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Analysis of Fractal Geometries and its Applications in Microstrip Antenna

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***Abstract*— These days, there are higher growth in wireless communication for wireless applications. Multiband or wideband and low profile antenna are in higher demand. With the higher advancement in antenna technology, there is a great need of low profile antenna. This demand is fulfilled by use of the fractal antenna because of its self-similarity and self-repetitive properties.**

In this review paper I provide the comprehensive review of fractal and proceed with its dimensions and why fractal is used. This paper describes the concept of fractal antenna and its different types of geometries. The merits and the demerits of fractal antenna is also given in this paper including the applications that are very useful in the research areas and other related fields.

Keywords- Microstrip patch antenna, Dimensions, Euclidean Iterations, Self-similarity, Wideband/ Multiband.

I. INTRODUCTION

Microstrip patch antenna was developed in 1972 by Bob Munson. This antenna consists of radiating patches which are placed on the top of the dielectric substrate. There is a conductive layer that is present on the bottom of the surface of substrate that forming a ground to the antenna. The dimensions and the shape of the patch are very important features of antenna. It is light in weight because of the absence of the machine part. It is compact, simpler, easy to manufacture. [1]

Dr. B Mandelbrot invented the term Fractal in 1975. It was derived from Greek word frangee and Latin word fractus, which means broken or irregular fragments. According to Dr. B Mandelbrot, he investigated the relationship between fractals and nature patterns existing in nature. [9] The first fractal antenna was built in 1988 by Dr. Nathan Cohen. There are so many types of antenna like wire antenna, aperture antenna, reflector antenna and other antennas. Fractal antenna is new in the field of antenna, designing which has more demand in military as well as commercial application. Fractals are simple and easy to manufacture and have self-similar and self-repetitive characteristic.

II. FRACTAL ANTENNA

Fractal antenna is combinations of antenna that are operating at different frequency with small size. It is a geometrical shape, that means, each part of the shape is similar version of the original shape. In wireless communication, navigation, military communication, we require the antenna that has compact size, higher gain and optimal performance. To meet these requirement, we need fractal antenna that has not deterministic and smaller size. The self-similar properties in fractal antenna shows the wideband behavior.

The space filling property of fractal used to reduce the size of antenna and make low profile antenna, that has much use in the communication system. A single fractal antenna can be used to operate many resonant frequencies. [8]

III. WHY FRACTALS ARE USED

Nowadays, small antenna is the main and required need for any application, because of the small space availability in the devices, deployment of diversity and multi input and multi output (MIMO). Fractal antenna provides better solution by designing the compact size and multiband antenna efficiency and have effective way with improved antenna performance than others. Fractal can be used in two ways to strengthen the antenna designs. The first is, fractal is in design of miniaturized antenna element and second is to use self-similarity in the geometry.[7]

IV. FRACTAL DIMENSION

In fractal geometries, fractal dimension is the unique feature. There are different types of fractal notation in the fractal geometries that are topological dimension, hausdrof dimensions, box counting dimensions and self-similarity dimension. Among these notations, self-similarity dimension is mostimportant parameter for the characterization of the fractal geometries. [7] The dimension of self-similarity is defined as follow:

$$D_s = \frac{\log(N)}{\log\left(\frac{1}{s}\right)}$$

Where,

N= self-similar copies

S= scale factor

V. FRACTAL GROMETRY

In fractal antenna, the geometries of this antenna can be explained and constructed by iterative process. Using fractal geometries, a compact and wideband antenna can be designed. Multiple iterations exist in single basic shape. Iterations can continue infinite but occupy finite space, therefore they are compact in size and support multiband frequency. The fractal geometries are classified into two types. They are:

- *Natural*
- *Mathematical*

A. ***Natural:*** The fractal that are found in the nature all around us are natural antenna. They are also called as random antenna. This type of geometries has been used to characterized the different structures that define difficult in the Euclidean geometries.

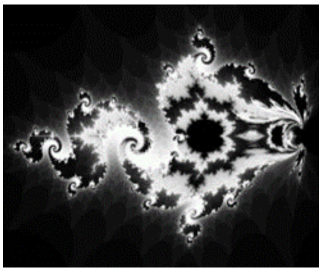

Fig.1

Fig1 shows the random geometry.

Most of these geometries that are infinitely, are further divisible.Eachdivision is the copy of the original. Example of natural fractal geometries are coastline, branches of tree or plants, rivers, galaxies etc.

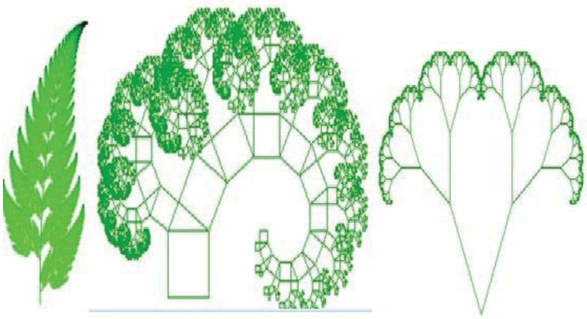

Fig.2

Fig.2 shows someexamples of the natural fractal antenna.

B. *Mathematically*: The mathematically fractal geometries are also known as deterministic geometries. The mathematically fractal geometries are those which are subjected to the equations that are based on the iterations. This fractal is visual. [9]

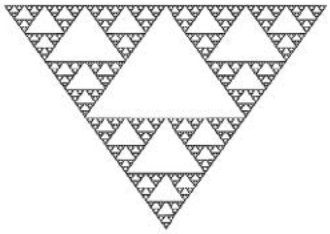

Fig.3

Fig.3 shows the example of mathematical or deterministic geometry.

This geometry is made up of two broken lines called generator. Each segment that form broken line is replaced by the original broken line generator. The repeating of these steps infinitely are results in the geometric fractals. Example of mathematically geometries are sierpinski gasket, Koch curve, Mandelbrot, Minkowski curve etc.

VI. TYPES OF FRACTAL GEOMETRY

A. *Sierpinski Gasket*

Sierpinski gasket is named after the Polish mathematician Sierpinski. He described the property of this fractal in 1961. [6] The sierpinski geometry is obtained by subtracting the central triangle from main triangle. After subtraction, three equal triangular geometries appear on the structure. Each one of these geometry is half of the main triangle. [1]

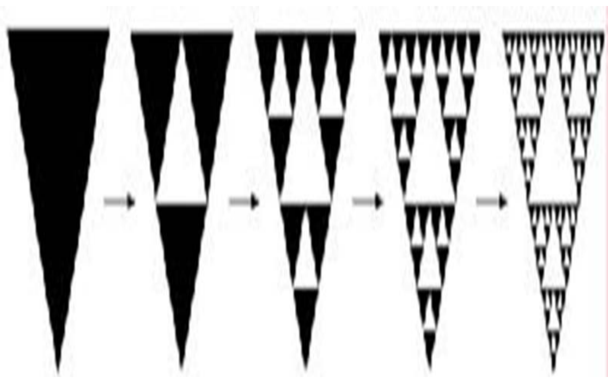

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Fig.4

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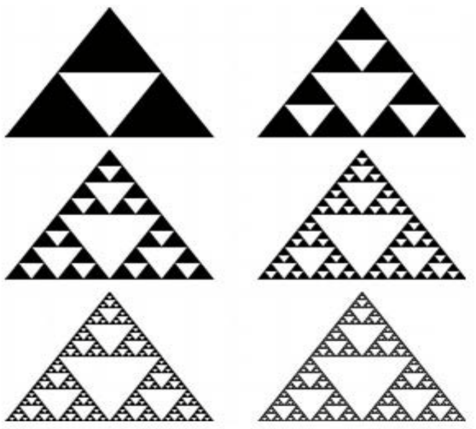


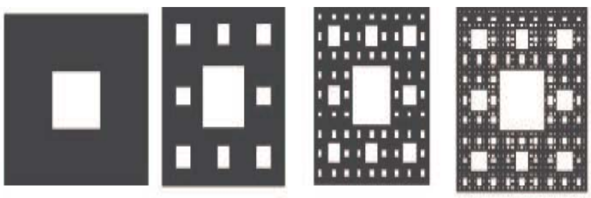
Fig.5

Fig.4 and fig.5 shows the iterations process of Sierpinski curve in which geometry is obtained by subtracting the central triangle from the main triangle.

The iterating the same process of subtraction in infinite number of times, the ideal factor sierpinski gasket is obtained. This is a deterministic fractal. It has properties that are common to all fractal like reappearance, which means whatsoever part of the triangle we take, if we magnify it, we will get exactly the same triangle in it. Equilateral triangles are formed in the sierpinski gasket in which midpoint of each side is use as the vertices of new triangle that take out from the main triangle. Continue the process for each remaining triangles, we remove the middle leaving behind the three smaller triangles. [9]

B. Sierpinski Carpet

The Sierpinski carpet structure is constructed similar to the Sierpinski gasket, but it contains squares shapes instead of triangles. In order to start this type of fractal antenna, it contain with a square in the plane, and then divides square into nine smaller squares where the open central square is remove. Also the remaining eight squares are divided into nine smaller congruent squares. [8]



Iteration1 Iteration2 Iteration3 Iteration4

Fig.6

Fig.6 shows the iterations process of Sierpinski carpet in which main square is divided into nine smaller square where central square is removed.

C. Koch Curve

Koch curve ae easy to construct and simple in design. Very firstly the researcher assumes a straight line. Then this is divided into three parts, and with a same length the segment at the middle is replaced with two others.This is the first iterated version of the geometry and it is called as the generator. The process is reused in the generation of higher iterations. It forms triangular shape also divided smaller triangle shapes. [7],[8]

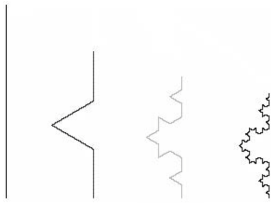


Fig.7

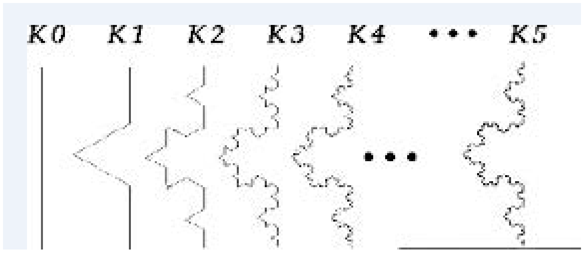


Fig.8

Fig.7 and Fig.8 shows the iteration process of Koch curve

D. Minkowski curve

Minkowski are also known as Minkowski Sausage. This antenna is available or dated back from 1907 by the German mathematician Hermann Minkowski. He invented the quadratics forms and continued fractals. Minkowski loops are used to reduce the size of an antenna by increasing the efficiency. Minkowski is just like Koch curve. Besides equilateral triangle is replaced by triangular. [7]

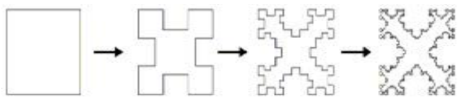


Fig.9

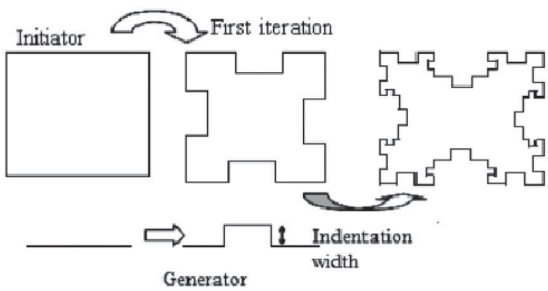


Fig.10

Fig.9 and Fig.10 shows the iteration process of Minkowski Curve

E. Hilbert Curve

Hilbert curve geometry contain a space filling property, and consist of large number of iteration, from this assume that it trying to fill the area it occupies. Additionally, the geometry also has the following properties: self -Avoidance, simplicity and self-similarity.This geometry is simplest than others, since it covers the area it occupies. In this, Hilbert curve the line segments do not intersect with each other and hence complexity will be reduced. [7]

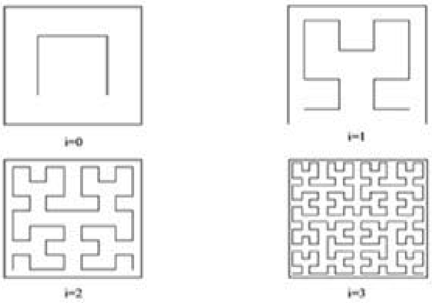


Fig.11

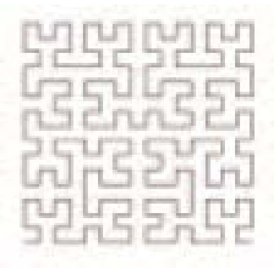


Fig.12

Fig.11 and Fig.12 shows the iterations process of Hilbert Curve

VII. MERITS OF FRACTAL ANTENNA

- Fractal antennas are small in size. Their sizes are so compact that are very useful for military applications.
- Better input impedance occurred in comparison of other antennas.
- Fractal antenna can support Wideband/ Multiband frequency which means only one antenna can be used instead of using many antennas.
- These antenna has compatible performance over huge frequency ranges
- Using fractal antenna, the probability of getting powerful solutions became very high.
- In fractal antenna we can add inductance and capacitance without using any component.
- Some antenna that has no better performance in harsh area because of large size, the fractal antenna get advantage over that. Fractal antennas are designed for the harshest conditions.
- Close packing of antenna.
- These antenna has instantons spectrum access.
- Fractal antenna lead to unique improvement in antenna array.
- They can enable optimum smart antenna technology.
- Lower cost.
- More reliable.

VIII. DEMERITS OF FRACTAL ANTENNA

- High gain loss
- Numerical limitations
- Complexity
- Performance start to decrease after first iterations.

IX. APPLICATIONS OF FRACTAL ANTENNA

- *Fractal antenna for UWB devices*
  Fractal antenna can be used as UWB that is inscribed for triangular circular antenna. UWB are ultra-wide band which is required for the devices that needed ultra-wide band frequency. The ultra-wide band frequency bandwidth is from 2.25GHz to 15GHz. The characteristic has been achieved from using fractal geometries.
- *Military applications*
  Modern military have presented the new challenges to the antenna designers. The need of compact and small size is increasing day by day. They need wideband frequency for the navigationing and targeting aspects. Fractal antenna has multiple band and genuinely wideband and has low profile, small antenna. Having these advantages, the fractal antenna is widely used for the military applications.
- Building commination
  Fractal provide universal wideband antenna technology that are ideal or useful for building communications. These antenna operating over 150MHz to 6GHz of frequency and deliveringOmni directional coverage.
- *Wireless network*
  Fractal antenna has huge use in the wireless communication like ZigBee, WiMAX and MIMO to deliver their maximum potential.
- Fractal antennas are very useful in the universal tactic communication.
- Fractal antennas applications in Signal Intelligence.
- Custom Application.
- Electronic Welfare
- Mobile devices
  From PDAs to cellular phones to mobile computing, today's wireless devise requires compact high performance and multiband antenna, these requirements are fulfilled by using the fractal antenna. That means fractal antennas are very useful in mobile communication.
- *Telematics communication*
  Providing navigational services to satellite are done by using the fractal antenna. TV multiple antenna also used fractal antenna for communication.

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- *RIFD*
  Fractal antenna takes an important role in the radio frequency identification
- *Astronomy*
  Scientist claims that structure of universal is fractal at all side. So fractal antenna is very important in the astronomy
- *Computer science*
  Fractals are very useful in computer science for fractal image compression
- *Fluid mechanics*
  The study of tuber lance in flow is very adapted to fractals. So fractals are very important in the fluid mechanics.

X. SCOPE OF FRACTAL ANTENNA

- Vehicle windshield with fractal antenna
- Biosensor attractions can be studied by using fractals.

XI. CONCLUSION

This paper concludes basic knowledge about the fractal antenna, their dimension, geometries, merits, demerits and application including the advancement and advantages of fractal antenna. There are many types fractal geometries that are used to reduce the size of antenna. This paper presents the different types of fractals can be used to design an antenna and the fractals play very important role to reduce the antenna size and make a best or most effective gain. Having the advancement, the fractal antenna consists of some limitation that make problems somewhere. There are lots of gain losses in fractal antenna that causes huge limitations in working. With increasing number of iterations of fractal, resonant frequency increases which results in lower returnlosses. Fractal antenna has ability to design particular multi-frequency. It is mechanical robustness. Through characterizing the fractal geometries and their result, it can be briefly noted that increasing the fractal dimensions leads to the higher degree of miniaturization.

So we have concluded that the triangular shaped antenna has more operating frequency and bandwidth as compared to the other fractal shapes. Fractal antennas are very useful in the early stages of development in the fields of research

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