Effect on Multiband Behavior of Square Fractal Dipole Antenna with the Variation of Angle between Square Fractals

Rajni Bala, Jaswinder Singh

***Abstract-** In this paper the design of square shape multiband dipole antenna using fractal geometry is described. The fractal antenna has been designed on substrate FR-4 having thickness h=1.4mm, ϵ_r= 4.4 with dimension 70×35mm. Ansoft HFSS software has been used to design and simulate the antenna. The antenna exhibit multiband resonances due to the self similarity in its structure. Firstly antenna was designed up to fourth iteration by keeping angle of 45^0 between adjacent squares. The experimental result indicates that the antenna resonates at six frequencies 0.75GHz, 2.15 GHz, 3.35 GHz, 4.65 GHz, 5.95 GHz and 7.25 GHz. It is observed that the multiband behavior of antenna is affected by the variation in angle between adjacent square fractals. In same design when angle between adjacent square fractals is reduced up to 10^0 the resonance frequencies also get reduced up to three, but at these three resonant frequencies the percentage of bandwidth get increased which means antenna shows wideband behavior.*

***Keywords:** Multiband antenna, Fractal, Resonant frequency*

I. INTRODUCTION

In modern wireless communications with increase in wireless application, there has been an increasing need for multiband, wideband, low profile, more compact and portable communications systems both for commercial and military application. Just as the size of circuitry has evolved to transceivers on a single chip, there is also a need to evolve antenna designs to minimize the size. Generally each antenna operates at single or dual frequency bands. So for different applications we require different antennas which cause space limiting problem. To overcome this we use multiband antenna where single antenna can operate at many frequency bands. Multiband antenna is designed by applying fractal shape into antenna geometry. For efficient radiation the size of antenna should be of the order of half wavelength or larger. But with decrease in antenna size, the gain, bandwidth and radiation efficiency reduces. This is due to the mismatching between source and antenna. As a solution to minimizing the antenna size while keeping high radiation efficiency, fractal antennas can be implemented.

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* Correspondence Author
Rajni Bala, Pursuing M.Tech, Department of Electronics and Communication, Beant College of Engineering and Technology, Gurdaspur, India
Dr. Jaswinder Singh, Associate Professor, Department of Electronics and Communication, Beant College of Engineering and Technology, Gurdaspur, India

The term fractal has its root in Latin word fractus which means broken or irregular fragments were originally coined by Mandelbrot [1] to describe a family of complex shapes that possess an inherent self-similarity in their geometrical structure of science and engineering. Fractals have found widespread applications in several branches of science and engineering described in [2]-[7]. One such area of fractals is in antenna engineering described in [8] [9]. In the recent years several fractal antennas based upon self similarity and space filling property has been designed [10]-[12] which leads to miniaturization of antenna. The geometries characteristics of sierpinski gasket or carpet fractals can be improved to design both monopole and dipole antenna with improved performance described in [13]. The most of the previous fractal antenna design work is focused on monopole antenna [10] [12]. Fractal geometry involves a recursive generating methodology that results in contours with infinitely intricate fine structures. This geometry which has been used to model complex objects found in nature such as clouds, coastlines etc. has space-filling properties that can be utilized to miniaturize antennas. The miniaturization of an antenna can be done using fractals without paying the price to manufacture an infinitely complex radiator [9].

II. ANTENNA DESIGN I

The antenna design I based on fractal geometry with dimension 70×30mm is shown in Figure 1. This fractal antenna has been designed on substrate FR-4 with thickness h=1.4mm and ϵ_r= 4.4. The copper conductor of height 0.01mm is taken and FR4 epoxy is placed over it. After that over the substrate, the square fractal dipole antenna is designed upto four iterations by keeping an angle of 45^0 between adjacent squares. Finally a radiation box is placed over the antenna and the set up is simulated using Ansoft HFSS.

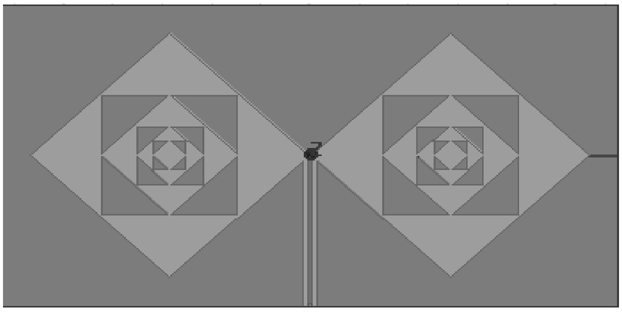

Figure 1: Square fractal dipole antenna design I

"Table 1: Dimensions of square fractals for antenna design I"

Iterations	Side of each square (mm)	Area of square conducting strip
Iteration1	$Sq_1 = 80$ $Sq_2 = 55$	$S_1 = (Sq_1)^2 - (Sq_2)^2$ $S_1 = 3375mm^2$
Iteration2	$Sq_3 = 40$ $Sq_4 = 27$	$S_2 = [(Sq_3)^2 - (Sq_4)^2] + S_1$ $S_2 = 4246mm^2$
Iteration3	$Sq_5 = 20$ $Sq_6 = 13$	$S_3 = [(Sq_5)^2 - (Sq_6)^2] + S_2$ $S_3 = 4507mm^2$
Iteration4	$Sq_7 = 10$	$S_4 = (Sq_7)^2 + S_3$ $S_3 = 4607mm^2$

The square shape antenna geometry is a plane fractal geometry constructed from squares. The fractal antenna design is obtained by subtracting a square after the rotation of 45^0 from the outer square. Different dimensions of square fractals taken in antenna design are given below in Table1.

If a is the side of first outermost square then the side of each odd-number square i.e. third, fifth and seventh square is of the order of $\frac{a}{2^n}$ where n =1, 2, 3 for third, fifth and seventh square respectively. Similarly if b is side of second outermost square $Sq_2 = b$ then $Sq_4 = \left(\frac{b-1}{2}\right)$. Similarly side of Sixth Square $Sq_6 = \frac{Sq_4 - 1}{2}$

III. ANTENNA DESIGN II

Square shaped fractal antenna with dimension $70 \times 35\ mm$ is designed again on same substrate FR-4 with thickness h=1.4mm and ϵ_r= 4.4. Again copper conductor of height 0.01mm is taken for antenna design. In this case an angle difference of 10 degree is kept between each adjacent square fractal. This means the different iterations of fractal antenna are obtained by subtracting a square of area approximately $\frac{1}{2^n}$ of the area of outermost main square, but this time after the rotation of 10^0 from the outer square. The square fractal dipole design II with angle difference of 10 degree between adjacent square is shown in Figure 2. The dimensions of square fractals taken in antenna design II for different iterations are given in Table 2. Each time number of iterations are increased and final simulation results are obtained for fourth iteration.

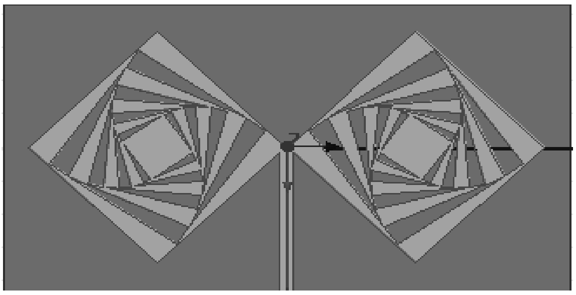

Figure 2: Square fractal dipole antenna design II

Table 2: Dimensions of square fractals for antenna design II

Iterations	Side of each square (mm)	Area of square conducting strip
Iteration1	$Sq_1 = 80$ $Sq_2 = 68$	$S_1 = (Sq_1)^2 - (Sq_2)^2$ $S_1 = 1776mm^2$
Iteration2	$Sq_3 = 59$ $Sq_4 = 50$	$S_2 = [(Sq_3)^2 - (Sq_4)^2] + S_1$ $S_2 = 2757mm^2$
Iteration3	$Sq_5 = 43.5$ $Sq_6 = 36.5$	$S_3 = [(Sq_5)^2 - (Sq_6)^2] + S_2$ $S_3 = 3317mm^2$
Iteration4	$Sq_7 = 32$ $Sq_8 = 26$	$S_4 = (Sq_7)^2 - (Sq_8)^2)^2 + S_3$ $S_3 = 3866mm^2$

IV. EXPERIMENT RESULTS AND DISCUSSION

The square shape fractal dipole antenna design I and antenna design II has been designed and simulated using Ansoft HFSS. After simulation following results were obtained.

A. SIMULATION RESULTS FOR DESIGN I

The antenna was designed for forth iterations shown in Fig4.3 and the set up was simulated. Experimental results shows that square shape antenna exhibit multi resonance frequencies. Square fractal antenna design I resonates at six different frequencies shown in Figure 3 with good value of VSWR and bandwidth. At each frequency value of VSWR was approximately equal to 1 shown in Figure 4. Antenna resonant frequencies with value of return loss and VSWR is shown in Table 3.

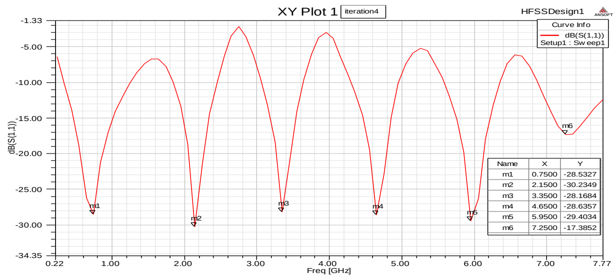

Figure 3: Return loss response of Square fractal dipole antenna Design I

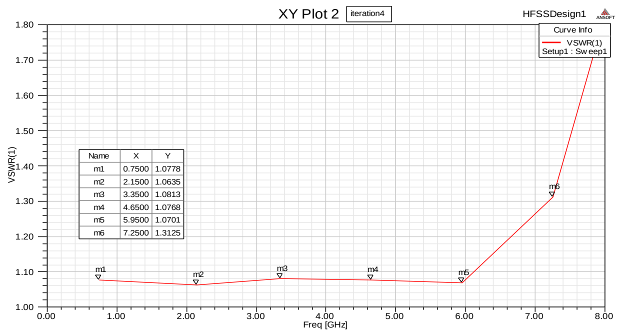

Figure 4: VSWR response of Square fractal dipole antenna Design I

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Table 3: Simulation result Square fractal dipole antenna Design I

Antenna Design II		
Resonant Freq(GHz)	Return Loss dB(S(1,1))	VSWR
0.75	-28.53	1.07
2.15	-30.23	1.06
3.35	-28.16	1.08
4.65	-28.63	1.07
5.95	-29.40	1.07
7.25	-17.38	1.3

The percentage of bandwidth for resonant frequency 0.75GHz, 2.15 GHz, 3.35 GHz, 4.65 GHz, 5.95 GHz and 7.25 GHz were 18%, 11%, 11%, 12%, 17% and 24% respectively. This shows the multiband behavior of antenna.

B. SIMULATION RESULTS FOR DESIGN II

In the square fractal dipole antenna shown in Figure 1, the angle between adjacent squares is 45^0 and after simulation six resonant frequencies were obtained shown in Figure 3. But in this case Square shaped fractal antenna with dimension $70 \times 35\, mm$ is designed again by varying angle between each square fractal by 10^0 instead of 45^0 is shown in Figure 2. Each time number of iterations are increased and simulation results obtained for fourth iteration using Ansoft HFSS is shown in Figure 5.

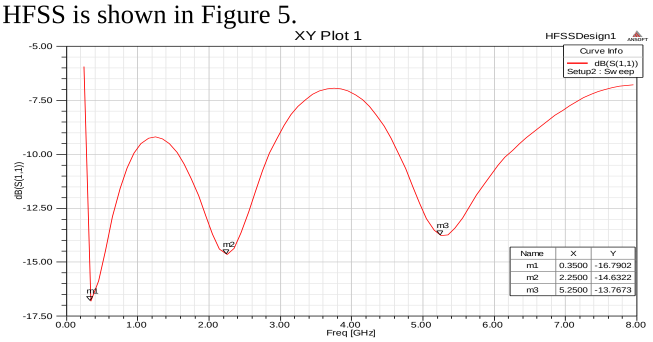

Figure 5: Return loss response of Square fractal dipole antenna Design II

The simulation result of Square fractal dipole antenna Design II shows that the antenna resonate at three frequencies 0.35GHz, 2.25 GHz, and 5.25 GHz shown in Figure 5. The percentage of bandwidth at 0.35GHz, 2.25 GHz, and 5.25 GHz are 14%, 25% and 33% respectively. Hence the percentage bandwidth obtained at different resonant frequencies is wide as compare to bandwidth obtained in Square fractal dipole antenna design I. It means this antenna design II can be used as wide band applications. The radiation pattern at resonance frequencies 0.35GHz, 2.25 GHz, and 5.25 GHz are shown in Figure 6(a), Figure 6(b) and Figure 6(c)

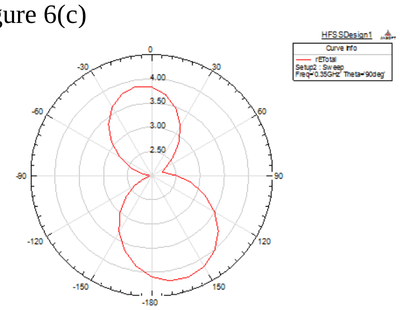

Figure 6(a): Radiation pattern at frequency 0.35GHz when $\theta = 90^0$

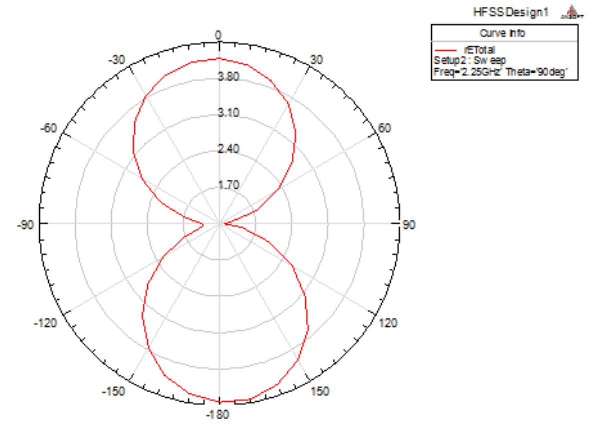

Figure 6(b): Radiation pattern at frequency 2.25GHz when $\theta = 90^0$

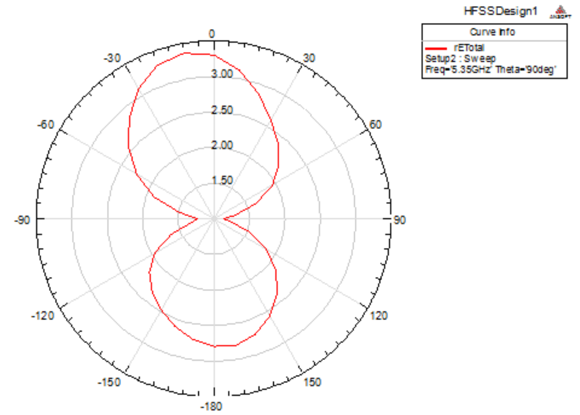

Figure 6(c): Radiation pattern at frequency 5.35GHz when $\theta = 90^0$

V. CONCLUSION

Antenna technology has being revised to fulfil demands imposed by the modern wireless systems, because conventional antenna technology can no longer meet future challenges. Fractal technology allows for design of smaller high-performance, with improved VSWR, multiband/wideband antennas.

It is also observed that the multiband behaviour of antenna is affected by the variation of angle between each square fractal. In antenna design when angle between adjacent squares was 45^0 then it shows multiband behavior by giving six resonant frequencies but when angle between each square fractal is reduced to 10^0 then antenna shows wideband behaviour for same iterations by giving three resonant frequencies with wide band. Hence same design can be used for multiband and wideband applications by just varying the angle between adjacent squares.

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AUTHOR PROFILE

Rajni Bala received her BTech. Degree in Electronics and communication from Sri Sukhmani Institute of Engineering Technology, Derabassi under Punjab Technical University Jalandhar. Presently she is pursuing M.Tech in Electronics and communication from Beant College of Engineering and Technology, Gurdaspur and also working as Assistant Professor in ECE department at Bhai Gurdas Institute of Engineering and Technology, Sangrur.
Email: er.rajni12@gmail.com

Dr. Jaswinder Singh is working as Associate Professor in ECE department at Beant College of Engineering and Technology, Gurdaspur.
E mail: j_singh73@rediffmail.com