Volume 5, Issue 2, February 2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Optimization of Sierpinski Carpet Fractal Antenna

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Abstract— This paper studies the Sierpinski Carpet fractal antenna in terms of optimality.The modified sierpinski fractal antenna shown to have the capability of being optimized, in terms of its return loss, bandwidth,gain.The sierpinski carpet antenna is a type of fractal antenna which are known to be most challenging research area in the field of wireless communication nowadays. In the field of communication two categories of signals play an important role they are narrowband and broadband signals. In this paper an attempt is made to generate sierpeinsiki antenna using simulation which uses the concept of fractal antennas i.e self similarity in the geometry over several frequency bands. The design analysis took place between ranges 1.9GHz/3.9GHz/4.5GHz/5.7GHz/7.3GHz/8.2GHz Using HFSS for which minimum return loss occur for baseshape, and first iteration, second iteration for broadband. The simulated results shows performance enhancement in terms of gain and comparison of return loss for different iterations.

Keywords— fractalantenna, sierpinskicarpetantenna,returnloss,frequency,gain,performance

I. INTRODUCTION

Fractal antennas have existed for a long time. In the research area fractal antenna theory is shedding new light on wireless communications. A fractal is a rough or fragmented geometric shape that can be subdivided in parts,each of which is (at least approximately) a reduced-size copy of the whole. Fractals are generally self-similar and independent of scale. There are many mathematical structures that are fractals; e.g. Sierpinski's gasket, Cantor's comb, von Koch's snowflake, the Mandelbrot set, the Lorenz attractor, et al. Fractals also describe many real-world objects, such as clouds, mountains, turbulence, and coastlines that do not correspond to simple geometric shapes. The terms fractal and fractal dimension are due to Mandelbrot, who is the person most often associated with the mathematics of fractals. Fractals[1] are complex geometric designs that repeat themselves, or their statistical properties on many scales, and are thus "self similar."Fractals, through their self-similar property, are natural systems where this complexity provides the sought-after antenna properties

Earlier methods were great at solving simple problems, such as single-band, hi-Q antennas. But with more complex applications and desire for maximum shrinkage for a given performance, only fractals promise to meet the demands of modern antennas. Some key benefits

of fractals are:

■ Very broadband and multiband frequency response that derives from the inherent properties of the fractal geometry of the antenna.

■ Compact size compared to antennas of conventional designs,while maintaining good to excellent efficiencies and gains.

■ Mechanical simplicity and robustness; the characteristics of the fractal antenna are obtained due to its geometry and not by the addition of discrete components.

■ Design to particular multifrequency characteristics containing specified stop bands as well as specific multiple passbands. Among the diverse types of fractals there are the deterministic ones that enable an easy explanation of basic features of fractal behaviour.

There exist various forms of fractals. Fractals are categorized into two major variations.

Deterministic fractal antenna works on the concept of a 'motif'. The term deterministic means that there is no randomness involvedi.e. italways produces the same original object after repetitive recursionand several scaling. The deterministic fractal antenna exhibit the property of strict self similarity or exact self similarity i.e. fractal appears identical at different scales. Fractals defined by iterated function systems often display exact self similarity. Examples: classic wideband antennas, Koch curves, Koch snowflakes, Julia set, sierpinsk gasket, sierpinski carpet.

Random fractals: are quite familiar and many look like random walks. Random fractals were used to generate array configurations that were somewhere completely ordered i.e periodic and completely disordered i.e random. Ex: Fractal arrays Sierpinski fractal determnisticstructures are designed by carrying out multiple iterations an a basic geometric shape such as triangle, circle or square. In this paper the fractal structure choosen is sierpinskicarpet[square]
Sierpinski carpet antenna: Have lower resonant frequencies than the conventional patch antennas, and this property can be used to reduce the size of the antenna,without degrading the antenna performances such as the return loss and radiation patterns.

This paper proposes a new miniaturized fractal antenna i.e optimized sierpinski carpet fractal antenna. The structure of the proposed antenna is the result of the modifications made with the basic fractal square . The design and simulation have been performed usingHFSS V13, a full-wave electromagnetic simulator. It offers the best accuracy for planar microstrip antenna designs. The simulation results reveal that designs are extremely good in terms of broadband operations.

In the literature study, a relatively large number of papers dealing with theSierpinski antenna were published.in the recent publication [8].the sierpeinsiki carpet fractal geometry simulated using IE3D covers the multibandsuch as 1.8/5.59/5.78/6.4/6.63/7.84 GHz and The square patch resonates at the frequency of 1.8 GHz with a return loss of -33 dB.After first iteration the Sierpinski carpet antenna resonates at two different frequencies namely 5.78 GHz and 6.63 GHzwith the better return loss of -14.09 dB and -22.63 dB respectively. Sierpinski carpet antenna has gone through the second iteration to exhibit the multiband characteristics at 5.59 GHz, 6.4 GHz and 7.84 GHz with the return loss of -16.86 dB, -15.15 dB and -18.87 dB respectively. Our research is based on further performance enhancement of sierpeinsiki antenna to exhibit the broadband characteristics at 2.0/3.9/4.5/5.7/7.3/8.2 GHz. The simulation is carried out using HFSS V13

II. DESIGN

In this research, focus is on further improvement of sierpeinski antenna by improving the performance parameters and reducing the antenna size. To achieve this objective, the steps involved are:

a) Choose proper substrate material suitable for the frequency of application in terms of dielectrical material, dielectric loss tangent and height of substrate)
b) Theoretically design the patch antenna using standard transmission line model analysis
c) Apply the sierpeinsiki fractal concept to square patch antenna
d) Generate the simulation. Simulation is done using HFSS13 in the following steps:

- Initially square patch antenna with calculated dimensions is simulated
- For the simulated patch antenna, fractal concepts are applied which generates sierpeinsiki antenna.
- Sierpeinsiki antenna recursively generates subsections of it which is in terms of number of iterations.

e) To plot the return loss versus frequency which represents the frequencies for which the minimum return loss occur for base shape, first iteration, 2nd iteration.
f) To find bandwidth and gain using equation/graph

III. EXPERIMENTAL ANALYSIS

In this work, the antenna is designed to operate in broadband at 2.0 GHz and other multiple frequencies using FR4 Epoxy dielectrical material with ε_r=4.4and dielectric loss tangent of 0.02 and height of substrate 1.58mm.The antenna is excited using 50Ω microstripline using PCB connector.

The analysis is based on the following two steps:

STEP I. Initially design a square microstrip patch antenna and simulate which is done as follows Design of square patch antenna is carried out through the following procedure:

a) Initially find the dimensions of microstrip patch antenna as follows:
b) The essential parameters for the design
chosen are f0=2.0 GHz to 8.2 GHz,ε_r=4.4, h=1.58mm
c) Calculation of width can be done using

W = C/2f0 ------(1)

d) Calculation of effective dielectric constant ε_{reff}

$$\varepsilon_{reff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left(1 + 12\frac{h}{w}\right)^{-1/2} \quad \ldots(2)$$

e) Calculation of effective length(L_{EFF})

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad \ldots\ldots..(3)$$

f) Calculation of length extension ΔL

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \ldots(4)$$

Where W =width, h=height

g)Calculation of actual length of patch (L):

L= Leff -2ΔL…….(5)

With the above dimensional values, simulation using HFSS13 is carried out.

STEP II. Secondly, apply the concept of self similarity (fractals) to the simulated antenna which generates the subsections of it, for which the spacing between each subsection and dimensions of each is to be determined, which in other words is known as the design of modified sierpeinsiki antenna

A.Modifiedsierpeinsiki antenna design procedure are as follows:

i.For the square patch antenna, the sierpeinsikicarper fractal concept is applied. For designing this fractal antenna HFSS V13 software is used

ii.Square shape is cut down from the center of microstrip patch antenna which shows first iteration and gives one resonance frequency.

iii.For 2nd iteration, again square shape is cut down from some portion of first iteration, resonant frequencies found at 2nd iteration

iv.Following equations are used to find the iterations, capacity dimensions and for fractional area are as:

$$N_n(no.of\ black\ boxes) = 8^n$$

$$L_n(ratio\ for\ length) = [1/3]^n$$

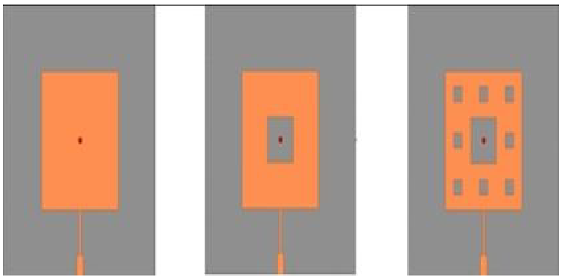
$$A_n(ratio\ for\ fractional\ area\ after\ nth\ iteration) = [8/9]^n$$

$$dn(capacity\ dimension) = \lim_{n \to \infty} \left[\frac{L_n N_n}{L_n L_n}\right]$$

Finally the size of antenna reduces with each iteration and is compared with measured results.

IV. SIMULATION RESULTS

Simulation of the proposed antenna is carried out by HFSS V13.The simulated return loss of two iterations is as shown in fig a below:



(a) (b) (c)

Figure 1 ANTENNA LAYOUT a)zero iteration b)one iteration c)two iteration

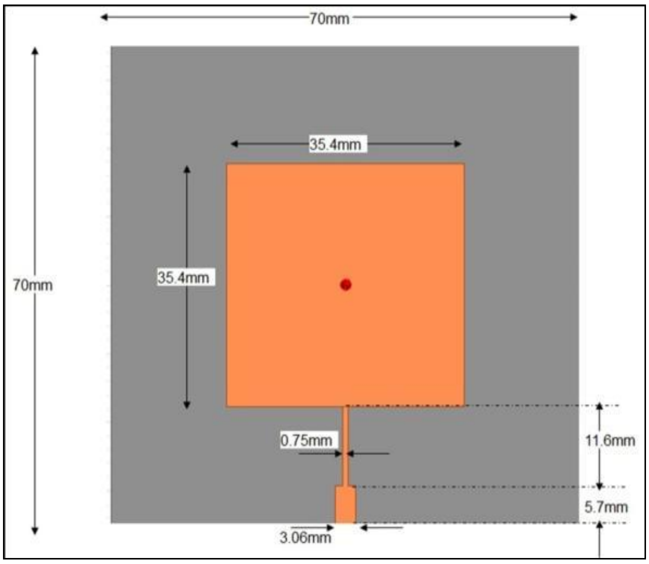


Figure 2 Antenna Dimension

Table below shows frequency and return loss for different frequency bands

Sl. No.	Iteration-0		Iteration-1		Iteration-2	
	FREQ(GHZ)	RL(db)	FREQ(GHZ)	RL(db)	FREQ(GHZ)	RL(db)
1.	1.9	-32.9	1.8	-14.9	1.75	-19.26
2.	3.9	-10.12	3.8	-8.49	3.65	-12.16
3.	4.5	-13.19	4.3	-8.80	4.12	-9.14
4.	5.7	-13.58	5.6	-16.14	5.55	-12.78
5.	7.3	-19.07	7.0	-25.59	6.50	-20.50
6.	8.2	-10.42	8.1	-13.63	7.77	-28.76

The graph represents frequency and return loss

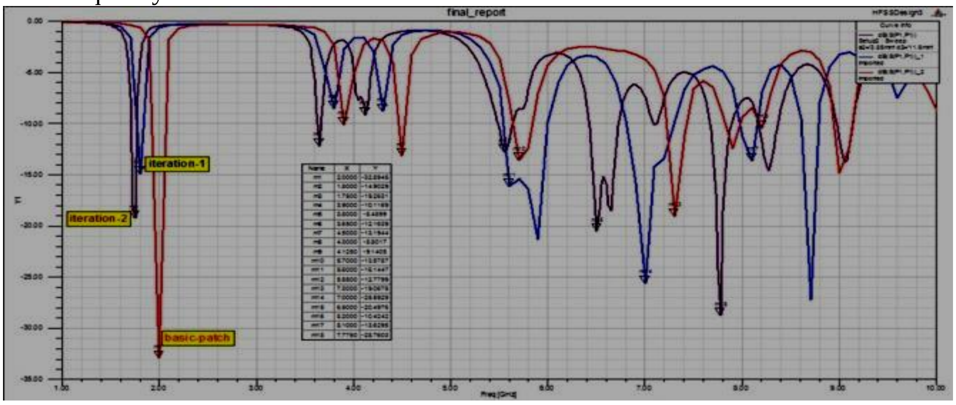
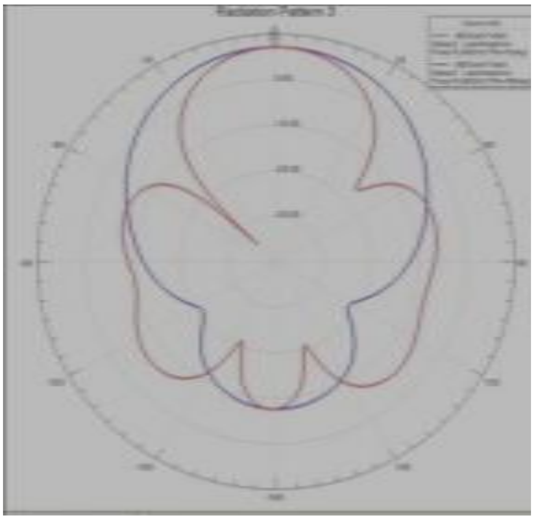


Figure 3a.Return loss for basic patch for iteration one



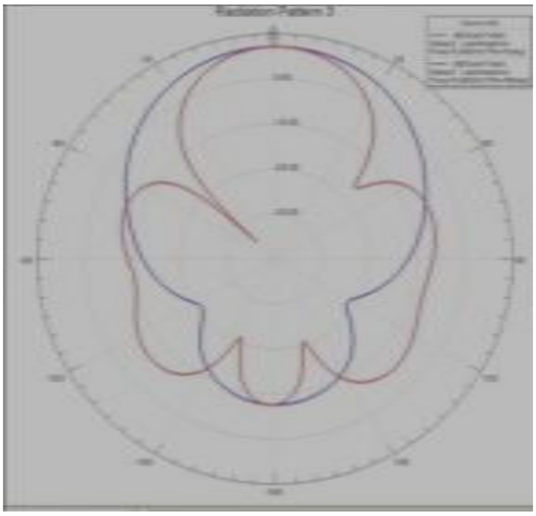


Figure 3b. Return loss for iteration two

IV. CONCLUSION

In this paper a square microstripsierpeinsiki carpet i.e., modified sierpeinsiki antenna is constructed using fractal geometry for broadband operation covering the frequencybands2.0GHz/3.9GHz/4.5GHz/5.7GHz /7.3GHz /8.2GHz. The measured results indicate that the antenna exhibits a good radiation and input return loss and significant size reduction. This type of antenna is the best for wireless communications for broadband operation. Hence the designed antenna is compact enough to be placed in a typical wireless device and this can be further improved**.** This can be further improved by improving the performance parameters and can be proved through fabrication.

ACKNOWLEDGEMENT

We the authors would like to thank the ISRO organization, Peenya, Bangalore for giving us the opportunity to carry out the work and guiding and supporting us constantly

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