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Multiband and Compact Fractal Antenna for Wireless Communication

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ABSTRACT: Antennas with low profile, compact size, multiband are in great insist in modern telecommunication system. Fractal antennas are simple, light weight and compact in size. Sierpinski carpet geometry based rectangular patch fractal antenna is described in this paper. Multiband antenna offers multiple telecommunication services in to single device. This leads to design multiband fractal antenna for wireless communication systems. Here, microstrip line feed method is used to excite the antenna. It is found that increase in number of iterations, number of resonant frequencies increases. This paper presents the design of fractal antennae on FR-4 substrate with dielectric constant 4.4 up to second iteration. The dimension of antennae is 13.5mm x 18mm and operates in frequency band between 4 GHz to 12GHz.

KEYWORDS: Fractal, Sierpinski carpet, Iteration, Multiband ,Compact.

I. INTRODUCTION

According to Webster's Dictionary a fractal is defined as being "derived from the Latin 'fractus' meaning broken, uneven any of various extremely irregular curves or shape that repeat themselves at any scale on which they are examined." Mandelbrot offered the following definition: "A fractal is a shape made of parts similar to the whole in some way" Fractal antennas are based on the concept of a fractal, which is a recursively generated geometry that has fractional dimensions [1]. For most fractals, self-similarity concept can achieve multiple frequency bands because of different parts of the antenna are similar to each other at different scales. The combination of infinite complexity and detail and self similarity makes it possible to design antennas with very wideband performances [2]. Sierpinski carpet fractal antenna is the most widely studied fractal geometry for antenna application. The fractal antenna consists of geometrical shapes that are repeated. Each ones have a unique attributes. The self similarity that distributed on this antenna expected to cause its multi-band characteristic. On the others hand its can solve a traditional antenna that operate at single frequency [3]. Sierpinski fractal antennas shows highly desirable properties, including the compact size It is found that the size reductions of the K-Sierpinski carpet fractal antennas are almost determined by K-value and have a little relationship with the size of the antennas.[4]

II. RELATED WORK

M.F.Abd.Kadir, A. S.Ja'afar, M. Z. A. Abdul Aziz.[3] has been obtained multiband frequencies 1.63 GHz,4.99 GHz,5.45 GHz,7.68 GHz,8.68 GHz and 9.99 GHz up to second iteration for the range 1GHz to 10 GHz. Yin-kun Wang, Jian-shu Luo and Ying Li Elissa [4] has been presented a general K-sierpinski carpet fractal and its IFS codes. They found that reduction of K-sierpinski carpet fractal antenna are determined by K which helps to design compact antenna. M. K. A. Rahim, M. Z. A. Abdul Aziz, and N. Abdullah [5] has been obtained wideband operation sierpinski carpet monopole antenna with dimension 38mm x 38mm which covers frequency range from 2-10 GHz. R.Mohanamurali, T.Shanmuganantham[7] presented multiband antenna 1.8,5.59,5.78,6.4,6.63,7.84 GHz with dimension 37mm x 37mm. After this literature survey in this paper the design of multiband and compact fractal antenna with dimension 13.5mm x 18 mm is presented.

III. ANTENNA DESIGN

The proposed antenna is designed with basic rectangular patch with dimensions length of 13.5 mm and width 18 mm FR-4 substrate with dielectric constant 4.4 and loss tangent of 0.019.Height of substrate is 1.5 mm, resonant frequency 5GHz.Then fractal antenna is designed up to second iteration. Microstrip line feed is used to excite the antenna. The feed point must be located at that point where input impedance is of 50 Ohm for resonant frequency. Therefore a trial and error method is used to locate feed point. The design steps are as follows

1. Calculation of the Width (W): The width of the Microstrip patch antenna is given by[5][6] equation.

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

$$c = 3\times10^8 m/s$$

$$\varepsilon_r = 4.4$$

$$f_o = 5GHz$$

$$W = 18.25mm$$

2. Calculation of Effective dielectric constant (ε_{reff})

$$\varepsilon_{reff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left[\frac{1}{\sqrt{1+\frac{12h}{W}}}\right]$$

$$h = 1.5mm$$

$$\varepsilon_{reff} = 3.90$$

3. Calculation of the Effective length (L eff)

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

$$L_{eff} = 15mm$$

4. Calculation of the length extension (ΔL)

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left[\frac{W}{h}+0.262\right]}{(\varepsilon_{reff}-0.258)\left[\frac{W}{h}+0.813\right]}$$

$$\Delta L = 0.68mm$$

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5. Calculation of actual length of patch (L)

$$L = L_{eff} - 2\Delta L$$
$$L = 13.6mm$$

6. Calculation of the ground plane dimensions (L_g and W_g)

$$L_g = 6h + L$$
$$L_g = 22.6mm$$
$$W_g = 6h + W$$
$$W_g = 27.2mm$$

For simplicity, the length and the width of the Rectangular patch and the ground plane have following values L = 13.5mm, W = 18 mm, L_g = 22.5 mm, W_g= 27 mm

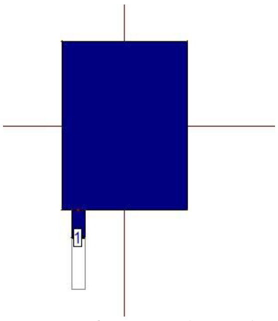

Fig.1 Geometry of Rectangular patch antenna

7. First Iteration [3][7][8]

For first iteration the basic rectangular patch is divided by 9 smaller rectangle and removed the middle rectangle from it so the remaining rectangle is 8, by taking scale factor L_1 =1/3
The area of Basic Rectangular patch antenna is

A=13.5mm x18mm =243 mm^2

The length L and width W of small rectangular patch can be determined as

L_2 = 13.5mm x L_1

L_2 = 13.5mm x 1/3= 4.5mm

W_2 =18mm x L_1

W_2 =18mm x 1/3= 6mm

Area for small rectangle is 4.5mm x 6mm =27 mm^2

Total area becomes after first iteration

A_1 =243 mm^2 - 27 mm^2 =216 mm^2

Total area in Percentage = $\frac{216}{243} \times 100 = 88.88\%$

Area reduced after first iteration is 100-88.88 = 11.12%

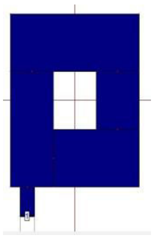

Fig.2 First iteration fractal antenna

8. Second Iteration [3][7][8]

For Second iteration the remaining 8 rectangular Patch is divided by 9 smaller rectangles and removed the middle rectangle from all so the remaining rectangles are 64, by taking scale factor L_3 =1/3.
The area of small Rectangular patch antenna is

A_3 = 4.5 mm x 6 mm =27 mm^2

The length L_4 and width W_4 of removed small Rectangular patch can be determined as

L_4 = 4.5mm x L_3

L_4 = 4.5mm x 1/3= 1.5 mm

W_4=6mm x L_3

W_4 =6mm x 1/3= 2mm

Area of removed small rectangle is 1.5mm x 2mm = 3mm^2

Area remaining for one rectangle after Second Iteration is 27 mm^2 - 3 mm^2 =24 mm^2

Total area remaining for 8 rectangle after Second Iteration A_4 = 8 x24 mm^2 =192 mm^2

Overall area in percentage = $\frac{192}{243} \times 100 = 79\%$

Area reduced after Second iteration is 100-79 = 21%

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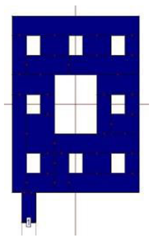
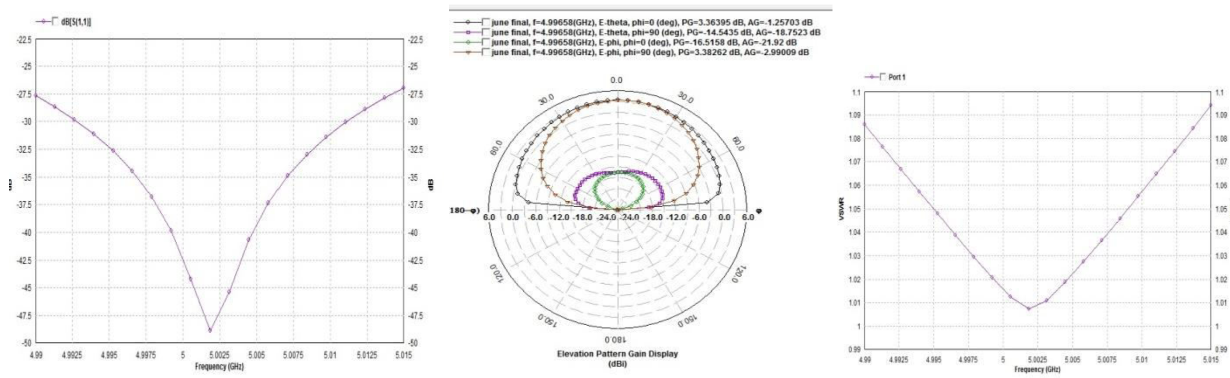


Fig.3 Second iteration Fractal antenna

IV. SIMULATION RESULTS

The results for designed antenna are shown in figure 4,5,6,7 and table from 1 to 7. The result includes return loss, radiation pattern and VSWR for rectangular patch, first iteration fractal antenna and second iteration fractal antenna.



(a) (b) (c)

Fig. 4. Rectangular Patch Antenna (a) Return loss (b) Radiation Pattern 2D (c) VSWR

Table 1 Return loss of Rectangular patch antenna

Freq(GHz)	dB[S(1,1)]
5.001	-48.87

Table 2 VSWR for Rectangular patch antenna

Freq(GHz)	Port 1
5.001	1.007

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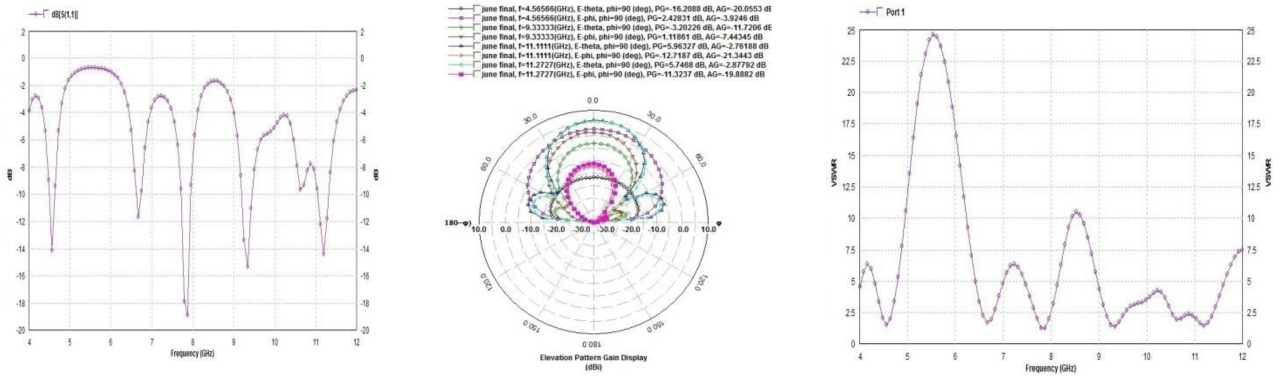


(a) (b) (c)

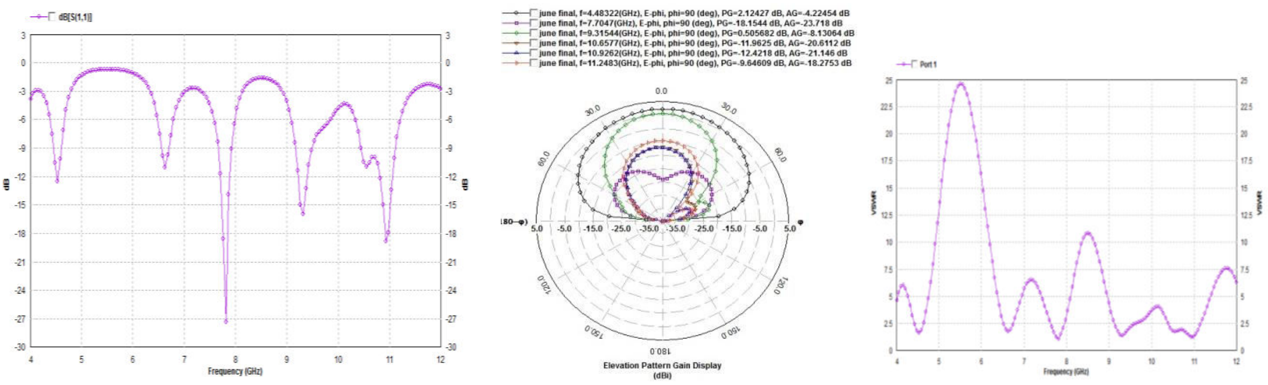
Fig. 5. First Iteration (a) Return loss (b) Radiation Pattern 2D (c) VSWR

Table 3 Return loss for first iteration

No.	Freq(GHz)	dB[S(1,1)]
1	4.565	-14.132
2	6.666	-11.684
3	7.878	-18.870
4	9.333	-15.328
5	11.191	-14.380

Table 4 VSWR for first iteration

No.	Freq(GHz)	Port 1
1	4.565	1.489
2	6.666	1.704
3	7.878	1.257
4	9.333	1.413
5	11.191	1.472



(a) (b) (c)

Fig. 6. Second Iteration (a) Return loss (b) Radiation Pattern 2D (c) VSWR

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Table 5 Return loss for Second iteration

No.	Freq(GHz)	dB[S(1,1)]
1	4.53	-12.50
2	6.63	-11.02
3	7.81	-27.37
4	9.31	-15.93
5	10.55	-10.99
6	10.92	-18.85

Table 6 VSWR for Second iteration

No.	Freq(GHz)	Port 1
1	4.53	1.621
2	6.63	1.781
3	7.81	1.089
4	9.31	1.379
5	10.55	1.785
6	10.92	1.257

Table 7 Comparison of simulated results

Iteration	Frequency Bands (GHz)	Gain(dBi)	Area reduced after Iteration
Rectangular patch	5GHz	3.4	-
1^{st}	4.56,6.66, 7.87,9.33, 11.19	6.3	11.12%
2^{nd}	4.53,6.63, 7.81,9.31, 10.55,10.92	6.3	21%

V. CONCLUSION

In this paper antenna has been designed and simulated for wireless communication with a range of frequency 4GHz to 12GHz. The multiband frequencies obtained up to second iteration after applied fractal geometry. The size of antenna is reduced by 21% at second iteration as compared to rectangular patch antenna. The VSWR is between 1 to 1.8.Hence the proposed antenna is multiband and compact enough to be placed in wireless devices.

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