Investigation of Modified Sierpinski Square Fractal Antenna on Finite and Infinite Ground Planes

Rupesh Tomar[#1], Paridhi Mudgal[#2], Gaurav Chaitanya[#3]
Department of Electronics and Communication Engineering,
Acropolis Institute of Technology and Research, Indore (RGPV, Bhopal)

Abstract :

In this paper, we propose Sierpinski square fractal antenna in which the Sierpinski approach is used to give wide-band characteristics. The results show that the return loss characteristics and VSWR improves as we move on to next iterations. The comparison of results is given for the antenna when used with finite and infinite ground planes. Its applications are in the field of short range and outdoor base communications.

Keywords— *Sierpinski, wide-band.*

I. INTRODUCTION

The term fractal was coined by Benoit Mandelbrot in 1975 for a class of irregular geometries which had diverse application in the field of science and engineering [1]. Fractals are made up of multiple copies of themselves at different scales and hence do not have a predefined size. These self similar sets are known as self affine sets as they are defined by liner contraction. Space filling, space invariance and lacunarity are also important properties of fractal [2].

The term lacunarity is used to indicate the hollow spaces (gappiness) in the fractal. If fractal tends to fill an area with the increase in no. of iteration then these are known as plane filling fractals. These are some unique features of fractals.
In 1916, Polish mathematician Sierpinski described some of the main properties of fractal shape hence the antennas Sierpinski carpet, Sierpinski gasket are named after him. Both these antennas have been efficiently used in past for the realization of antenna array with specific operational features [4]. In this paper we are using same Sierpinski approach to design Sierpinski square fractal antenna and its simulation results are also discussed. The best results are shown in the last iteration that is modified iteration so, the proposed antenna is also known as modified Sierpinski square fractal (MSSF) [3].

II. SIERPINSKI SQUARE FRACTAL ANTENNA

The geometry of Sierpinski square fractal antenna is generated with the help of IFS generation method [5].

$$W(x) = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x1 \\ x2 \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix}$$

$$W(x) = ax1 + bx2 + e, cx1 + dx2 + f$$

$$a = \delta \, Cos\varnothing 1$$
$$b = -\delta \, Sin\varnothing 2$$
$$c = \delta \, Sin\varnothing 1$$
$$d = \delta \, Cos\varnothing 2$$

where, a, b, c, and d control rotation and scaling, while e and f control linear translation. IFS for proposed antenna shown in Fig.1 is composed of three transformations [6].

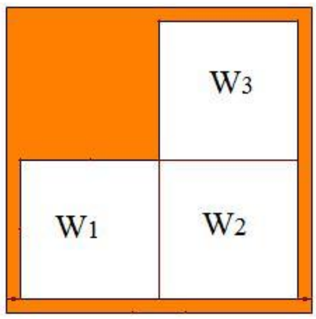

Fig.1. IFS of Sierpinski Square Fractal Antenna

$$W1(x) = \begin{bmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{bmatrix} \begin{bmatrix} x1 \\ x2 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$W2(x) = \begin{bmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{bmatrix} \begin{bmatrix} x1 \\ x2 \end{bmatrix} + \begin{bmatrix} \frac{1}{2} \\ 0 \end{bmatrix}$$

$$W3(x) = \begin{bmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{bmatrix} \begin{bmatrix} x1 \\ x2 \end{bmatrix} + \begin{bmatrix} \frac{1}{2} \\ \frac{1}{2} \end{bmatrix}$$

$$W(X) = W1(x) \cup W2(x) \cup W3(x)$$

The similarity dimension for Sierpinski square fractal antenna (D = 1.5849) evaluated from the formula [5]:

$$D = \frac{\log N}{\log \frac{1}{\delta}}$$

Where,
N = no. of self similar parts
δ= scale factor

For the proposed antenna N = 3, δ = ½.

III.ANTENNA DESIGN

The antenna proposed in this paper is designed using FR4 epoxy glass substrate with thickness h = 1.58 mm, relative permittivity (ϵ_r) = 4.4 and loss tangent (tan δ) = 0.005. Antenna has been fed through a 50 Ω micro-strip transmission line having length L_f and width W_f. All the dimensions are listed in the Table 1; corresponding geometry is shown in Fig.2.

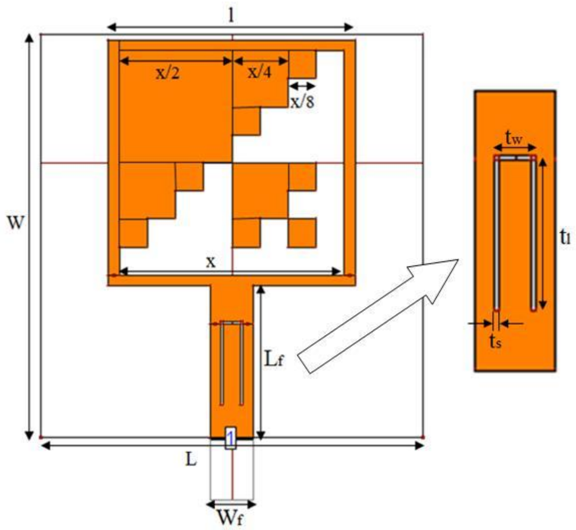

Fig.2. Geometry of Sierpinski Square Antenna

Table I : Dimensions of Square Sierpinski Antenna

L	W	W_f
34 mm	36 mm	3.8 mm
L_f	x	l
13.5 mm	20 mm	22 mm
t_s	t_w	t_l
0.2 mm	2 mm	7.4 mm

This antenna consists of fractal geometries in which square of side x is a generator. The first iteration is achieved by dividing the square into 4 equal parts and upper left portion is filled with metal. By repeating the same generator method next iterations are achieved. Antenna geometry is shown in Fig. 2

The ∩-slot is used to avoid the interference between different WLAN systems. The band stop function is achieved by the ∩-slot which acts as a filter element to make antenna non responsive at the band stop frequency [3].

IV. SIMULATION RESULTS

The propose Sierpinski square fractal is designed and simulated using HyperLynx 3D EM software. We are comparing the results of antenna in finite and infinite planes. In infinite plane the return loss characteristics for different iterations show that the return loss improves as we move on to next iterations. The base shape (Fig.3) has a return loss of 8.05 dB at 10 GHz (Fig.4). In the first iteration shown in Fig.6 we get return loss of 12.08 dB at 11 GHz (Fig.7) having bandwidth of 7% (10.5-11.2). The second iteration in Fig.9 has a lower resonant frequency of 6 GHz and return loss 9.77 dB is shown in Fig.10. The third and modified iterations are shown in Fig.12 and Fig.15 respectively. They give almost the same results having a slight difference in the return loss at 11 GHz. Also they give bandwidth of 17% (10.2 - 11.9 GHz) having return loss value of 11 at 6 GHz.

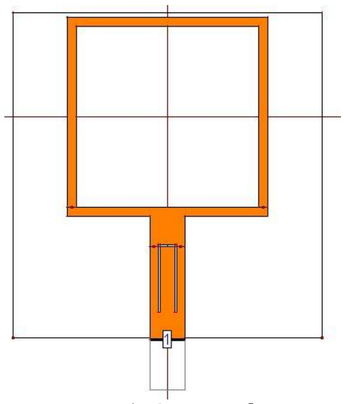

Fig.3. Base shape

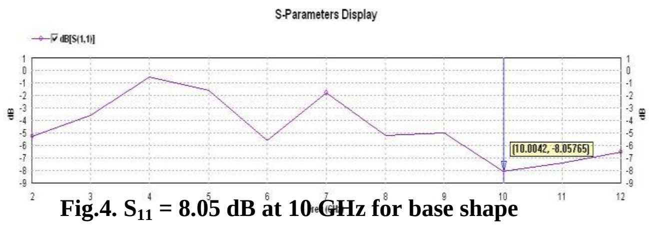

Fig.4. S_{11} = 8.05 dB at 10 GHz for base shape

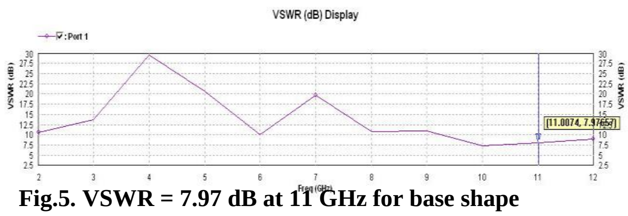

Fig.5. VSWR = 7.97 dB at 11 GHz for base shape

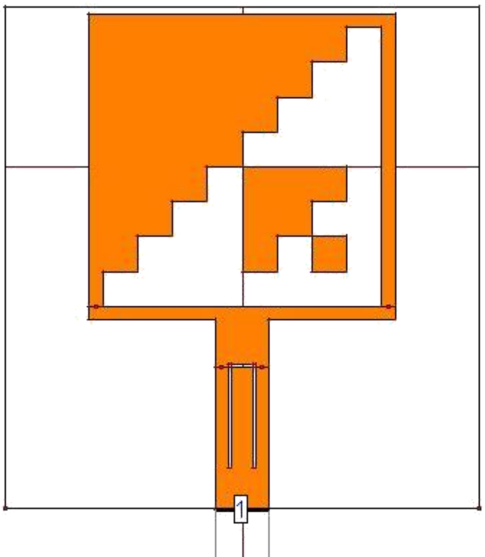

Fig.6. Prototype Antenna in Iteration 1

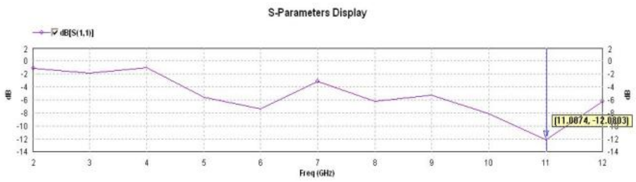

Fig.7. S_{11} = 12.08 dB at 11 GHz for Iteration 1

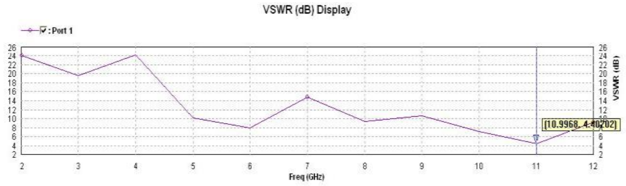

Fig.8. VSWR = 4.40 dB at 11 GHz for Iteration 1

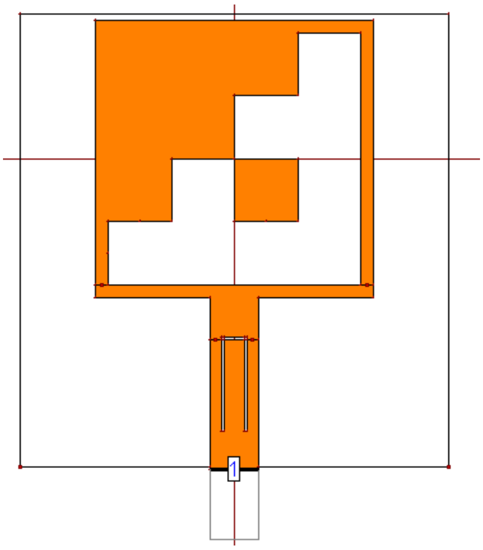

Fig.9. Prototype Antenna in Iteration 2

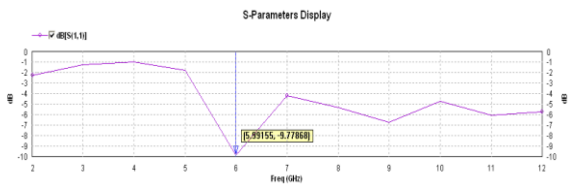

Fig.10. S_{11} = 9.77 dB at 5.99 GHz for Iteration 2

Fig.11. VSWR = 9.46 dB at 10.99 GHz for Iteration 2

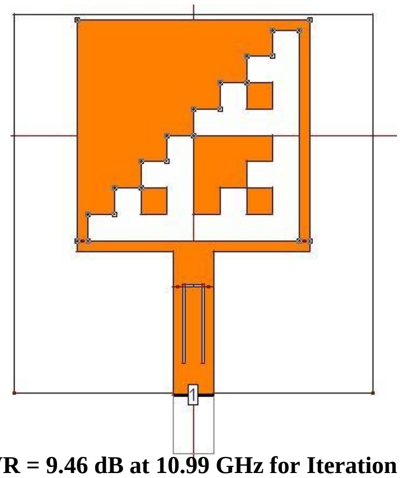

Fig.11. VSWR = 9.46 dB at 10.99 GHz for Iteration 2

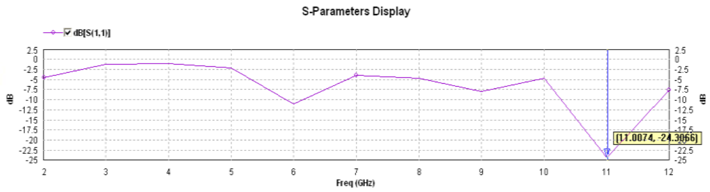

Fig.13. S_{11} = 24.30 dB 11 GHz for Iteration 3

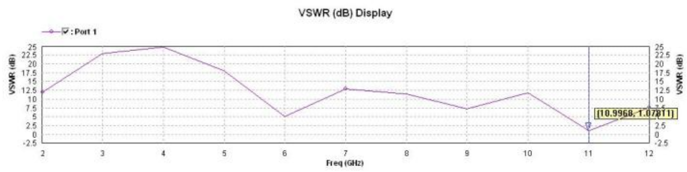

Fig.14. VSWR = 1.07 dB at 10.99 GHz for Iteration 3

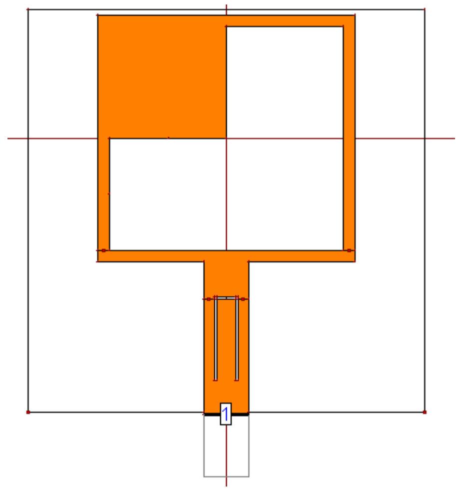

Fig.15. Prototype Antenna in Modified Iteration 3

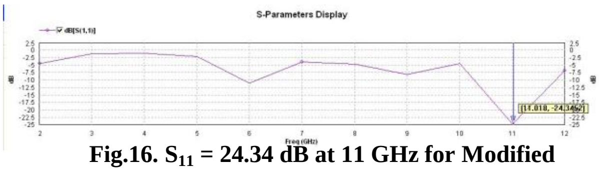

Fig.16. S_{11} = 24.34 dB at 11 GHz for Modified Iteration 3

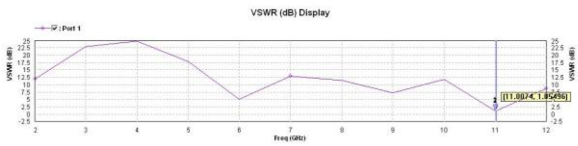

Fig.17. VSWR = 1.05 dB at 11 GHz for Modified Iteration 3

TABLE II : Comparison of Results of MSSF on Infinite and Finite Ground Planes

Antenna	Iteration	Frequency(GHz)	S_{11} (dB)	VSWR
Infinite ground plane	0	10	-8.05	2.30
	1	11	-12.08	1.66
	2	6	-9.77	1.95
	3	6	-11.00	1.80
		11	-24.30	1.16
	Modified	6	-11.00	1.70
		11	-24.34	1.13
Finite ground plane	0	9	-13.38	1.55
	1	10	-13.69	1.52
	2	9	-25.19	1.18
		12	-10.00	1.93
	3	5	-10.50	1.86
		9	-12.63	1.59
		12	-9.50	2.04
	Modified	5	-10.00	4.11
		9	-12.63	1.77
		12	-9.50	2.13

The comparison of results of MSSF on infinite and finite ground planes is given in table 2, from where we can conclude that infinite ground plane is better than finite ground plane.

V. CONCLUSION

The direct relationship between fractal dimension and antenna properties helps us to achieve the wide-band characteristics, miniaturization etc. In this paper, the comparison results between the finite and infinite ground planes show that the infinite ground plane gives better VSWR and return loss characteristics as compared to finite ground plane and the proposed antenna uses the Sierpinski fractal to give wide-band characteristics too. The proposed antenna is used for wireless applications like WLAN and also used for military applications, short range and outdoor base communications.

REFERENCES

[1] D. H. Werner, R. L. Haupt, and P. L. Werner, Fractal antenna engineering: The theory and design of fractal antenna arrays , IEEE Antennas and Propagation Magazine, Vol. 41, No. 5,1999.

[2] K. J. Vinoy, Jose K. Abraham, Vijay K. Varadan, On the Relationship between Fractal Dimension and the Performance of Multi-Resonant Dipole Antennas Using Koch Curves, IEEE transactions on antennas and propagation, vol. 51, no. 9, September, 2003.

[3] Yogesh Kumar Choukiker, A thesis on Investigations on Some Compact Wideband Fractal Antennas, 2003.

[4] Carles Puente-Baliarda,Jordi Romeu,Rafael Pous,Angel Cardama, On the Behavior of the Sierpinski Multiband Fractal Antenna, IEEE transactions on antennas and propagation, vol. 46, no. 4, April 1998.

[5] Wojciech J. Krzysztofik, On the Relationship between Fractal Dimension and the Performance of Multi-Resonant Dipole Antennas Using Koch Curves, Microwave Review, December, 2013.

[6] Abd Shukur Binn Jaafar, A thesis on Sierpinski gasket patch and monopole fractal antenna, March 2005.