Optimization Of Patch Size Of Fractal Hybrid Antenna For Gps Application

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ABSTRACT

In this paper we propose the optimization of patch size for a fractal hybrid antenna that can be used in GPS applications. This project is about two different models namely sierpinski gasket fractal antenna and Koch rectangular fractal antenna. A fractal antenna in general is characterized by space filling and self-similarity properties. These fractal shaped antennas have their own unique characteristic that improves antenna achievement without degrading antenna properties. Due to the space-filling properties of fractal geometry, the proposed antennas are smaller in size than conventional Euclidean-type ones. The antenna designs for dual-band Global Positioning System (GPS) is usually done in the frequency range of 1.2GHz to 1.575GHz. In conclusion, we says that it is possible to optimize the patch size, keeping the operational frequencies same to that of the earlier antenna models, and with a few deviations from the previous results like radiation pattern, bandwidth and gain are computed, it can also be normalized by using advanced manufacturing tools and selection of appropriate materials for better results.

Keywords – ***Antenna, Bandwidth, GPS, Hybrid model, Koch, Optimization, Microstrip, Parameters, Sierpinski,***

I. INTRODUCTION

In modern wireless communication systems and increasing of other wireless applications, wider bandwidth, multiband and low profile antennas are in great demand for both commercial and military applications. This has initiated antenna research in various directions; one of them is using fractal shaped antenna elements. Traditionally, each antenna operates at a single or dual frequency bands, where different antenna is needed for different applications. This will cause a limited space and place problem. In order to overcome this problem, multiband antenna can be used where a single antenna can operate at many frequency bands. One technique to construct a multiband antenna is by applying fractal shape into antenna geometry. Fractal's antennas are widely preferred for wireless communication systems as they are of small size, light weight, low profile, low cost, and are easy to fabricate and assemble.

The objective of this paper is to be design and fabricate the hybrid fractal antenna using sierpinski gasket model and Koch rectangular model. The behavior and properties of these antennas are investigated. This paper presents the optimization of patch size for fractal hybrid antenna design for global positioning system (GPS) in the frequency range of 1.2 GHz to 1.57 GHz. This hybrid fractal antenna fabricated from two different models namely sierpinski gasket fractal antenna and Koch rectangular fractal antenna. In addition to the theoretical design procedure, we developed a program for identifying the length and width of the patch in c# using Microsoft visual studio 2010 software. This hybrid fractal antenna has been fabricated with proper procedure in microwave measurements lab using microwave antenna trainer kits. The antennas have been fabricated and tested.

II. GLOBAL POSITIONING SYSTEM (GPS)

The Global Positioning System (GPS) is a space-based Global Navigation Satellite System (GNSS) that provides location and time information in all weather, anywhere on or near the earth, where there is an unobstructed line of sight to four or more GPS satellites.

2.1 Basic concept of GPS

A GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the earth. Each satellite continually transmits messages that include

- The time the message was transmitted
- Precise orbital information (the ephemeris)
- The general system health and rough orbits of all GPS satellites (the almanac)

The current GPS consists of three major segments. These are the space segment (SS), a control segment (CS), and a user segment (US).

2.2 GPS frequencies

All satellites broadcast at the same two frequencies [1], 1.575GHz (L1 signal) and 1.227GHz (L2 signal). Different bands of Global Positioning System (GPS):

Band	Frequency	Description
L1	1575.42 MHz	Coarse-Acquisition (C/A) and encrypted precision P(Y) codes, plus the L1 Civilian (L1C) and Military (M) codes on future Block III satellites.
L2	1227.60 MHz	P(Y) code, plus the L2C and Military codes on the Block IIR-M and newer satellites.

Table 1. GPS frequencies

III. MICROSTRIP PATCH ANTENNA

A Microstrip patch antenna consists of a very thin patch that is placed as a small fraction of a wavelength above a conducting ground plane. The patch and the ground plane are separated by a dielectric. The patch conductor is normally copper and can assume any shape but for this project square patch is used and this simplifies the analysis and performance prediction. The patches are usually photo etched on the dielectric substrate and the substrate is usually non-magnetic. The relative permittivity of the substrate is an important parameter to consider. It is because relative permittivity will enhances the fringing fields that account for radiation. This type of antenna is characterized by its length L, width w, and thickness h.

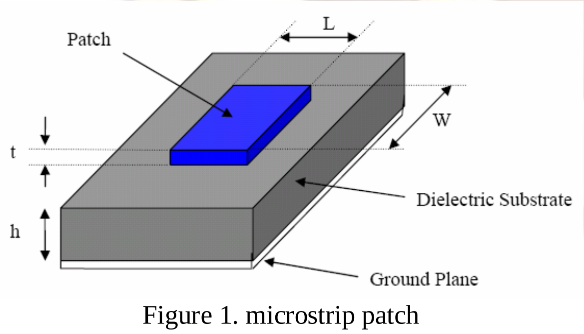

Figure 1. microstrip patch

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation, but such a configuration leads to a larger antenna size. In order to design a compact microstrip patch antenna, higher dielectric constants must be used which are less efficient and result in narrower bandwidth. The advantages of microstrip antenna [2] are light weight, low profile, low cost and easily to integrate with other circuit. However there are several disadvantages of microstrip antenna are narrow bandwidth, low gain, low efficiency and surface wave excitation.

3.1 Feeding techniques:

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. The four most popular feed techniques are the microstrip line, coaxial probe, aperture coupling and proximity coupling. In this paper coaxial probe coupling technique is used.

IV. FRACTAL ANTENNA

The term fractal means broken or fragmented. Benoit Mandelbrot [3] showed that many fractals existed in nature and that fractals could accurately model certain irregularly shaped objects or spatially non-uniform phenomena in nature that cannot be accommodated by Euclidean geometry, such as trees or mountains, this mean that fractals operating in non-integer dimension.

Mandelbrot defined fractal as a rough or fragmented geometric shape that can be subdivided in parts, each of which is a reduced-size copy of the whole. In the mathematics, fractals is a class of complex geometric shapes commonly exhibit the property of self-similarity, such that small portion of it can be viewed as a reduced scale replica of the whole. Fractals can be either random or deterministic. Most fractal objects found in nature are random, that have been produced randomly from a set of non-determined steps. Fractal that has been produced as a result of an iterative algorithm, generated by successive dilations and translations of an initial set, are deterministic. A fractal often has the following features:

- It has a fine structure at arbitrarily small scales.
- It is too irregular to be easily described in traditional Euclidean geometric language.
- It has self-similar and space-filling properties.
- It has a Hausdorff dimension which is greater than its topological dimension.
- It has a simple and recursive definition.

4.1 Advantages and Disadvantages

Advantages of fractal antenna technologies are:

- Miniturization
- Better input impedance matching wideband/multiband (use one instead of many)
- Frequency independent (consistent performance over huge frequency range)
- Reduced mutual coupling in fractal array antennas

Disadvantages of fractal antenna technologies are:

- Gain loss
- Complexity
- Numerical limitations

4.2 Sierpinski Gasket Fractal Model

Sierpinski gasket triangle is a deterministic fractal. It has the basic properties that are common to all fractals like recurrence, which mean whatever part of the triangle we take, if we magnify it, we will find exactly the same triangle in it. The deterministic construction for the Sierpinski gasket is shown in Figure 3. We begin with an equilateral triangle. Then use the midpoints of each side as the vertices of a new triangle, which we then remove from the original. We continue this process, from each remaining triangle we remove the middle leaving behind three smaller triangles.

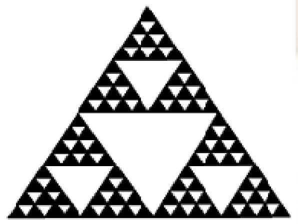

Figure 2. Sierpinski gasket model

Construction of Sierpinski gasket using an iterated function system:

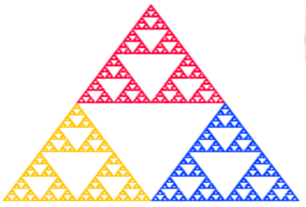

Figure 3. Sierpinski triangle using iterated function system

An alternative way of computing the sierpinski triangle uses an iterated function system and starts by a point at the origin ($X_0 = 0, Y_0 = 0$). The new points are iteratively computed by randomly applying (with equal probability) one of following three coordinate transformations:

$X_{n+1} = 0.5X_n$

$Y_{n+1} = 0.5Y_n$; A half-size copy

This coordinate transformation is drawn in yellow in the figure.

$X_{n+1} = 0.5X_n + 0.25$

$Y_{n+1} = 0.5Y_n + 0.5\frac{\sqrt{3}}{2}$; A half-size copy shifted and up

This coordinate transformation is drawn using red color in the figure.

$X_{n+1} = 0.5X_n + 0.5$

$Y_{n+1} = 0.5Y_n$; A half-size copy doubled shifted to the right

When this coordinate transformation is used, the triangle is drawn in blue.

4.3 Koch Rectangular Fractal Model

Koch rectangular fractal antenna [4] is based on the basic structure of rectangular or square patch. The use of fractal antenna techniques is to reduce the size of UHF linear dipoles, monopoles. To be an efficient radiator an antenna size must be an appreciable portion of a wavelength. Therefore the antennas that operate at low frequencies are physically very large. When the size of antenna is made smaller than the operating wavelength, it becomes highly inefficient.
Basically, antenna is designed based on the wavelength, λ. It is well known that λ is given by the following equation.

$$\lambda = \frac{c}{f}$$

Where c is the light velocity and f is the resonant frequency. Consequently, the size of the antenna will increase as the resonant frequency decreases the same frequency. Rectangular patch antenna normally designed at nearly half wavelength. . The fractal antenna is designed such to obtain a smaller size antenna that can operate at the same frequency.
Square patch antenna normally designed at nearly half wavelength [5].

$$L = W = \frac{0.5\lambda}{\sqrt{\varepsilon_r}}$$

Where ε_r is the material dielectric constant.

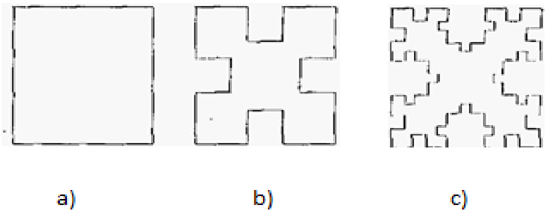

Figure 4. The antenna structures (a) Basic structure (b) first iteration fractal (c) second iteration fractal

V. DESIGN OF HYBRID FRACTAL ANTENNA

This hybrid fractal antenna is designed from two different fractal models namely Sierpinski gasket and Koch rectangular fractal model.

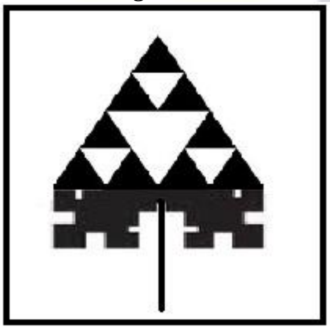

Figure 5. hybrid fractal antenna

We have developed a program for identifying the length and width of the patch basing on the equation as specified in "Hand book Microstrip Antenna Design by Ramesh Garg". The program was developed in c# using .Net frame work. A backend is also to be developed to store the values for later usage. A graph is plotted with variation in frequency from 1 to 2GHz in steps of 100MHz is shown in figure 6. The length and width values are as shown below for dielectric substrate $\varepsilon r = 9.8$, height of the substrate $h = 1.27$, loss tangent value = 0.009,

Frequency (GHz)	Length (mm)	Width (mm)
1	48.6802381	36.66581743
1.1	44.25107149	33.95695167
1.2	40.55724678	31.63502908
1.3	37.4294549	29.6194802
1.4	34.74668831	27.85107897
1.5	32.42015568	26.28523657
1.6	30.38322489	24.88769195
1.7	28.58491326	23.63165118
1.8	26.98554613	22.49583467
1.9	25.55378534	21.46311139

Frequency (GHz)	Width (mm)	Radiation (Ω)
1	0.036666	1702.827
1.1	0.033957	1611.682
1.2	0.031635	1533.2
1.3	0.029619	1464.737
1.4	0.027851	1404.352
1.5	0.026285	1350.589
1.6	0.024888	1302.329
1.7	0.023632	1258.699
1.8	0.022496	1219.007
1.9	0.021463	1182.695

Table 2. Length VS width and radiation resistance values from 1 GHz to 2GHz.

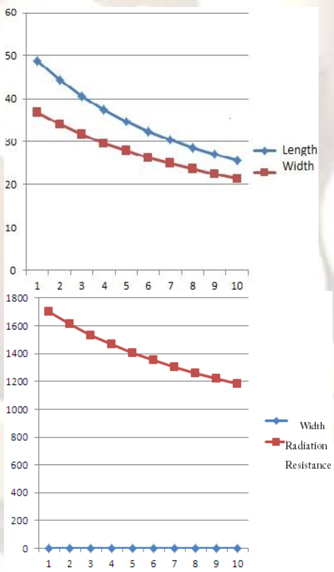

Figure 6. Graphs for Length vs. Width and width vs. radiation resistance

Considering the ideal frequency value of GPS as 1.5 GHz the length and width are taken from the tabular column a hybrid fractal antenna is fabricated from sierpinski gasket patch and Koch rectangular patch. Both antennas are iterated by two times. This hybrid antenna is used to reduce the patch antenna size. The hybrid fractal microstrip patch antenna is fabricated using FR4 PCB material and 50 Ω SMA connector.

VI. CONSTRUCTED MODEL AND RESULTS

6.1 CONSTRUCTED MODEL

The below figure is the actual model that is fabricated using a general purpose PCB. The layout of the PCB acts as both the transmitter and receiver whose parameters are yet to be obtained.

Figure 7. Hybrid fractal antenna with connector

6.2 Results

Fractal hybrid antenna has been fabricated and tested at Microwave antennas lab using microwave integrated circuit analyzer source and receiver MIC 10 kits and antenna polar plot system. The radiation pattern of the hybrid fractal antenna at 1.57 GHz frequency (Transmitter as dipole antenna and Receiver as hybrid fractal antenna):

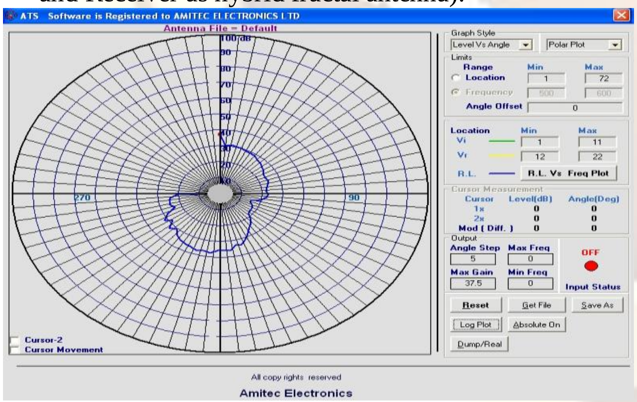

Figure 8. Radiation pattern of the hybrid fractal antenna

Level vs. angle Log and Linear plot of the hybrid fractal antenna in Cartesian form:

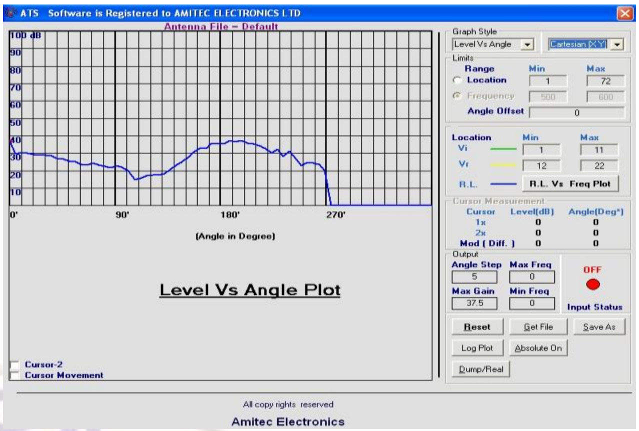

Figure 9. Log plot of the hybrid fractal antenna in cartesian form

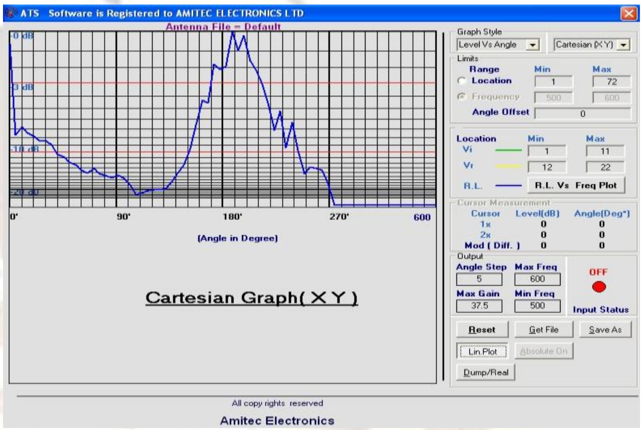

Figure 10. Linear plot of the hybrid fractal antenna in cartesian form

The radiation pattern of the dipole antenna at 1.57 GHz frequency when hybrid fractal antenna as transmitter (Transmitter as hybrid fractal antenna and Receiver as dipole antenna):

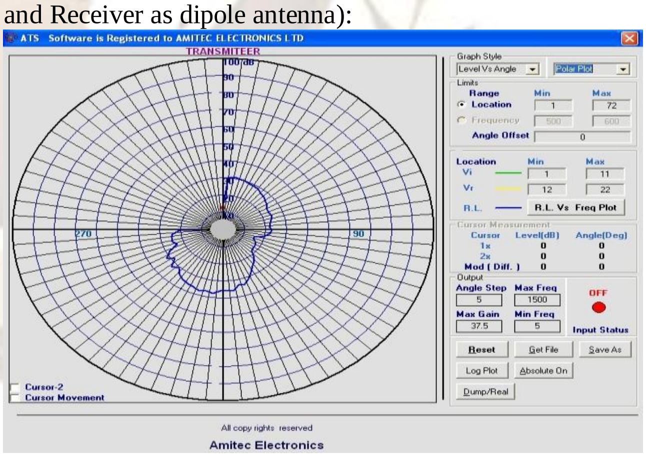

Figure 11. Radiation pattern of the receiver dipole antenna when hybrid fractal antenna as transmitter

Level vs. angle Log and Linear plot of the receiver antenna in Cartesian form:

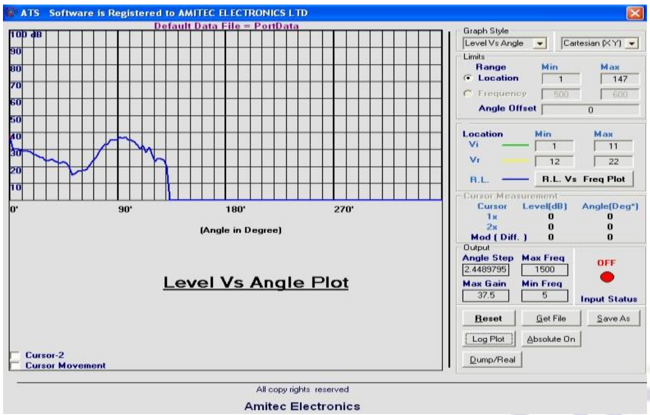

Figure 12. Log plot of the receiver antenna in Cartesian form

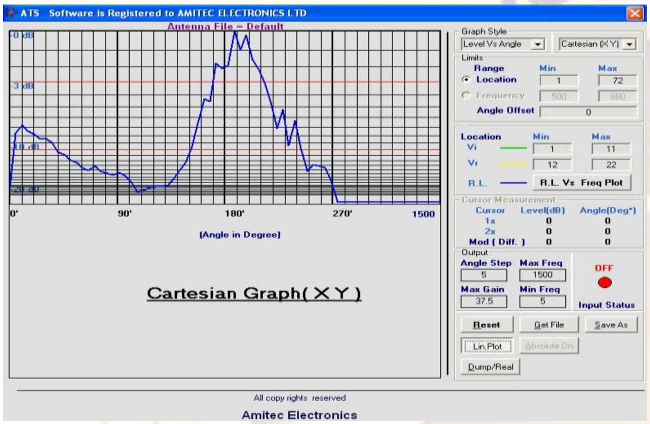

Figure 13. Linear plot of the receiver antenna in Cartesian form

VII. CONCLUSION

In this paper, a hybrid fractal microstrip antenna has been proposed and fabricated for GPS application with an optimization on the patch size with improved gain, bandwidth and radiation pattern.

From design and measurement results, radiation pattern of hybrid fractal antenna was not so good because it doesn't complete the 360 degrees, because of the fabrication material & substrate thickness. Also when the number of iteration is increased the number of resonant frequency is also increased. The fractal structure has indeed reduced the patch size with a maximum gain of 37.5 dB. Therefore, the proposed and designed antenna is feasible for use as a low-profile and low-cost dual-band antenna for supporting various wireless communications services.

References

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