Design and Simulation of Compact Multiband Fractal Microstrip Antenna for Radar and Satellite Applications

Puneeth Kumar T R
Assistant Professor
Department of Telecommunication Engineering
Siddaganga Institute of Technology
Tumakuru, India

Abstract—*This paper presents multiband I shaped fractal patch antenna. There are three iterations have been applied one by one on square patch which results in fractal patch antenna which resonates at 4.7 GHz, 6.4 GHz, 7.5 GHz, 8.4GHz and 9.18GHz respectively with bandwidth of 200 MHz, 100 MHz, 400MHz, 150MHz and 350 GHz at corresponding frequencies. This antenna finds applications for defense and secures communication, C band (4 GHz to 8 GHz) and X band (8 GHz to 12 GHz) applications where antenna can be used for satellite communication and RADAR application. Proposed antenna is designed using IE3D and results are analyzed in terms of return loss, bandwidth and VSWR.*

Keywords- I shape, Fractal, Patch antenna, Multiband, IE3D electromagnetic solver.

I. INTRODUCTION.

With the huge advancement in wireless communication systems and increasing its applications, multiband antenna with various shapes and design have become a great demand and desirable for various wireless applications, which gives raise to different shapes and types of antenna for the variations in antenna characteristic. There are different shapes and types of antennas designed for the variations in antenna characteristics. There are various shapes such as sierpinski, gasket, minskowsi, Hilbert curve; Koch curve, tree structure, etc are considered for the design of Fractal technique has got numerous applications in the field of science which includes fractal electro dynamics where the fractal concepts are combined with electromagnetic theory. Fractal antenna engineering focuses on two areas one is the design and analysis of fractal elements and other concerns to the application of the fractal theory to the design of antenna arrays. Both the antenna types are highly desired in various commercial and military sectors. Most of the fractal antenna elements possess compact size, low profile, cost effective, multi-band operations, easy feeding and their shape can be modified for better optimization. The fractal geometries feature two properties self-similarity and space filling properties. Both these properties become a reason attractive to consider fractal geometry. Similarity of antenna holds the duplication of itself at several scales and can operate at several wavelengths in similar fashion, which reduces the antenna size and occupies lesser space. The space filling property fill the area occupied by the fractal antenna as the number of iteration is increased. Higher the order of fractal antenna, lesser the antenna size .This reason makes the fractal antennas compact, multiband and use full for cellular applications and microwave applications.

In this paper I shaped fractal antenna is considered. This antenna finds applications for defense and secures communication, C band (4 GHz to 8 GHz) and X band (8 GHz to 12 GHz) applications where antenna can be used for satellite communication and RADAR application The length and width of the patch antenna are calculated by the following equations [4]. Where c is the velocity of light and εr dielectric constant of the substrate.

II. PATCH ANTENNA DESIGN EQUATIONS.

1. Calculation of width: The width of the microstrip patch antenna is given by the equation as,

$$W = \frac{c}{2f[\frac{\varepsilon r+1}{2}]^{.5}}$$

2. Calculation of effective dielectric constant:

$\varepsilon_{reff}=\left(\frac{\varepsilon_r+1}{2}\right)+\left(\frac{\varepsilon_r-1}{2}\right)[1+{}^{10h}/_{w}]^{1/2}$

3. Calculation of effective length:

$$L_{eff}=\frac{c}{2f_o\ (\varepsilon_{reff})^{1/2}}$$

4. Calculation of length extension:

$$\frac{\Delta l}{h}=0.412\frac{\left(\varepsilon_{reff}+0.300\right)\left({}^{w}/_{h}+0.262\right)}{\left(\varepsilon_{reff-0.258}\right)\left({}^{w}/_{h}+0.813\right)}$$

5. Calculation of actual length of the patch:

$$L=L_{eff}-2\Delta L.$$

6. Calculation of ground plane dimensions (Lg and Wg): Ideally the ground plane is assumed to be infinite size in length and width but practically it is impossible to make such infinite size ground plane. So to calculate the length and width dimensions of the ground plane following equations are used.

$$L_g=L+6h,\quad W_g=W+6h.$$

III. LITERATURE SURVEY

A dual frequency antenna [1] was obtained by replacing a segment of a square ring microstrip antenna with fractal Minkowski curve. To control resonant characteristics, width of two sides had been increased. Stacked fractal antenna [2] for reducing radio interference had been proposed for GPS application using fractal geometry. In this two antennas with different radiation pattern were stacked one over other. A novel and compact printed monopole antenna [3] was presented with simple but radiating patch for multiple wireless communication systems and mobile devices. Multiband operation with circular polarization [4] of radiation was obtained by combining square and Giuseppe Peano fractal geometries, which were realized on two layer microstrip antenna. A novel CPW [5] feed inscribed triangle circular fractal patch antenna had been proposed. Proposed monopole fractal antenna offered UWB (Ultra Wideband) characteristics from 2.25 GHz to 15 GHz at VSWR 2:1. A compact, low profile and low cost self-affine antenna [6] with wideband characteristics for wireless applications had been proposed using cantor fractal geometry. Proposed antenna had a gain of 5.04 dB at 2.5 GHz. A novel microstrip fed antenna [7] design based on monopole patch for triple frequency operation had been presented using DGS (Defected Ground Structure). A novel microstrip fed ultra wideband printed Pythagorean tree [8] fractal monopole antenna had been presented. By only increasing tree fractal iterations, new frequency bands were obtained. A monopole square patch antenna [9] was introduced by shaping its edges in form of Giusepe Peano fractal and its surface area in form of Sierpinski carpet fractal. It found application for UWB and WLAN (Wireless Local Area Network). New design to suppress harmonic radiation [10] from microstrip antenna with proximity coupled feeding line had been implemented in multilayer substrate. Microstrip line fed printed wide slot antenna with a fractal shaped slot [11] for bandwidth enhancement by etching wide slot was proposed and experimentally studied. A Novel technique to reduce the size of microstrip patch antenna was proposed. By etching the patch edges according to Koch curve and inserting Sierpinski carpets into patch, it was found that resonant frequency of antenna get reduced. A wideband vertical patch antenna was depicted from fractal antenna concept. By using a dual Koch loop structure, a wideband antenna with 42% bandwidth and 8 dBi gain at center frequency was obtained. Koch iteration technique had been applied to obtain two fractal versions of folded slot antenna [12]. A Broadband Planar Sierpinski fractal antenna for multiband application was proposed. Fractal geometry and slotted ground had been used to obtain broadband characteristics.

IV. IMPLEMENTATION

By applying fractal geometry on the patch, area of patch decreases and resonant length increases. Figure 1 given below shows Minkowski fractal geometry algorithm [1].

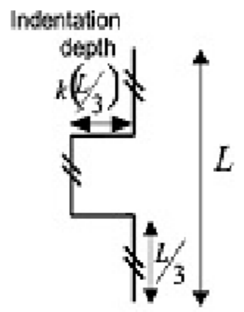

Figure 1. Minkowski Fractal Geometry

This algorithm has been applied to square as shown in figure 2. By Dividing square of length 37.6218 mm into three equal parts of 12.5406 mm each and by cutting 2 squares of 12.5406 mm length from parallel sides, I shape patch as shown in figure 3 has been formed. The table I mentioned below shows the dimensions of proposed I shape fractal antenna. The substrate material Rogers RTDuroid/5880 with dielectric constant of 2.2 and loss tangent of 0.0009 has been used. A Coaxial feed with feed point coordinates (16.7, 16.7, 0) are selected in such way that impedance matching takes place.

TABLE I: PROPOSED ANTENNA DIMENSIONS

Parameter	value
Length of patch	37 mm
Width of patch	37 mm
Thickness of Substrate	2.6 mm
Dielectric constant of substrate	2.2
Loss tangent of the substrate	0.0009
Feed to the patch	Co-axial feed

The three iterated fractal geometries are as shown in figure 3, 4 and 5. Initially a square patch having a length of 37.6218 mm is taken as shown in figure 2 and coaxial feed has been applied to it. Feed point (16, 13, 0) is chosen in such a way that impedance matching take place.

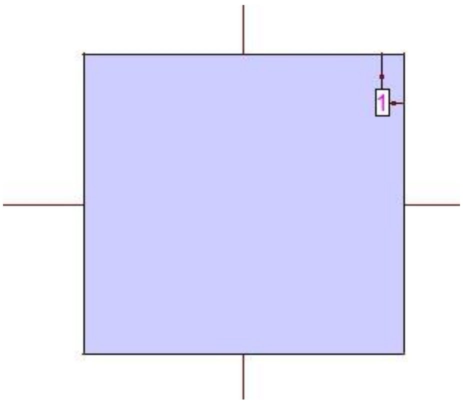

Figure2. Basic square patch geometry

I shape patch with first iteration is shown below in figure 3.The vertical length of 37.6218 mm is divided into 3 parts each of length 12.5406 mm. Two square cuts of 12.5406 mm length are made in center of both sides to make I shape. By doing this area will get minimized.

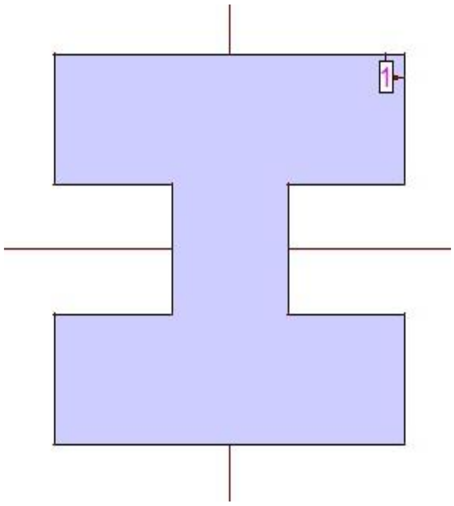

Figure3. First iteration on basic patch geometry

In the 2nd iteration same algorithm has been applied and modified I-shaped patch has been obtained by removing 2 squares of length 4.1802 mm from each square of length 12.5406 mm. Hence self-similar shape as shown in figure 4 has been obtained.

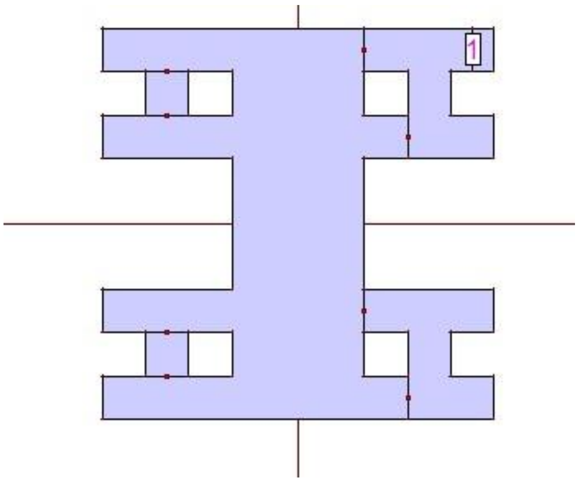

Figure4. Second iteration on basic patch geometry

By applying 3rd iteration further the patch has been modified by removing 2 squares of length 1.3934 mm from each square of length 4.1802 mm. Hence geometry as shown in figure 5 has been obtained. It can be clearly seen from figure 5 that I shape repeats itself. Hence it is called a self-similar structure.

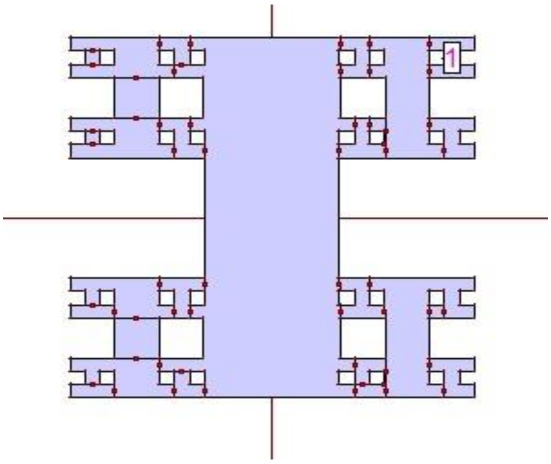

Figure5. Third iteration on basic patch geometry

From above it is observed that by applying fractal geometry on square patch, effective area decreased and resonant length gets increased which results in better characteristics.

V. RESULTS AND DISCUSSION

After application of three iterations of fractal geometry on square patch of length 37.6218 mm using Rogers RT duroid-5880 as a substrate of thickness 2.6 mm I-shaped fractal microstrip patch geometry has been formed. Antenna as shown in figure 2 resonates at 5.89 GHz, with a return loss of -13.87 dB, VSWR of 1.5 and 245 MHz bandwidth. Different iterations of fractal geometries have been applied one by one on square patch and results are analyzed as shown in table II. Figure 6 and 7 shows return loss Vs frequency graph and VSWR Vs frequency for 3rd iterated fractal patch geometry.

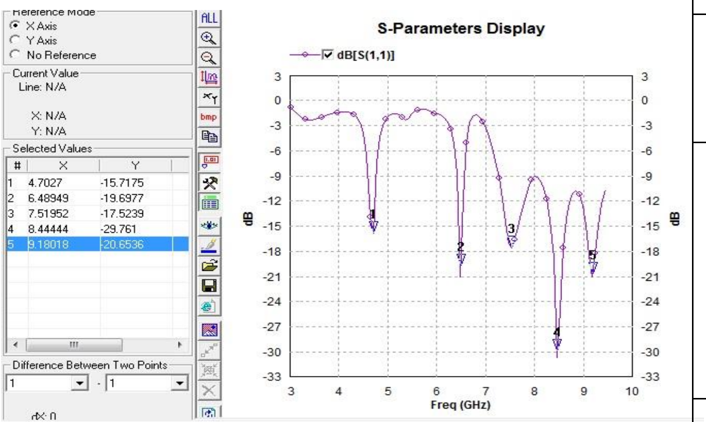

Figure6. Return loss vs. frequency plot for 3rd iteration patch geometry.

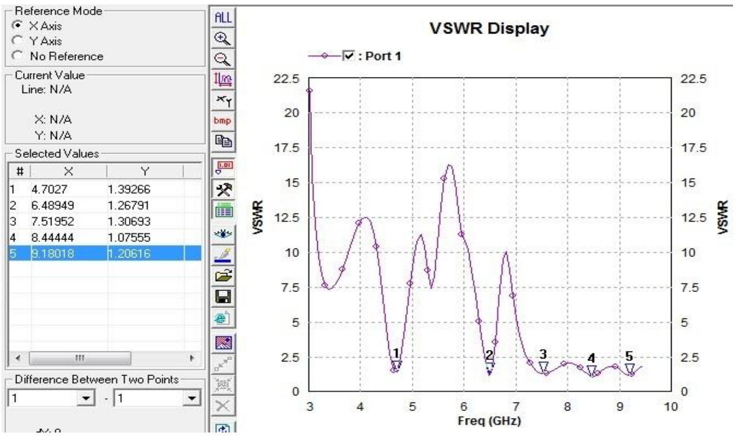

Figure7. VSWR vs. frequency plot for 3rd iteration patch geometry.

In this study bandwidth values are obtained between points where -3 dB return loss line cut the curve between return loss and frequency. From radiation patterns as shown in figure 8, 9 10 and 11 it is clear that this antenna has maximum energy radiated in main lobes and small amount of energy is radiated in minor or side lobes. Figure 8, 9 10 and 11 shows radiation pattern corresponding to that at frequency of 6.4 GHz, 7.5 GHz, 8.4 GHz and 9.1GHz.

Table II: Comparison table for different fractal iterations

Iteration	Frequency(GHz)	Return loss(dB)	VSWR	-3dB Bandwidth(MHz)
0	5.89	-13.88	1.5	245
1	4.68	-15	1.43	110
	5.51	-14	1.49	250
2	4.7	-20	1.23	150
	6.48	-30.3	1.07	120
	7.51	-16.53	1.35	500
	8.44	-41.75	1.01	50
3	4.7	-15.71	1.39	200
	6.48	-19.69	1.26	100
	7.51	-17.52	1.30	400
	8.44	-29.76	1.07	150

	9.18	-20.65	1.2	350

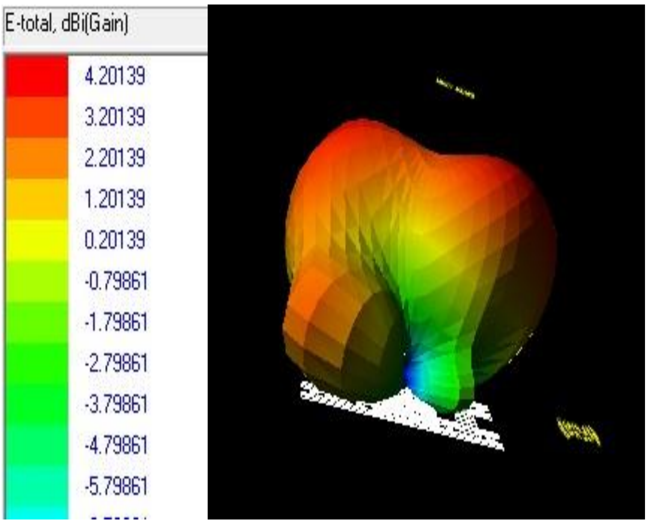

Figure8. Radiation Pattern at 6.48 GHz

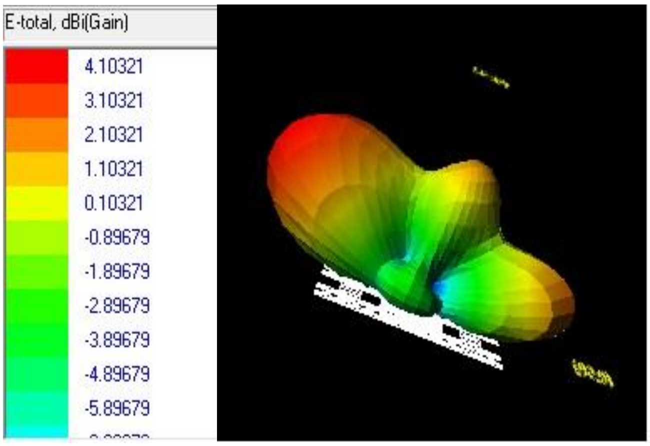

Figure9. Radiation Pattern at 7.51 GHz

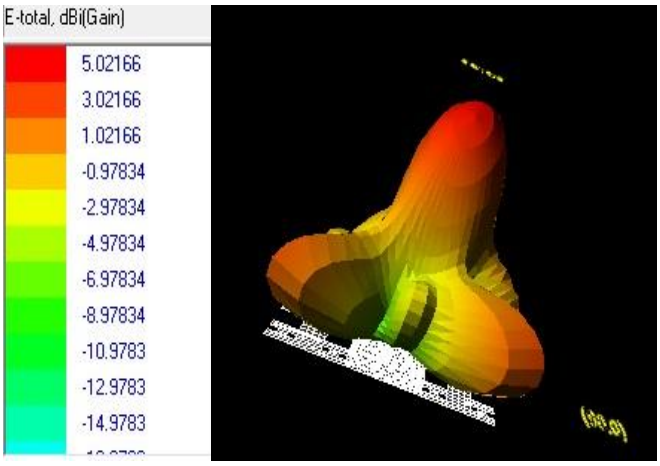

Figure10. Radiation Pattern at 8.44 GHz

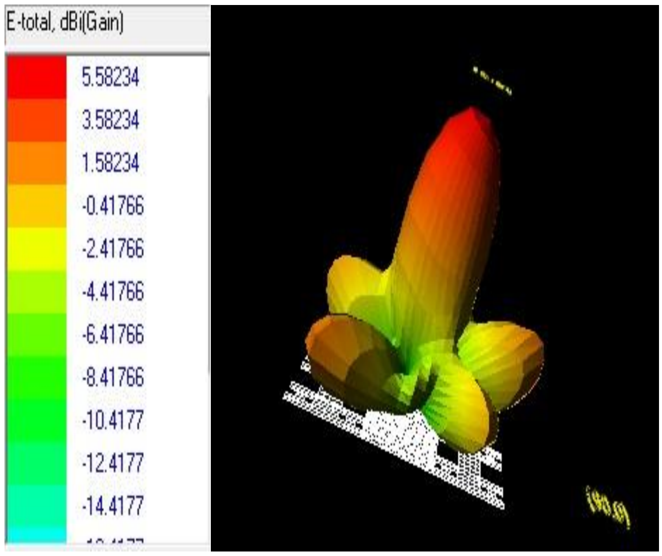

Figure11. Radiation Pattern at 9.18 GHz

VI.CONCLUSION

From above discussions it has been concluded that by applying different iterations of fractal geometry, characteristics of antenna improve a lot. Initially square patch is taken and antenna resonates at single band. By applying three iterations of fractal geometry, number of bands increase from one to five. Further by applying fractal geometry effective area has been decreased and gain and bandwidth gets increased. Proposed antenna finds application for defense and secure communication, C band and X band applications. In these bands antenna can be used for satellite communication and RADAR applications. This antenna has a bandwidth of 500MHz at 7.51 GHz band and 350 MHz at 9.18 GHz. In future defected ground structure can be applied to this antenna which may improve further characteristics of antenna.

REFERENCES

[1]. Rajeev Shankar Pathak, Vinod Kumar Singh, Shahanaz Ayub, "Dual Band Microstrip Antenna for GPS/ WLAN/ WiMAX Applications", IJETED, ISSN: 2249-6149, Issue 2, Vol. 7, November 2012.

[2]. Behera Subhrakanta and Vinoy K. J., 2012. "Multi-Port Network Approach for the Analysis of Dual Band Fractal Microstrip Antennas", IEEE Transactions on Antennas and Propagation, Vol. 60, No. 11, pp 5100-5106

[3]. Carlos Puente-Baliarda, Jordi Romeu, Rafael Pous and Angle Cardama, (1998). "On the Behaviour of the Sierpinski Multiband Fractal Antenna", IEEE Transaction on Antennas and Propagation Letters, Vol. 46, No. 4.

[4]. Liu Wen-Chung, Wu Chao-Ming and Dai Yang, 2011. "Design of Triple-Frequency Microstrip-Fed Monopole Antenna Using Defected Ground Structure", IEEE Transaction on Antennas and Propagation, Vol. 59 No. 7, pp 2457-2463

[5]. N.Cohen, "Fractal Antenna Applications in Wireless Telecommunications", in *Professional Program Proc. of Electronic Industries Forum of New England,* IEEE, pp.43-49, 1997.
[6]. Pourahmadazar Javad, Ghobadi Changiz and Nourinia Javad, 2011.m "Novel Modified Pythagorean Tree Fractal Monopole Antennas for UWB Applications", IEEE Antennas and Wireless Propagation Letters, Vol.10, pp 484-487
[7]. Oraizi Homayoon and Hedayati Shahram, 2011. "Miniaturized UWB Monopole Microstrip Antenna Design by the Combination of Giusepe Peano and Sierpinski Carpet Fractals", IEEE Antennas and Wireless Propagation Letters, Vol.10, pp 67-70
[8]. Sanchez Luis Inclan, Vazquez-Roy Jose Luis and Iglesias Eva Rajo, 2009. "Proximity Coupled Microstrip Patch Antenna With Reduced Harmonic Radiation", IEEE Transaction on Antennas and Propagation, Vol. 57, No. 1, pp 27-32
[9]. Best, S.R. (2005). "The Koch Fractal Monopole Antenna: The Significant of Fractal Geometry in Determining Antenna Performance." Technical Report. Manchester, NH: Cushcraft Corporation.
[10]. Chen Wen-Ling, Wang Guang-Ming, and Zhang Chen-Xin, 2008. "Small-Size Microstrip Patch Antennas Combining Koch and Sierpinski Fractal-Shapes", IEEE Antennas and Wireless Propagation Letters, Vol.7, pp 738-741
[11]. Sweety Jain, Pankaj Singh Tomar, G.S.Tomar, "Design & Analysis of Proximity Fed Circular Disk Patch Antenna", International Journal of Emerging Technology and Advanced Engineering Volume 2, Issue 10, pp 126-131, October 2012.
[12]. Wong T. P., Lau Carmen K. L., Luk Kwai Man and Lee Kai-Fong, 2007. "Wideband Fractal Vertical Patch Antenna", IEEE Antennas and Wireless Propagation Letters, Vol.6, pp 5-6
[13]. Balanis, C.A. (1997). "Antenna Theory: Analysis and Design." 2nd ed. New York: John Wiley and Sons, Inc.