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Review on Miniaturization of Antenna Using Fractal Geometry for Advanced Wireless Communication System

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Abstract: In wireless communication systems using microwaves and radio frequency Antenna is very important element. As the demands on system changes antennas are reconfigurable as well they can perform over several frequency bands. In addition from the aesthetic design point of view antenna requires to be miniaturized. An excellent solution for compact (i.e., miniature) antennas multi-band antennas have been found in Fractal antennas. A geometric shape called fractal has property of self similarity. Family of complex shapes describe by term fractal that acquire an inherent self-affinity or self-similarity in geometrical structure. Fractals also model many natural objects and processes. It is the nature's language [1]. As compare to conventional Euclidean antenna fractural can fill the space occupied by the antenna in a useful manner, which helps pairing of energy to free space in less volume from transmission lines.For improvement in antenna design Fractals be able to use in design of miniaturized antenna elements and in the self-similarity in the geometry. This would permit the operator to include a number of aspects in one antenna [2].Fractal antennas are easily in the receiver package due to compactness. There is inconvenience to user since the length of monopoles is longer than handset. It would be highly helpful to design an antenna with similar radiation properties as the quarter- wavelength monopole while retaining its radiation properties.The main goals of this project are to overcome these disadvantages and to develop an antenna with characteristics such as Operates in the X-band (8 to 12GHz) frequency range has a bandwidth of 20 to 30%.

I. LITERATURE SURVEY & PROBLEM FORMULATION

An antenna is defined by Webster's Dictionary as "a usually metallic device (as a rod or wire) for radiating or receiving radio waves". The IEEE Standard Definitions of Terms for Antennas (IEEE Std. 145–1983) defines the antenna or aerial as "a means for radiating or receiving radio waves" [3].Many different structures can act as antennas. Generally, antennas are constructed out of conducting material of some nature and can be constructed in many shapes and sizes. The size is related to the wavelength of operation of the antenna. An antenna designed for operation at 10 KHz is almost always much larger than an antenna designed for operation at 10 GHz.

A. Fractal's Definition

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" [4]. 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 curve. Fractals also describe many real-world objects, such as clouds, mountains, turbulence, and coastlines that do not correspond to simple geometric shapes.

As we see fractals have been studied for about a hundred years and antennas have been in use for as long. Fractal antennas are new on the scene. The geometry of the fractal antenna encourages its study both as a multiband solution and also as a small (physical size) antenna. First, because one should expect a self-similar antenna (which contains many copies of itself at several scales) to operate in a similar way at several wavelengths.That is, the antenna should keep similar radiation parameters through several bands. Second, because the space-filling properties of some fractal shapes (the fractal dimension) might allow fractal shaped small antennas to better take advantage of the small surrounding space.

B. Fractals as Space-filling Geometries

A fractal is mathematically defined to be infinite in intricacy, this is not desirable if antennas are to be fabricated using these geometries. For example, the complexity and repetition of a cloud does not extend to infinitely small or large scales, but can be approximated as doing so for a certain band of scales. From the scale of human perception, a cloud does seem to be infinitely complex in larger and smaller scales. The resulting geometry after truncating the complexity is called a "prefractal". A prefractal drop the intricacies that are not distinguishable in the particular applications. While Euclidean geometries are limited to points, lines, sheets, and volumes, fractals include the geometries that fall between these distinctions, a fractal can be a line that approaches a sheet. The line can meander in such a way as to effectively almost fill the entire sheet. These space-filling properties lead to curves that are electrically very long, but fit into a compact physical space and can lead to the miniaturization of antenna elements.

As mentioned earlier and indicated by Gianviffwb (2002) that prefractals drop the complexity in the geometry of a fractal that is not distinguishable for a particular application. For antennas, this can mean that the intricacies that are much, much smaller than a wavelength in the band of useable frequencies can be dropped out. This now makes this infinitely complex structure, which could only be analysed mathematically, manufacturable [5].

The Hilbert curve is an example of a space-filling fractal curve that is self voiding (i.e.has no intersection points). The first four steps in the construction of the Hilbert curve are shown in below Fig. 1

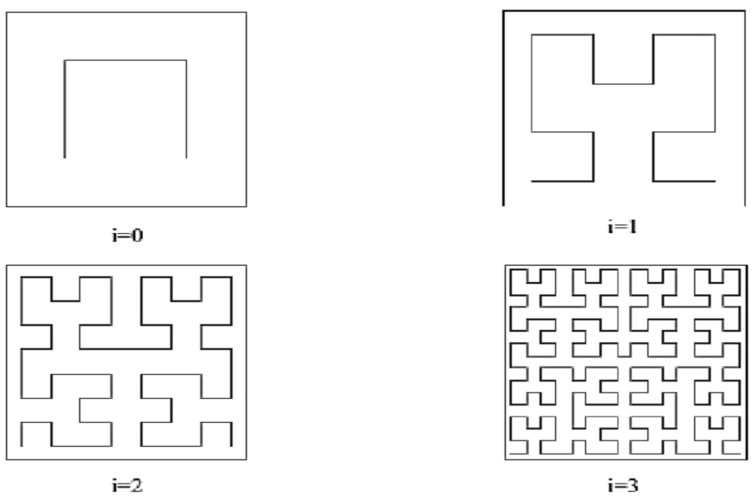

Fig. 1 Generation of four iterations of Hilbert cuves

C. Fractals as Miniaturized Antennas

A fractal can fill the space occupied by the antenna in a more effective manner than the traditional Euclidean antenna. This leads to more effective coupling of energy from feeding transmission lines to free space in less volume. Fractal loop and fractal dipole wire radiators are contrasted with linear loop and dipole antennas, fractals effectively fills the space and because of fractal dimensions allows antenna miniaturization.. Fractal antennas do not need to be limited to only wire antennas.

D. Fractals as Multiband Antennas

Fractal antennas show multiband or log periodic behavior that has been attributed to self similar scale factor of the antenna geometry. Fractal loop shows improved impedance and SWR performance on a reduced physical area when compared to non fractal Euclidean geometries. In order to enable more operating bands within lower spectrum, a higher scaling factor is required. Fractal antenna Represents a class of electromagnetic radiators where the overall structure is comprised of a series of repetition of a single geometry and where repetition is at different scale.

E. Fractal Geometry

There are many fractal geometries that have been found to be useful in developing new and innovative design for antennas. Fig.2 shows some of these unique geometries

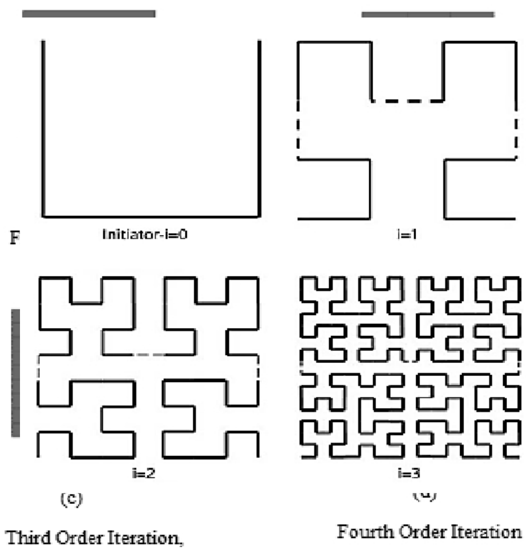

Fig.2 Example of other fractal antennas

F. Sierpinski Carpet

Sierpinski Carpet fractal antenna is realized by successive iterations applied on a simple square patch as shown in Fig. 3.3(a), which can be termed as the zeroth order iteration.A square of dimension equal to one third of the main patch is subtracted from the center of the patch to retrieve first order iteration, as shwn in Fig. 3.3(b). The next step is to etch squares which are nine times and twenty seven times smaller than the main patch as demonstrated in Fig. 3.3(c) and 3.3(d) respectively. The second and third order iterations are carried out eight times and sixty four times respectively on the main patch This fractal can be termed as third order fractal as it is designed by carrying out three iterations. The pattern can be defined in such a way that each consequent etched square is one-third in dimension as compared to the previous one sharing the same centre point. This procedure of design carried out on a square shaped patch can be implemented on any of the four geometries named above [6]

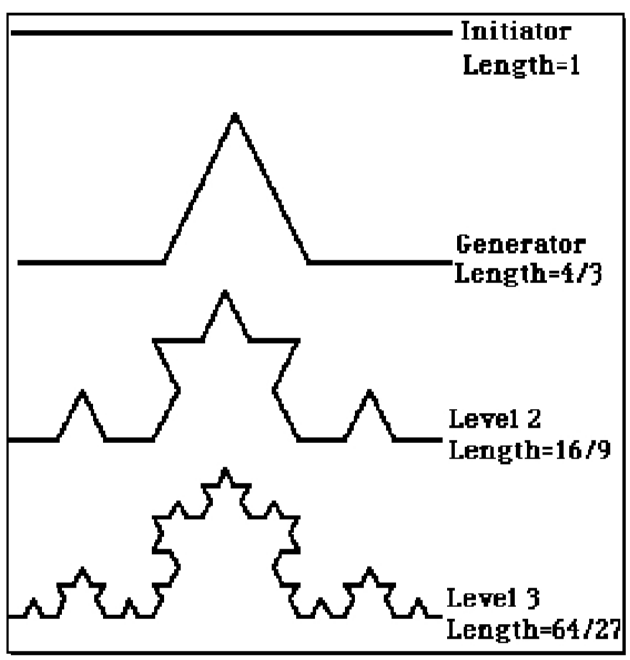

Fig. 3 Four stages in construction of sierpinski carpet [6]

G. Koch Curves

The geometric construction of the standard Koch curve is fairly simple. It starts with a straight line as an initiator. This is partitioned into three equal parts, and the segment at the middle is replaced with two others of the same length. This is the first iterated version of the geometry and is called the generator. The process is reused in the generation of higher iterations.

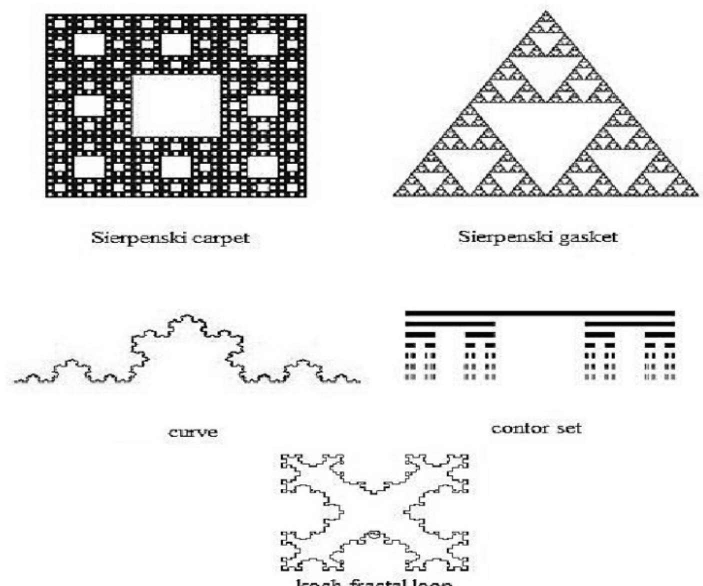

Fig.4 Step of construction of koch curves geometries

H. Hilbert Curves

Fig.5 shows the first few iterations of Hilbert curves. It can be noticed that each successive stage consists of four copies of the previous, connected with additional line segments. This geometry is a space-Filling curve, since with a larger iteration, one may think of it as trying to fill the area it occupies. Additionally the geometry also has the following properties: self-Avoidance (as the line segments do not intersect each other), simplicity (since the curve can be drawn with a single stroke of a pen) and self-similarity.

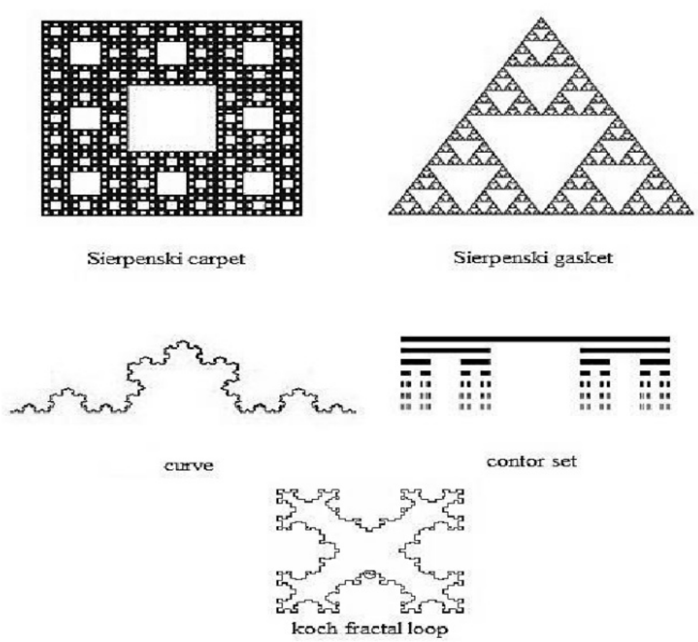

Fig. 5 Four stage in construction of Hilbert curves.

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I. Sierpinski Gasket Geometry

Sierpinski gasket geometry is the mostly widely studied fractal geometry for antenna applications. Sierpinski gaskets have been investigated extensively for monopole and dipole antenna configurations. The self-similar current distribution on these antennas is expected to cause its multi-band characteristics. It has been found that by perturbing the geometry the multi-band nature of these antennas can be controlled. Variations of the flare angle of these geometries have also been explored to change the band characteristics of antenna. Antennas using this geometry have their performance closely linked to conventional bow-tie antennas. However some minor differences can be noticed in their performance characteristics. It has been found that the multi-band nature of the antenna can be transformed into wideband characteristics by using a very high dielectric constant substrate and suitable absorbing materials [7].

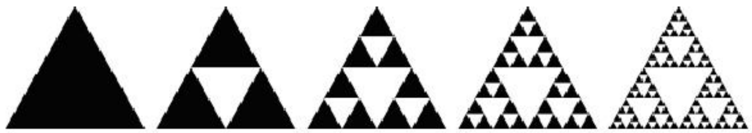

Fig. 6Four iterations of the Sierpinski fractal

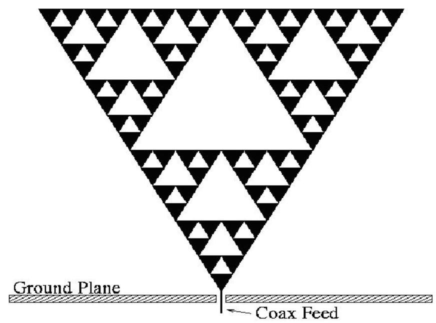

Fig.7 Sierpinski Gasket monopole

II. PROPOSED METHOD (TECHNIQUE, TOOLS)

There are many methods of analysis for microstrip antennas. The preferred models for the analysis of microstrip patch antennas are the transmission line model, cavity model, and full wave model which include primarily integral equations/Method of Moment. Then using iteration fractals generated the focus of this project is to study patch antennas using Fractal and includes modifications to improve the behavior of antenna design. Also modification using Sierpinski fractal patch antenna for improved performance The aim of project is to design small, multiband patch antenna using fractal.

This presents the following work:

A. Understanding the antenna concept.
B. Measurement of the antenna properties
C. To study and have deep insight into fractals their basic concepts including their properties and generations.
D. To analyze Fractal antenna system
E. To design small, multiband antennas.
F. To find their resonant values and return loss.

Let Nn be the number of black boxes, Ln is the scale factor for length of a side of white boxes, An is the scale factor for fractional area of black boxes after the nth iteration Let the length of the square patch is 37 mm.

$$Nn = 8^{n}$$

$$Ln = [1/3]^{n}$$

$$An = L^{2}nNn = [8/9]^{n}$$

First iteration of Microstrip carpet structure is designed by dividing a square into nine smaller squares. Then the square at the centre is eliminated which results in 8 squares.

$$L_1 = [\tfrac{1}{3}]^1 = 0.33$$

L1 is the scale factor for first iteration the length of the small square is determined by takingthe product of L1 and actual size of a square Length of Small Square is 12.21.

The A1 is the scaling factor for the fractional area after performing first iteration. For basic square patch antenna, the area (A0) is 37x37 mm2. The area of the small square at the center is 12.21x12.21= 149.08 mm2.This smaller square is removed and hence the effective area becomes

$$Area_1 = 1369 - 149.08 = 1219.92$$

$$A_1 = \frac{Area_1}{A_0} = 0.8905$$

Hence the antenna area is reduced by 10.95%.

Similarly after second iteration size can be further reduced to design a microstrip patch antenna using fractal for wireless communication it becomes necessary to use simulation programs to test the performance of Antenna using software like HFSS,IE3d,FEKO,CST etc .before fabrication.

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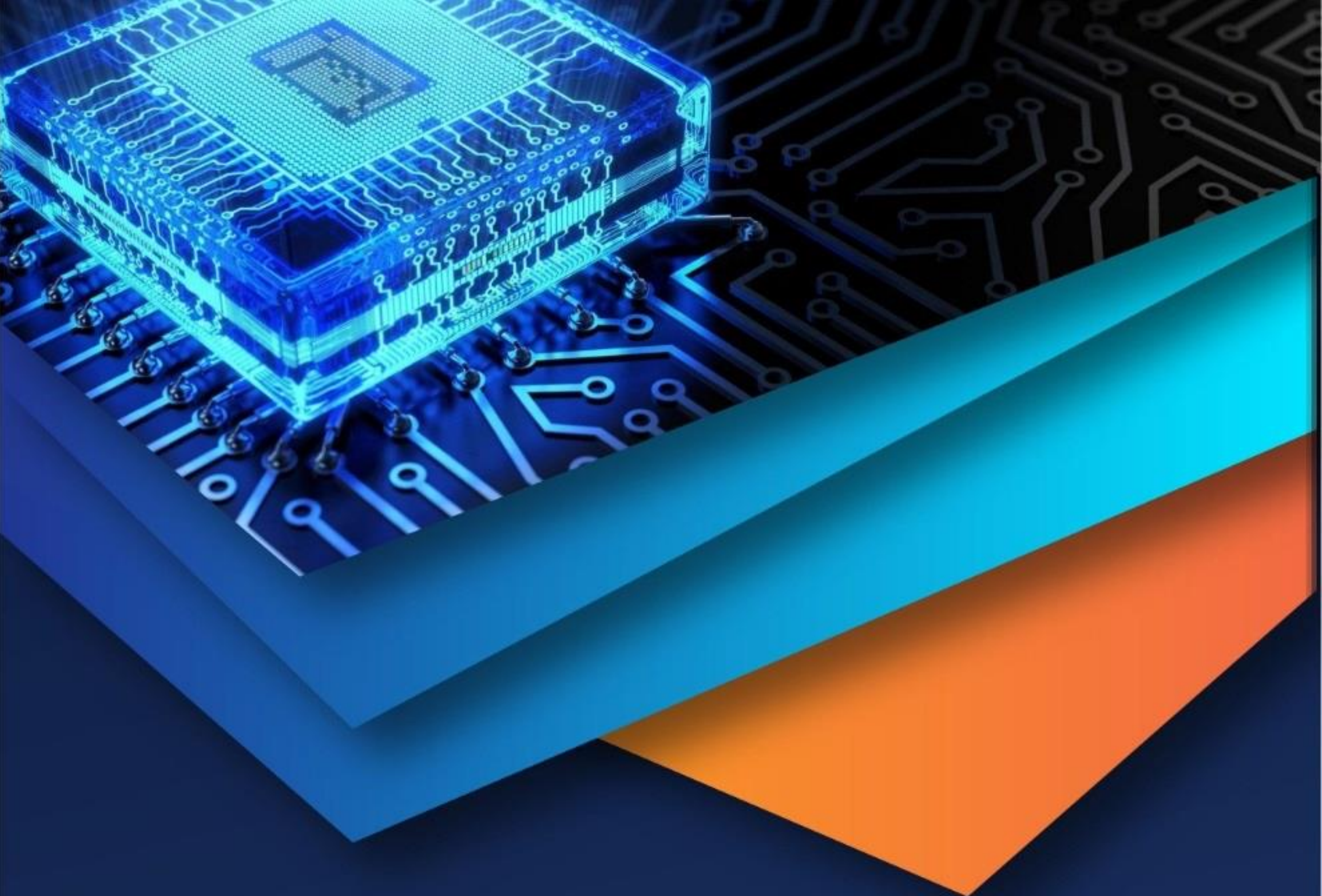

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