked by fractal methods: Cantor linear array, Sierpinski gaskets and carpets, fractal trees, Hilbert, Smale, Koch and Minkowski curves, etc. [3-7]. There are wide variety applications for fractals in many branches of science and engineering, as antenna theory. These antennas are compact size, low profile, conformal, multiband and broadband properties In the fractal electrodynamics, the fractal geometry is combined with electromagnetic theory for the purpose of investigating a new class of radiation, propagation, and scattering problem [6, 7]. It is a simple geometry fragment: segment of broken line, quadrate, triangle, circle, tree, more complicated figure, etc. Design iterative process of the fractal antennas is a replacement of every part of the base element by the whole generating element. Thus complicated fractal antenna constructions of different orders (iterations) are worked out.

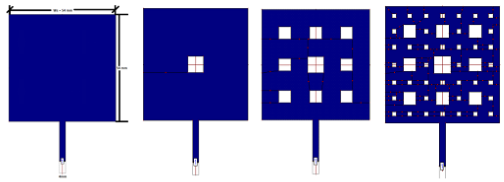
II. ANTENNA DESIGN

A. Design Calculation

The sierpinski fractal microstrip antenna fed with stripline are considered as the reference antenna i.e. it is a zeroth iteration as shown in the Fig.1(a) whose dimension is 54 mm *54 mm is printed on a dielectric substrate of thickness 1.6 mm. The material used is FR4 with a dielectric constant of $\varepsilon_r = 4$, which are operated over various bands of frequencies. This designed antenna is fed by microstrip line of 50 Ohm impedance. The construction of the sierpinski carpet begins with a square. The square is cut into 9 congruent sub squares in a 3-by-3 grid, and the central sub-square is removed. The same procedure is then applied recursively to the remaining 8 sub squares. The area of the carpet is zero (in standard Lebesgue measure). The Hausdorff dimension of the carpet is log 8 / logs 3 ≈ 1.8928. Comparison is made and are summarized below for both without stacked and with stacked sierpinski carpet fractal microstrip antenna.

B. Sierpinski carpet mistrostrip fractal antennas for microstrip line feeding without stacking

Fig.1(a) is the reference antenna, fig.1(b) to fig.1(d) shows 1st, 2nd and 3rd iterated antennas respectively. Fig. 2 shows the fabricated antennas.



1(a) 1(b) 1(c) 1(d)

Figure 1. (a) Geometry of reference antenna (b) 1st iterated antenna, (c) 2nd iterated antenna (b) 3rd iterated antenna

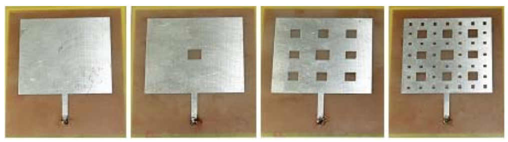


Figure 2. Fabricated view of base antenna, 1st, 2nd and 3rd iterated antennas

C. Sierpinski carpet mistrostrip fractal antennas for microstrip line feeding with stacking

The stacking technique is implemented on sierpinski carpet fractal microstrip antenna for the ref, 1st, 2nd and 3rd iterations**.** Fig. 3 shows the fabricated view of the stacked sierpinski carpet mistrostrip fractal antennas for microstrip line feed.

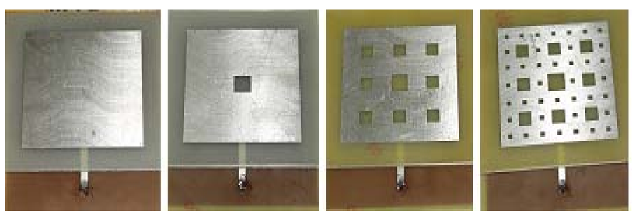
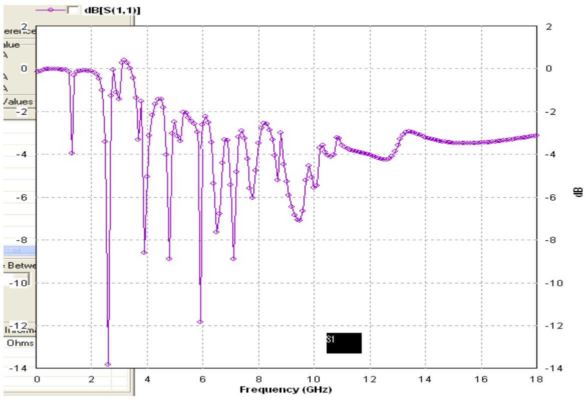


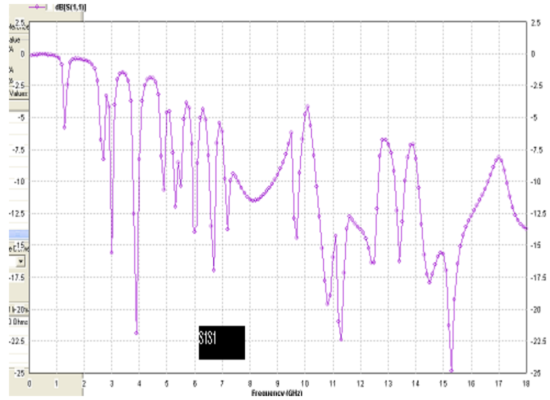
Figure 3. Fabricated view of stacked sierpinski carpet mistrostrip fractal antennas

III. Results and Discussion

Sierpinski fractal microstrip antennas were examined for without and with stacking using IE3D simulation tool. The parameters like return loss and bandwidth were analyzed using well known simulator, and it was verified using vector network analyzer. Simulated results were found to be in a good agreement with the experimental analysis.

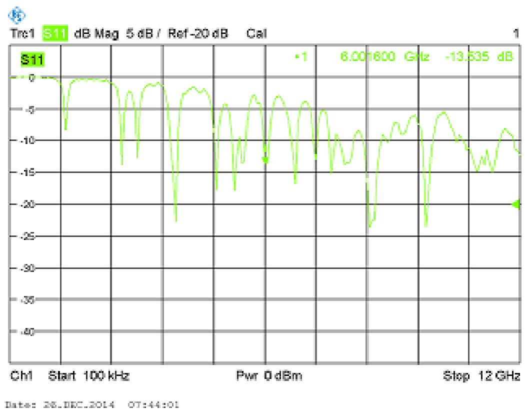
Fig.4, fig.6, fig.8 and fig.10 show the results of simulated return loss characteristics and fig.5, fig.7, fig.9 and fig.11 show the corresponding practical return loss characteristics taken from vector network analyzer for both without stacked and with stacked structures of sierpinski carpet mistrostrip fractal antennas for microstrip line feeding. Table1 summarizes the various results of the performance parameters like the variation of bandwidth, resonant frequency, return loss and gain with reference to without and with stacking of sierpinski carpet fractal microstrip antenna. The best possible resonant frequency is operating around 6 GHz, for the various iterations were statistically analyzed and which are summarized in the table1. Fig. 12(a) to fig.12(d) and fig.13(a) to fig.13(d) show the graph of frequency vs. gain for reference to 3rd iterations for without and with stacking respectively.

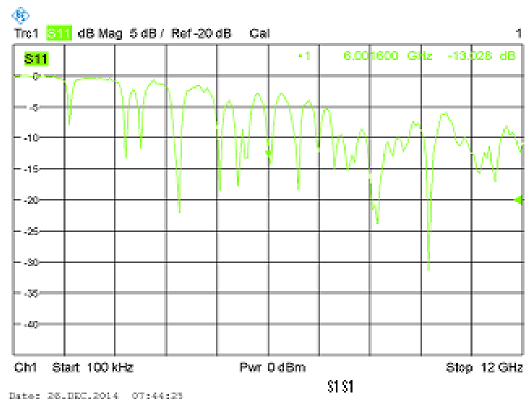




4(a) (4b)

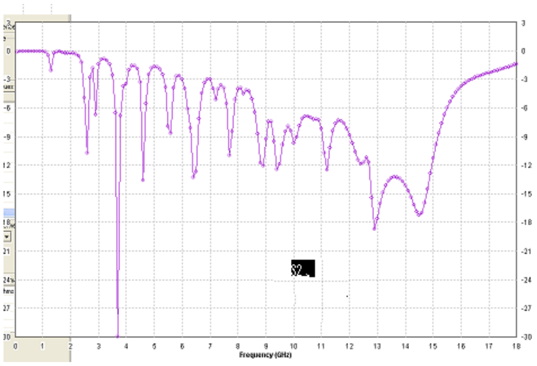
Fig.4 Simulated return loss characteristics of without and with stacking implemented on sierpinski fractal antenna for reference antenna

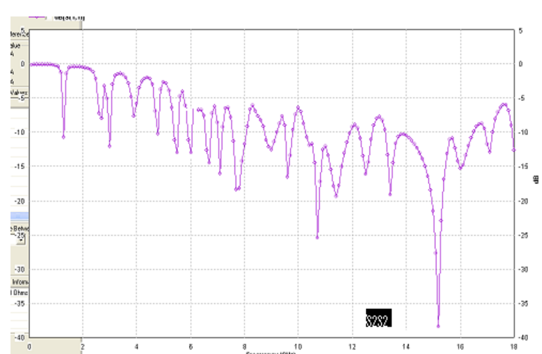




(5a) (5b)

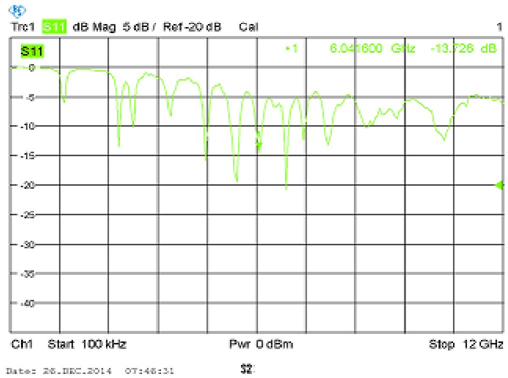
Fig.5 Practical return loss characteristics of without and with stacking implemented on sierpinski fractal antenna for the reference antenna



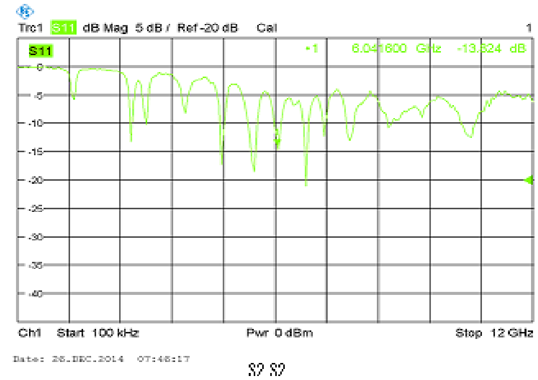


6(a) 6(b)

Figure 6.Simulated return loss characteristics of without and with stacking implemented on sierpinski fractal antenna for 1 st iteration antenna

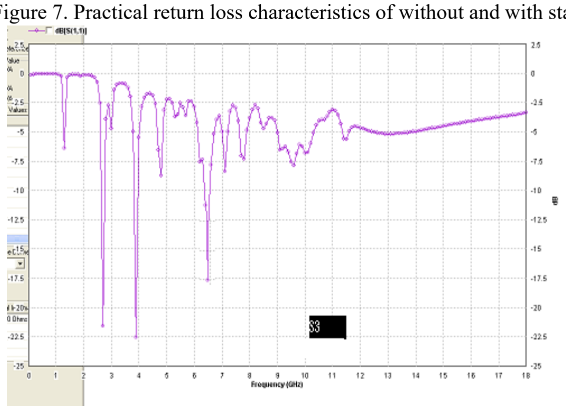


7(a)

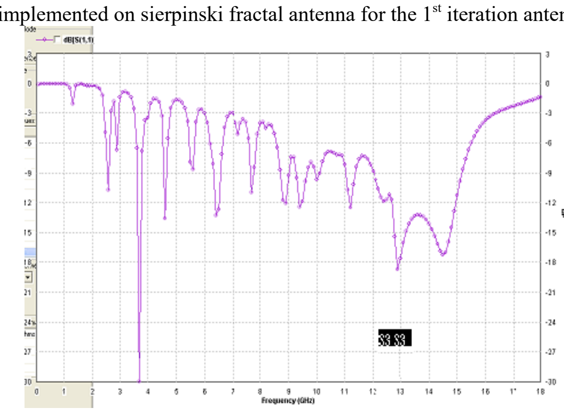


7(b)

Figure 7. Practical return loss characteristics of without and with stacking implemented on sierpinski fractal antenna for the 1st iteration antenna

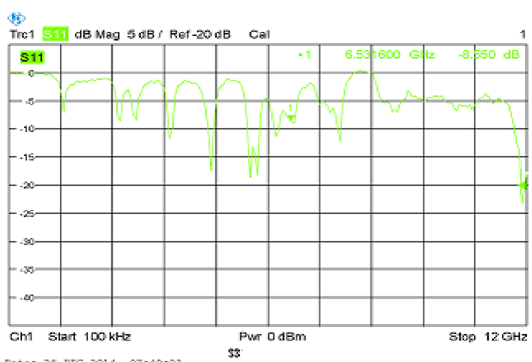


8(a)

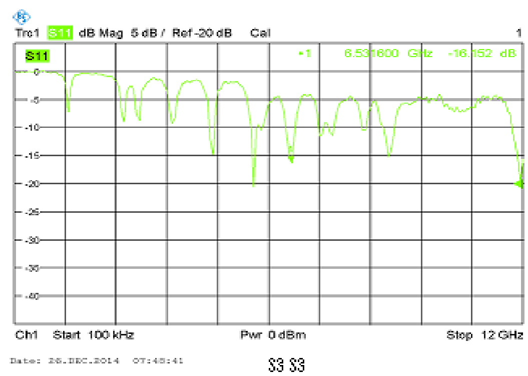


8(b)

Figure 8. Simulated return loss characteristics of without and with stacking implemented on sierpinski fractal antenna for 2nd iteration antenna

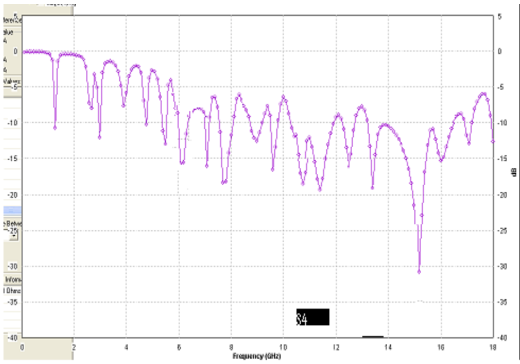


9(a)

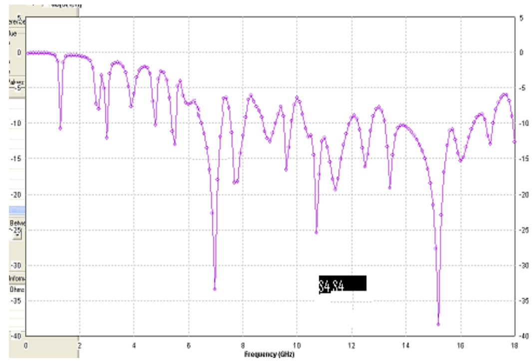


(9b)

Figure 9. Practical return loss characteristics of without and with stacking implemented on sierpinski fractal antenna for 2nd iteration antenna

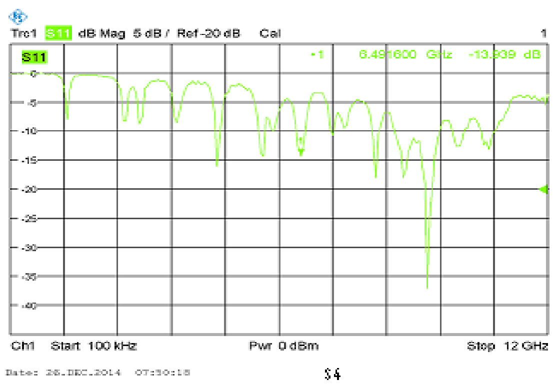


10(a)

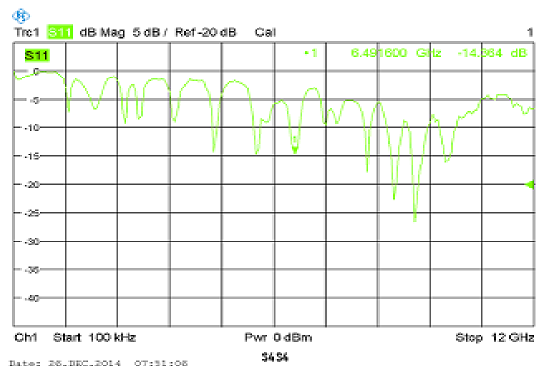


10(b)

Figure 10. Simulated return loss characteristics of without and with stacking implemented on sierpinski fractal antenna for 3rd iteration antenna

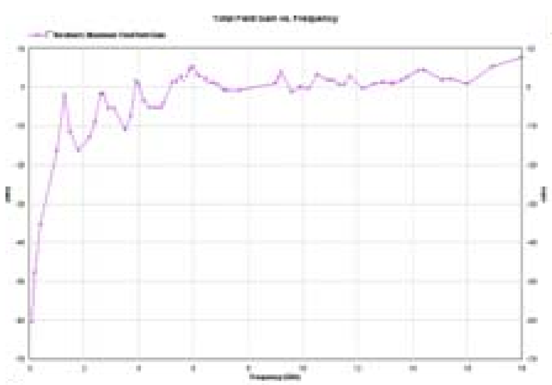


11(a)

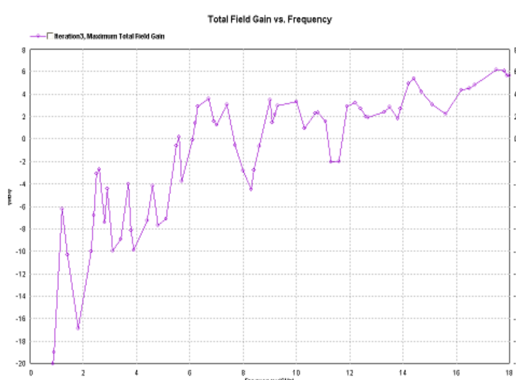


11(b)

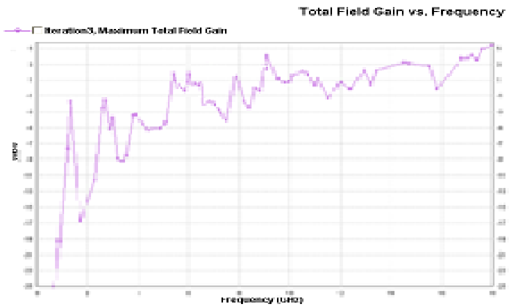
Figure 11. Practical return loss characteristics of without and with stacking implemented on sierpinski fractal antenna for the 3rd iteration antenna



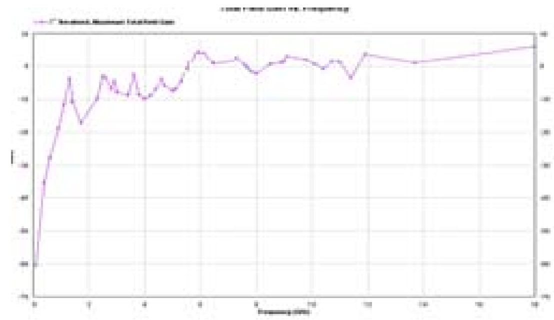
12(a)



12(b)

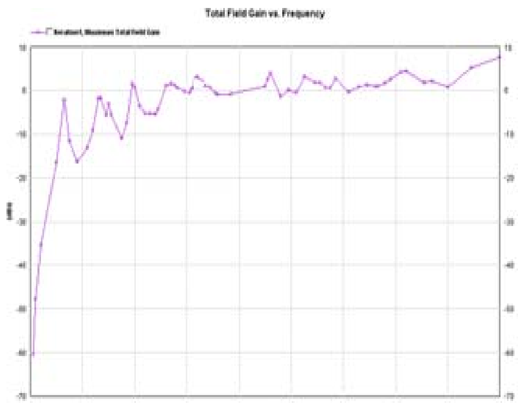


12(c)



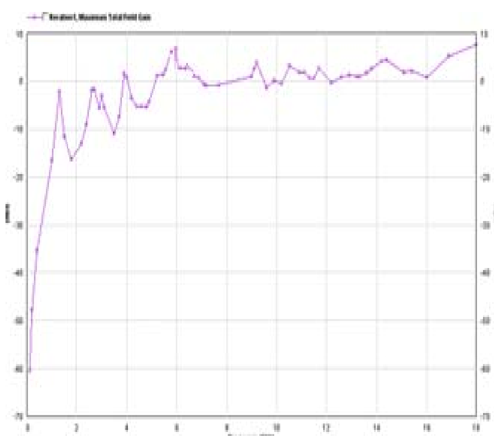
12(d)

Figure 12. Frequency vs. gain for without stack

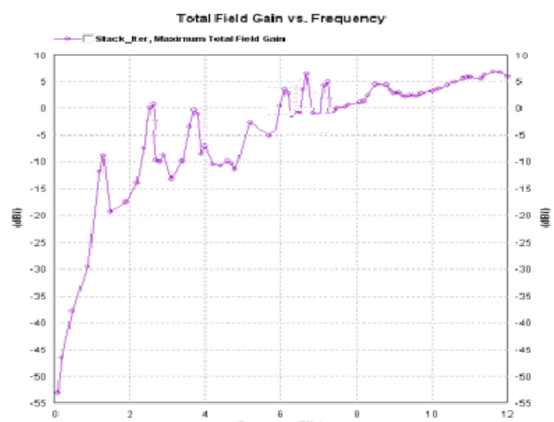


13 (a)

13(b)



13(c)



13(d)

Figure 13. Frequency vs. gain for with stack

Table 1 Result of the simulated and experimental for stacked and without stacked

Iterations for stripline feeding	Resonant frequency (GHz)		Return loss(dB)		Gain (dB_i)	Bandwidth (MHz)	
	Simulated GHz	Experiment	Simulated	Experiment	Simulated	Simulated	Experiment
Reference iteration antenna							
Without stack	5.9	6.0	-14	-13.02	3.0	55	50
With stack	6.0	6.0	-15	-13.5	0.5	150	120
1st iteration Antenna							

Without stack	**6.0**	**6.04**	**-14.5**	**-13.72**	**4**	**175**	**150**
With stack for	**6.0**	**6.1**	**-12**	**-13.82**	**4**	**180**	**210**
2nd iteration Antenna							
Without stack	**6.4**	**6.53**	**-12**	**-10**	**3.0**	**200**	**210**
With stack	**6.4**	**6.5**	**-14.8**	**-16.15**	**4.1**	**300**	**300**
3rd iteration Antenna							
Without stack	**6.6**	**6.5**	**-16**	**-17.5**	**4.2**	**230**	**400**
With stack	**6.52**	**6.49**	**-16**	**-14**	**5.2**	**450**	**475**

For without stacking, the reference antenna displays a resonant frequency of -14 db at 5.9 GHz with a gain of 3db and a bandwidth of 55 MHz and in the experimental analysis value observed for resonant frequency at -13.5 db with a bandwidth of 150 MHz. With stacking, the simulated values for the reference antenna displays the resonant frequency of -15db with increased bandwidth of 150 MHz and experimental analysis shows -13.5db with an increase of bandwidth to 120 MHz, compared with reference without stacking. After first iteration, the resonant frequency shifts in significant as summarized in Table1. Results of different antennas with various resonant frequencies whose characteristic features like return loss and its band width are summarized. Experimental results are close in agreement with the simulated results using IE3D software. The resonating frequency seems to be shifted with the increase of the iterations for both cases, without and with stacking.

IV.CONCLUSION

This paper outlines a design of sierpinski carpet fractal microstrip antenna with a stripline feed for without and with stacking, which operates for various frequency bands.

A comparison is carried out with reference to without and with stacking. The optimized bandwidths obtained after third iteration with an enhanced bandwidth of 220 MHz for simulated and 75 MHz for practical. An improvement of gain is from 3db to 4.2 db for without stacking and it is 0.5db to 5.2 db for stacking.

REFERENCES

[1] K. Fujimoto, J. R. James, “Mobile Antenna Systems Handbook, Artech House, Boston-London,2001
[2] B. B. Mandelbrot, “The Fractal Geometry of Nature”, N.Y. W. H. Freeman, 1996
[3] H. O. Peitgen, P. H. Rixter, “The Beauty of Fractals”, Images of Complex Dynamic Systems, Springer-Verlag, Berlin-N.Y-1998,
[4] H. O. Peitgen, H. Jurgens, D. Saupe, “Chaos and Fractals”, New frontiers in science, Springer-Verlag, New-York-2010
[5] D. H. Werner, R. L. Haupt, P. L.Werner, “Fractal Antenna Engineering: The Theory and Design of Fractal Antenna Arrays”, IEEE Antennas and Propagation Magazine, vol. 41, No.5, October, pp.37-59, 1999.
[6] D. H. Werner, S. Ganduly, “An Overview of Fractal Antenna Engineering Research”, IEEE Antennas and Propagation Mag., vol. 45, No.1, February, pp. 38-57, 2003.
[7] C.Puente-Baliarda, R.Pous, Fractal Design of Multiband and Low Side-Lobe Arrays, IEEE Antennas and Propagation, Vol.. 44, No.5, p.730-739, 2005