Comparison of Sierpinski Fractal Antennas For Improved Performance And Reduced Size

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***Abstract*—In the current communication system, fractal shapes are introduced in the antenna technology to minimize the size considerably. Fractal denotes geometrical structures describing complex shapes which are self similar. Normally when the size of the antenna reduces, the performance reduces but when fractal antennas are used the performance is increased. In this paper, a sierpinski fractal antenna for WLAN applications is designed which would be working at a center frequency of 5GHz(5.1-5.8GHz). This antenna was designed and simulated using CST(Computer Simulation Technology) software. It is fabricated with FR4 substrate of thickness 1.575mm. The number of iterations are increased to increase the gain. An array of the structure was created to maintain the return loss. Each iteration was simulated and their results were compared.**

***Keywords*—fractal antenna, sierpinski gasket, wireless local area network (WLAN)**

I. INTRODUCTION

Mathematician, Benoit Manlbrot defined Fractals as structures whose dimensions cannot be limited to whole numbers. They are the same at every scale. The concept of fractal has the idea of detailed pattern repeating itself. Fractal allows to design miniature antennas and also help to integrate multiple telecommunication components into a single device. The two concept of fractals are self similarity and space filling.Self similarity is when an object is exactly similar to a part of itself and space filling is the property when the size becomes larger with the same area when the number of iterations are increased. Iterations results in a larger effective length keeping the area same. The fractal antennas are used for multilevel purpose. Due to this reason these antennas are very compact. They can be used in multiband or wideband. They are widely used in cellular based telephony and microwave applications. They are immensely used in wireless applications as they as small in size, with less weight and low cost. They are very easy to fabricate and assemble. The types of fractals available are Koch curve, Hilbert curve, sierpinski and minikwoski loop.

A wireless local area network (WLAN) connects two or more devices using some wireless distribution method. They usually provide a connection through an access point to the wider Internet. This gives users the ability to move around within a local coverage area and be connected to the network. Modern WLANs are based on IEEE 802.11 standards. Due to the ease of installation WLANs have become popular in home and in commercial complexes.

Among fractal geometries the sirepinski gasket is a widely used geometry for antenna application. Sierpinski gaskets are mostly used in monopole and dipole configuration. Its multi-band characteristics are caused by self-similar current distribution. This multi-band nature can be controlled by perturbing the geometry. Also, the band characteristics of the antenna can be changed by varying the flare angles. The conventional bow-tie antennas have their performances closely linked to those geometries, though minor differences can be noticed. Wideband characteristics can be derived from the multi-band nature of these antennas by using high dielectric constant substrate and suitable absorbing materials.

II. PRILIMINARY NOTES

Several design structures of the sierpinski gasket antennas are studied. Initially, an investigation for mobile communication using fractal antennas was done . A sierpinski gasket triangle antenna was designed with small capacitive feed strip which resulted in omnidirectional radiation pattern. This was obtained with simple geometry [1].

As an advancement defected ground structure is implemented in fabrication of the sierpinski gasket antenna. Defected ground slot is a slot created in the ground structure of the antenna. This antenna, fabricated for a frequency of 5.8GHz resulted in a compact sized antenna [2].

Necessity of dual band increased with the increase of WLAN applications. The bands are given with frequencies 2.4GHz and 5GHz. A sierpinski triangle with complementary split ring resonator(CSSR) based ground plane was fabricated with 2 iterations. The antenna covers both frequency bands with good radiation characteristics [3].

The antenna research was extended in many ways. One of the ways was to produce a fractal antenna with a high gain which was done at a frequency of 868MHz. this was done on a FR4 substrate and it resulted in a high gain of 16.4db and with more efficiency[4].

III METHOD

The three iterations of the designed antenna were simulated using CST(Computer Simulation technology)software. This was done using FR4 substrate and PEC(artificial material) is used as the ground material. An array was created to increase the gain of this antenna.
All the measurements are obtained from the simulation and these values were compared and analyzed for various iterations and improvements were noticed.
The iterations of the Sierpinski gasket fractal antenna was designed using the CST software on a fr4 with a dielectric constant of 4.3 and substrate thickness of 1.575mm and its loss tangent in 0.025. The specifications are shown below:

TABLE I. SPECIFICATION OF THE SUBSTRATE

Parameter	**Specification**
Substrate material	FR-4
Dielectric constant	4.3
Substrate Thickness	1.575mm
Ground material	PEC

IV. SIERPINSKI GASKET FRACTAL ANTENNA DESIGN

The design of this antenna involves the designing of a rectangular antenna and then the sierpinski shape was derived from this. Then slots were created in the triangular shape. The number of slots increased in each iteration. An array of the structure was created to increase the gain of this antenna.

The figure1 shows the prototype of sierpinski gasket for three iterationsand the results regarding return loss, gain and bandwidth are compared.

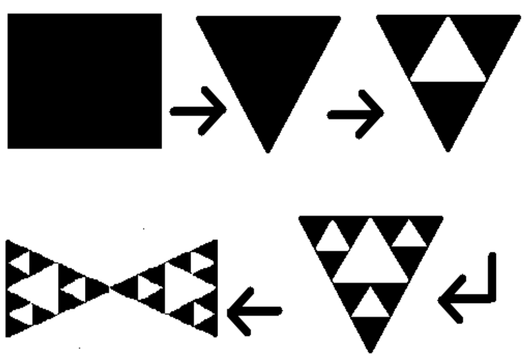

Fig. 1 Iteration of sierpinski gasket antenna

This antenna is designed adhering to the requirement of VSWR<2. The dimensions of the proposed sierpinski gasket antenna its parameters are given in the Table II.

TABLE II DIMENSION OF SIERPINSKI GASKET

PARAMETERS	VALUE(mm)
Outer width	35
Inner width	3.06
Patch thickness	0.035
Substrate thickness	1.575
Substrate length	70
Substrate width	50

A.*Design formula:*

The width(1) and length(2) of the patch are calculated using

$$W = \frac{C}{2fr}\sqrt{\frac{2}{\varepsilon r+1}} \qquad (1)$$

$$L = \frac{c}{2fr\sqrt{\varepsilon eff}} - 2\Delta L \qquad (2)$$

Where effective parameters are calculated by (3) and (4)

$$\varepsilon eff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1+\frac{12h}{w}\right]^{-\frac{1}{2}} \qquad (3)$$

$$\frac{\Delta L}{h} = \frac{(0.412)(\varepsilon eff+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon eff-0.258)\left(\frac{w}{h}+0.8\right)} \qquad (4)$$

The length of the feed is calculated by (5)

$$lf = \frac{c}{4fr\sqrt{\varepsilon r}} \qquad (5)$$

V. SIMULATION AND RESULTS

The figure2 shows the prototype of the proposed antenna for third iteration with array structure. The parameters of the antenna are identified using CST. And the results for each iteration are tabulated and compared. The result shows good improvement of gain for increasing the iteration of gasket antenna.

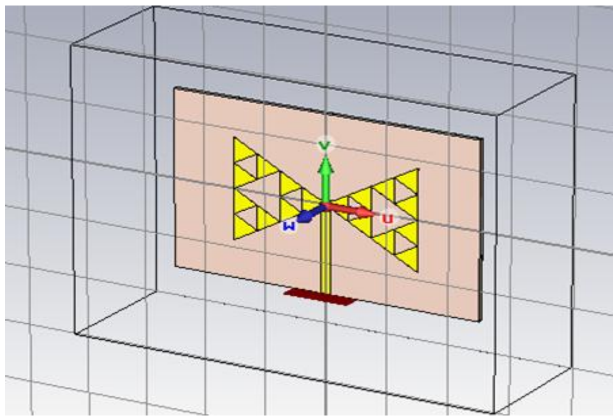

Fig. 2 Third iteration sierpinski gasket antenna

A. *Iteration1*

The centre frequency obtained for the iteration 1 is 5.115GHz which has the return loss of -19.242db. The antenna produces a gain of 6.467dbi and bandwidth of about 186Mhz Fig. 3. The gain of the iteration1 is shown in Fig. 4.

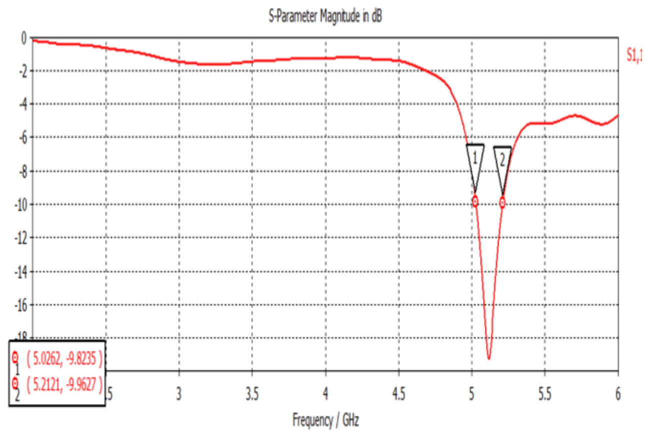

Fig. 3 Frequency and return loss for Iteration 1

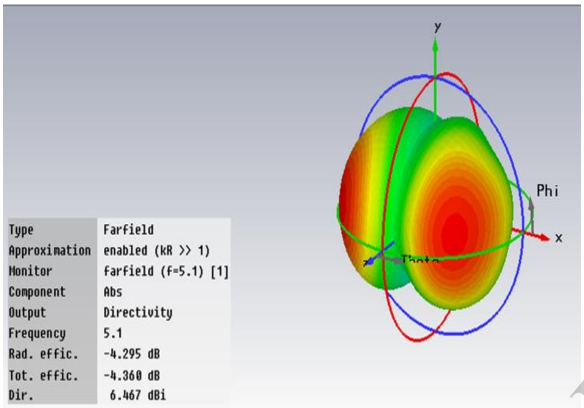

Fig. 4 Radiation Pattern for Iteration 1

B. *Iteration2*

The centre frequency obtained for the iteration 2 is 5.1GHz which has the return loss of -12.1db. The antenna produces a gain of 7.847dbi and bandwidth of about 180MHz Fig. 5. The gain of the iteration2 is shown in Fig .6.

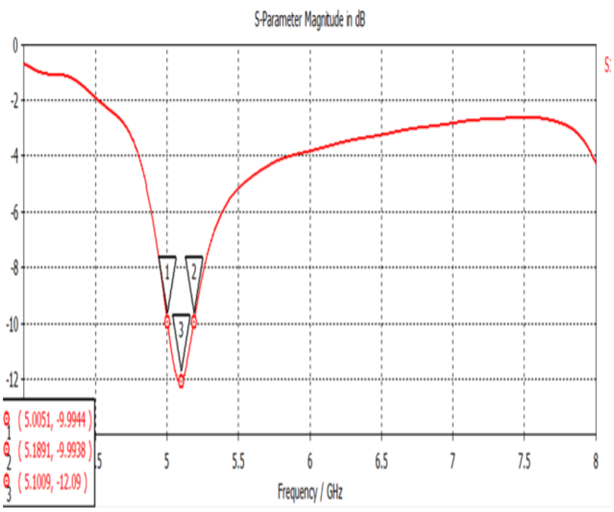

Fig. 5 Frequency and return loss for Iteration 2

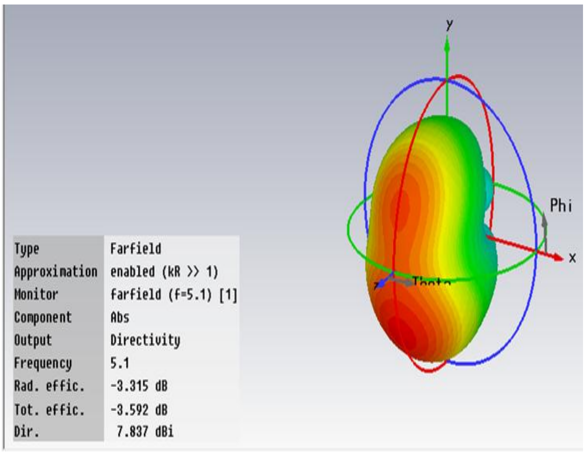

Fig. 6 Radiation Pattern for Iteration 2

C. *Iteration3*

The centre frequency obtained for the iteration 3 is 5.6 GHz which has the return loss of -20.38db. The antenna produces a gain of 8.909dbi and bandwidth of about 146Mhz Fig. 7 The gain of the iteration3 is shown in Fig. 8.

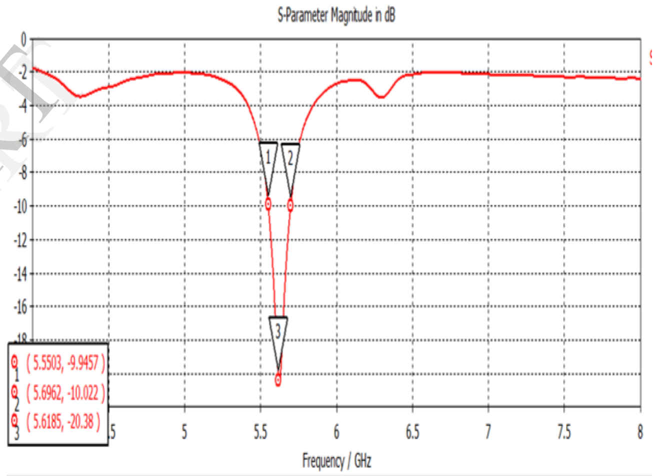

Fig. 7 Frequency and return loss for Iteration 3

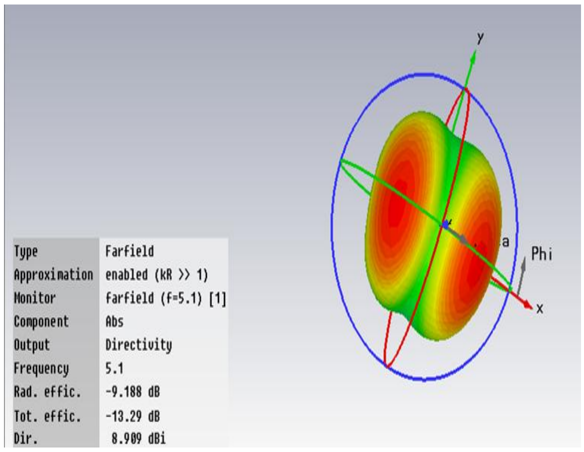

Fig. 8 Radiation Pattern for Iteration 3

The results of various iteration are grouped and compared in the Table III

TABLE III

COMPARISON OF ANTENNA PARAMETERS FOR ITERATIONS

Iterations	Centre frequency (GHz)	Gain (dbi)	Band Width (MHz)	Return loss (db)
Iteration1	5.115	6.467	186	-19.242
Iteration2	5.1	7.837	180	-12.1
Iteration3	5.6	8.909	146	-20.38

CONCLUSION

Sierpinski gasket fractal antenna was designed and the various values for several iterations were examined and compared with each other. The desired increment in the gain is achieved.It resulted in a small size antenna which is a major factor to be considered. This antenna is in the 5GHz(5.1-5.8GHz) range and can be used for all WLAN applications.

REFERENCES

1. Lale, A.A.; Khiste, B.V.; Burshe, G.; Khobragade, S., "Study of Sierpinski triangle gasket," *Electronics Computer Technology (ICECT), 2011 3rd International Conference on* , vol.3, no., pp.386,390, 8-10 April 2011
2. Ismail, K.; Ishak, S.H., "Sierpinski gasket fractal antenna with defected ground structure (DGS)," *ICT Convergence (ICTC), 2012 International Conference on* , vol., no., pp.441,446, 15-17 Oct. 2012
3. Jian-gang Liang; Cheng Zhou; Cheng-li Fan, "Sierpinski triangle monopole antenna with CSSR-based ground plane for WLAN applications," *Microwave and Millimeter Wave Technology (ICMMT), 2012 International Conference on* , vol.4, no., pp.1,3, 5-8 May 2012
4. Franciscatto, B. R.; Vuong, T.-P.; Fontgalland, G., "High gain Sierpinski Gasket fractal shape antenna designed for RFID," *Microwave & Optoelectronics Conference (IMOC), 2011 SBMO/IEEE MTT-S International* , vol., no., pp.239,243, Oct. 29 2011-Nov. 1 2011
5. Baliarda, C.P.; Borau, C.B.; Rodero, M.N.; Robert, J.R., "An iterative model for fractal antennas: application to the Sierpinski gasket antenna," *Antennas and Propagation, IEEE Transactions on* , vol.48, no.5, pp.713,719, May 2000
6. J. Soler and J. Romeu, "Generalized Sierpinski fractal antenna," IEEE Trans. Antennas Propagat., vol. 49, pp. 1237–1239, Aug. 2001.
7. Douglas H. Werner and SumanGangguly, "An Overview of FractalAntenna Engineering Research," *IEEE Antennas and PropagationMagazine,* Vol. 45, No.1, February 2003.
8. FerchichiAbdelhak, SbouiNoureddine, Gharssallah Ali, "AnElectrical Model to Sierpinski Gasket Patch Antenna," *Fifth AdvancedInternational Conference on Telecommunications, IEEE,* 2009.
9. R. L. Yadava, M. Ram and S. Das, " Multiband Triangular FractalAntenna For Mobile Communications," *International Journal ofEngineering Science and Technology*, Vol. 2(11), 2010.
10. Ji-Chyun Liu, Bing-HaoZeng, Hung-Lin Chen, Sheau-ShongBor,and Dau-Chyrh Chang.: 'Compact fractal antenna withself-complementary Hilbert curves for WLAN dual-band andcircular polarization applications', Microwave and OpticalTechnology Letters, 2010, 52, (11) pp. 2535-2539.
11. A. Ando et al..: '2.4/5-GHz dual-band horizontally polarizedomni-directional antennas for IEEE 802.11n WLAN base station',APS'2007, 2007, pp. 2057-2060.
12. Joan Gemio, JosepParrón Granados, and JordiSolerCastany.:'Dual-Band Antenna With Fractal-Based Ground Plane forWLAN Applications', IEEE Antennas and wireless propagationletters, 2009, 8, pp.748-751.
13. C. Puente, J. Romeu, R. Pous, and A. Cardama, "On the behaviorof the Sierpinski multiband antenna," *IEEE Trans. AntennasPropagat.*, vol.46, pp. 517–524, Apr. 1998.
14. S.R. Best, "The Koch Fractal Monopole Antenna: The significantof fractal geometry in determining antenna performance,"Technical Report. Manchester, NH: Cushcraft Corporation, 2005.
15. C. Borja, G. Font, S. Blanch, and J. Romeu, "High directivity fractal boundary microstrip patch antenna," *Electron.Lett.*,vol. 36, no. 9, pp. 778–779, Apr. 27, 2000.