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Review On Fractal Antenna: Inspiration Through Nature

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Abstract

In this article, the latest developments in the field of fractal antenna engineering are theoretically as well as structurally reviewed and its future scope is discussed. Fractal design is a geometric pattern that is repeated at every scale and therefore cannot be represented by classic geometry. Fractal has unique property that it can make copies of itself at different scales. Fractal antenna mainly focused on two fields: one is the design and analysis of fractal antenna and second is applications of fractal antenna.The concept of fractal antenna are very old but designing for broadband application is quite new. The fractal antenna geometry is preferred as compare to other microstrip antenna because of low profile, easy to design, miniaturization and multiband characteristics, which make them suitable candidate to satisfy today's wireless communication system.

Keywords: *Frequency band; space filling; symmetric geometry; multi band; radiation field; patch antenna; super wide band (SWB)*

1. Introduction

In 1970, Dr B. Mandelbrot coined the term Fractal. Fractal antenna has demand in military as well as commercial area where for antenna design it owns highly desirable properties;

(1) compact size
(2) low profile
(3) multiband
(4) conformal

Microstrip antenna is efficiently used because of its useful properties like small size, multiband, low profile and many more. Fractal is basically a miniaturized structure which stands for broken or irregular pieces. There are several advantages of microstrip antennas over conventional microwave antenna. Comparing between microstrip patch antenna and microwave antenna, the microstrip patch antenna has better aspects. Microstrip antenna is light in weight, low profile, small in size, its fabrication is easier then microwave patch antenna. Mandelbrot explained the complex structure to own the self similarity geometrical structure.

Fractal: - The idea of fractal shape is originated from the natural inspiration which is called nature like tree structure, leaves, mountain, galaxies, cloud boundaries and many more natural structures.

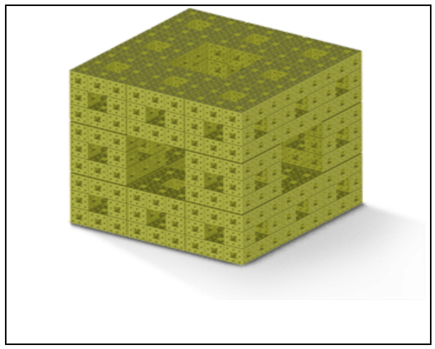


Fig: 1 Fractal basic structure

Fractal antenna is geometry based not as material based structure. Segments are look like each other and individual segment are also look like an object [2].

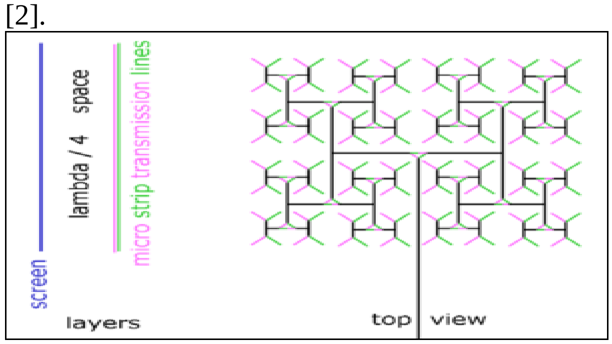


Fig: 2 lambda/4 height

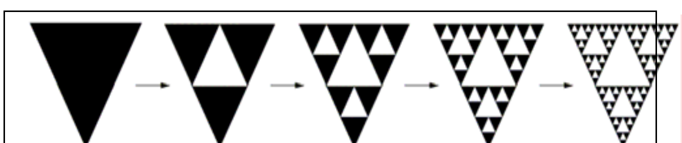
We use antenna height greater than λ/4 because by this its radiation pattern is good and return loss is also desirable [2].

1.1 CHRONOLOGY:

1947 – Chu limits the small antennas performance.
1983 – Benoit B. Mandelbrot "coins" the word fractal. He study the properties of fractal self similarity and space filling.
1986 – Kim and Jaggard use fractal geometry in antenna theory.
1988 – The first practical antenna was designed by Nathan Cohen in his Boston apartment ham radio station.
1998 - The cash prize of $230,000 was received by Carles Puente, Baliarda for designing the fractal antenna which has its application in a GSM and DCS as its base station antenna.
Fractal antennas are broken into two geometric types, one is random and other is deterministic.
Basics of antenna consider two objectives on the basis of frequency coverage:
(1) Narrowband – this is designed to operate on small range frequency.
(2) Wideband or broadband – this is designed to operate on wide range of frequency i.e. 3.1 to 10.6 GHz [19].

1.2 Useful geometries of fractal

- For designing a new and different fractal antenna we use some of the basic geometry which is useful in designing of new shape that means a new shape is introduced by the use of some common geometry. First geometry is serpinski shown in (fig: 3, stage 0) by the figure we can say that it is a shape of equilateral triangle in the stage 0. In the next step stage 1, there is a small triangle cut in the vertices that are generated on the middle point of the original triangle (see in fig: 3, stage 1) and this process is repeating in the next three remaining triangle. This is also known as generation of serpinski [3,4].



Stage 0 Stage 1 Stage 2 Stage 3 Stage 4

Fig: 3 Generation of serpinski

Black triangular area is denoted the portion of metal which is conducting whereas the white area denotes the portion where metal is not present or removed.

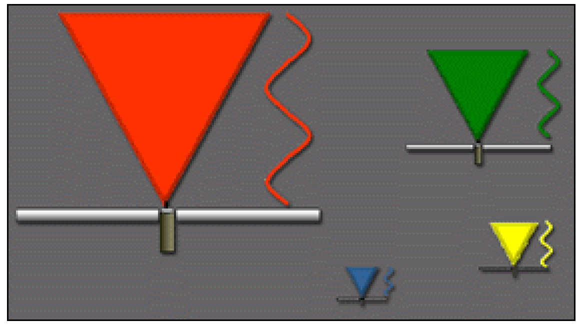


Fig: 4 Four separate antennas used four discrete frequency

In this fractal serpinski shape there is a four separate antenna and for all antennas there is different frequency taken [23].

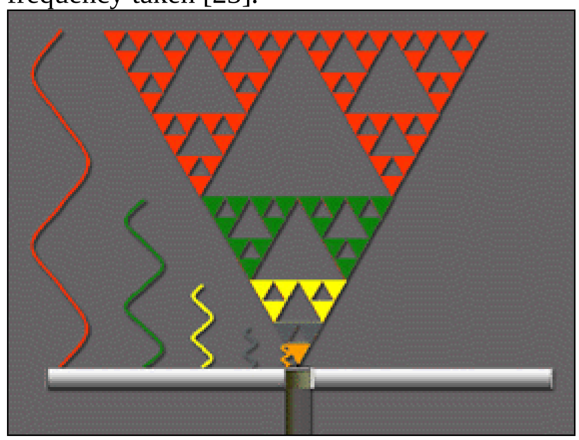


Fig: 5 One Antenna for four frequency bands [23]

In this there is only one antenna at different- different frequency bands. This shape of antenna is serpinski [23].

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- Another fractal geometry is Koch snowflake. There is also a starting point with a solid equilateral triangle (fig: 3 stage 0). It is not like serpinski geometry because in serpinski we cut smaller and smaller triangle in the middle but in Koch we add the equilateral triangle in the main triangle [5].

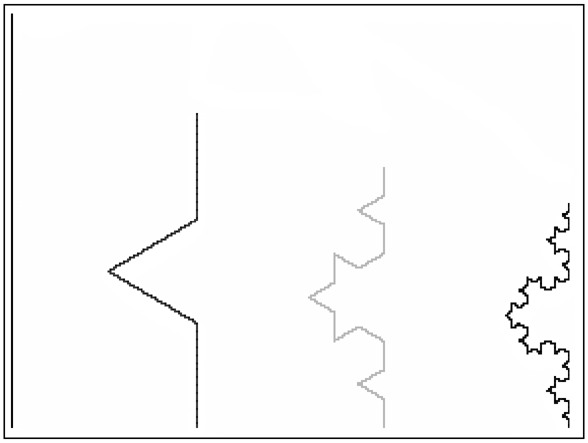

Fig: 6 Geometry of Koch dipole

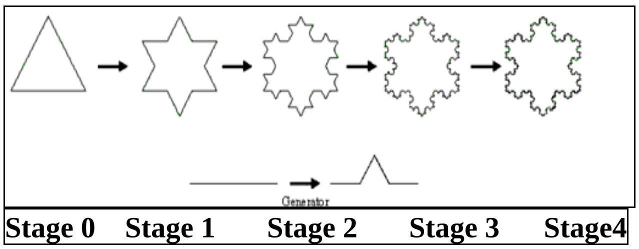

Fig: 7 Generation of Koch snowflakes

Let area of first iteration is A_K andA_{K+1} is the area of next iteration [6]

$$A_{K+1} = A_K + \frac{\sqrt{3}}{12}(4|3)^{K-1}a^2 \quad \textbf{(1)}$$

Where is the side of the initial triangle that has an area $A_0 = \sqrt{\frac{3}{4}}\ a^2$ the geometric series given by (1) converges by,

$$A = \frac{2}{5}\sqrt{3}a^2 \quad \textbf{(2)}$$

The perimeter increases at each new iteration. The overall perimeter for iteration k is given by**,**

$$l_k\text{=3a}(4|3)^k \quad \textbf{(3)}$$

I. Results On The Basis Of Return Loss, Gain And VSWR For First Three Iteration Of Koch Structure

- At 3.5GHz the return loss is -12.25 dB for second iteration. At 1.27 GHz the return loss measured is -6.69 dB for first iteration [6].

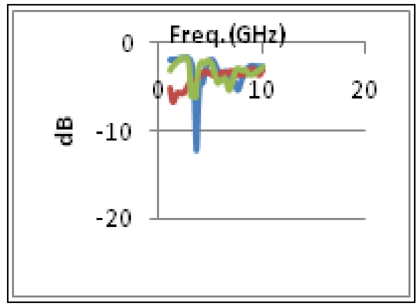

Fig: 8 Return loss result for Koch first three iteration

- At 42^0 gain is -21.0031 dB for second iteration and at 4^0 gain is -32.0117dB for first iteration [6].

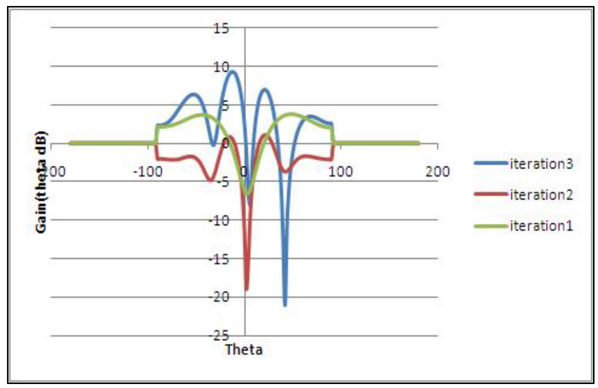

Fig: 9 Gain of first three iteration

- For first iteration at 3.5GHz frequency the VSWR is 1.6 and at 1.27 GHz frequency VSWR is 2.7 for first iteration [6].

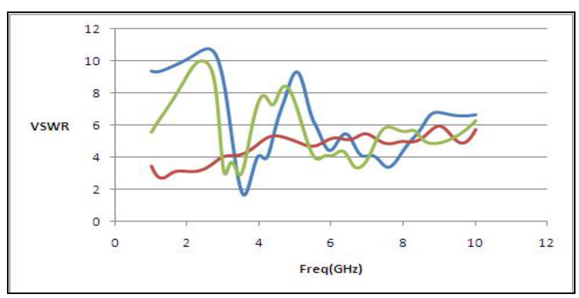

Fig: 10 VSWR for first three iteration

There are many shapes under this fractal geometry like serpinski, triangular, swastika and many more. In fractal geometry there are a large number of shapes like Serpinski, Minkowski, Triangular, Rectangular, swastika, etc [7].

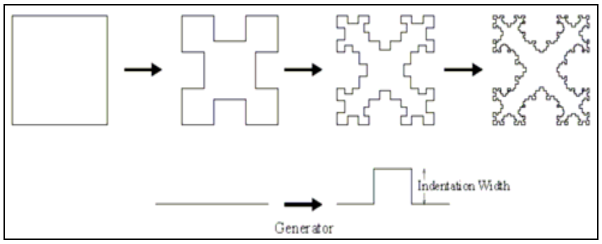

Fig:11 First four iterations of Minkowski loop

2. Feeding methods

In this there are many feeding techniques but here, we study about microstrip feeding technique, coaxial feeding technique and coplanar waveguide [24].

2.1 Microstrip feed

Microstrip feeding is easy to fabricate and easy to model. When the substrate heaviness increases, then surface waves and radiation pattern increases [11].

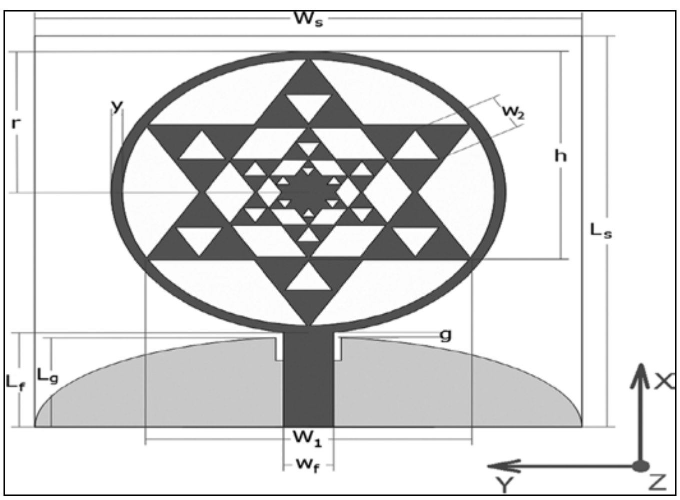

Fig: 13 Geometry of the proposed MSTF antenna with microstrip feeding technique

This is MSTF shape in which we use the feeding technique microstrip feeding technique [12].

Table: 1 Optimal parameter values of the antenna

Parameter	Description	Optimal value
$W_s = W_g$	Width of antenna	20 mm
L_s	Length of the antenna	20 mm
R	Radius of the external circle	7.2 mm
Y	Space between two circle	0.4 mm
H	Height of the elemental triangle	10.3 mm
G	Distance between patch and ground	0.2 mm
W_f	Width of the feed line	1.9 mm
W_1	Feed of the elemental triangle	12 mm
W_2	One face of primary slot	1.7 mm
L_g	Length of the ground plane	4.6 mm
L_f	Length of the feed line	4.8 mm

Here we presented a novel MSTF antenna with a very small size [12]. By increasing the number of iteration and optimizing parameter values of the antenna with desired values we attained better impedance matching and better bandwidth. This is the result of the fractal's properties like space filling property and self similarity property. The MSTF antenna's operating frequency covers all the band of frequency between 1 to 30 GHz. The MSTF can be best for UWB and SWB applications [12, 13].

2.2 Coaxial probe feed

Coaxial probe feed is easy to fabricate but its radiation pattern is low profile and there is no accurate model that could be obtained. There is also a narrow bandwidth [24, 14].

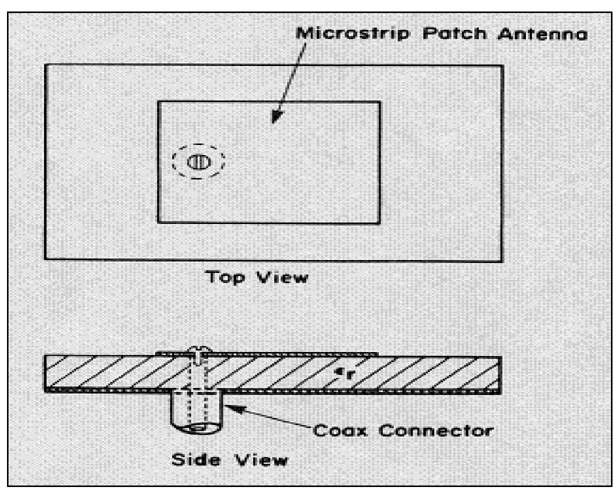

Fig: 14 Coaxial feeding techniques

In this we use coaxial cable which is made by some cylinders and inner and outer probe which is further cut through the ground. By this we can easily feed via coaxial feeding technique. There are two views in this figure one is top view and another is a side view [24].

More examples for coaxial probe feed and microstrip

STRIP FEED COAX FEED

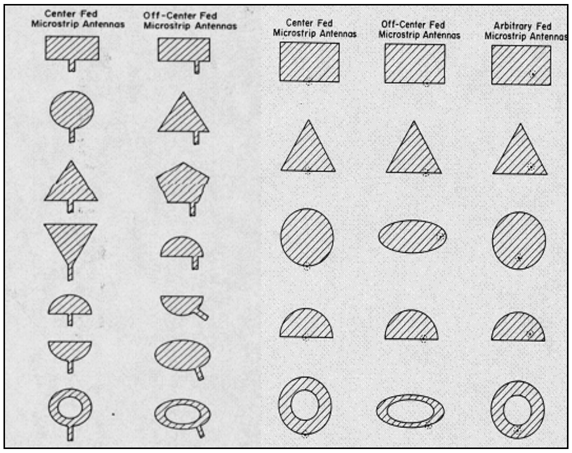

Fig : 15 Different examples of feeding techniques

2.3 Coplanar waveguide feed line

In this we deals with coplanar waveguide in which patch antenna is designed and simulated with coplanar waveguide feed line. In this the patch is connected to ground via slot and the return loss is controlled by slot length. CPW is suitable for multilayer fabrication. It has low attenuation and dispersion and does not design easily the wide range of characteristics impedance [24, 16].

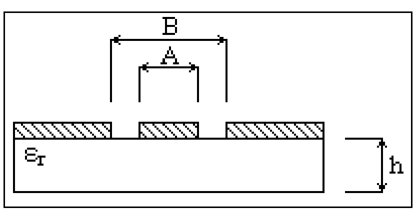

Fig: 16 CPW feed structure

3. Patch antenna

Basic structure of patch antenna

Patch antenna has a low profile and it is mounted on a plane surface. It is made up of a metal and the ground plane is of a large sheet of metal. Patch antenna are easy to fabricate and it is also known as microstrip antenna by Howell in 1972 [24].

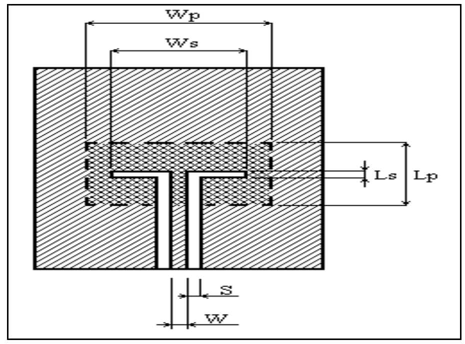

Fig: 17 Patch antennas with micro strip feeding

4. Effect of thickness in fractal antenna

Mainly works done on the fractal were assumed electrically thin. When it is electrically thicker substrate then it has a higher permittivity which is used now days. Now for many cases where we used thin substrate they fail to predict the resonant frequency or input impedance, or both [17].

By this we can say that at various thicknesses there is low and high permittivity or changeable permittivity and these results can be comparing with theoretical models and practical models. Using three types of feed we vary thickness and permittivity [17, 18].

5. Properties of fractal antenna:

5.1 Self Similarity

5.2 Scaling

Fractal has its standard property, known as self-similarity and space filling but self similarity is better for its iteration function [2, 3].By using algorithm we hold scaling and similarity. Repeating a given operation over and over again, on every smaller or larger scale called a self-similar structure. Repetitive operations are symbolic, geometric and algebraic move towards a good self- similarity. Koch curve is the best example of repetitive operations which is proposed in 1904 by the Swedish mathematician Helge von Koch [6].

Iterated function system (IFS) generates fractal structure. By using scaling factor fractal antenna structure is iterated.

Numerous techniques have been proposed for the miniaturization of microstrip patch antennas with multiband characteristics. Fractal structure is made in order to obtain a reduced size multiband antenna. This is mainly due to the self similarity property of fractals [4, 5].

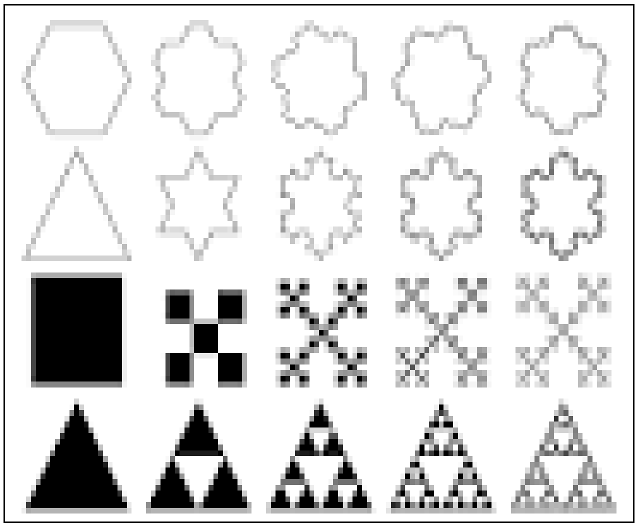

Fig: 12 Different shapes and iterations

6. Applications

Fractal has many improvements in their structure by its applications .There are many ideas where fractal has a real impact. By the fractal antenna there is phenomenon of space consuming geometry. There are many examples of this application based are hand held wireless and other wireless devices like laptop, mobiles, wifi and many more which are used in daily life routine. Fractal includes multiband transmission application also. In this application its example is Global positioning satellites (GPS).

Area of resonant antenna is decreases by the fractal antenna which could be lower the Radar cross section (RCS). It is used in military application where the RCS is a main or effective parameter [5].

7. Advantages and disadvantages

There are several advantages and disadvantages of fractal antenna:

7.1 Advantages of fractal antenna

- Compact size
- Low profile
- Good impedance matching
- Wide band or multiband (use only one antenna)

7.2 Disadvantages of fractal antenna

- Gain loss
- Complex structure
- Benefits are lessen in size after first few iteration
- Mathematical limitations [5].

Conclusion

In this paper we explained the antenna and a brief overview of fractal geometry and there is we can understand the different shapes of patches like triangular, serpinski, minkowski, rectangular etc. Here we study different types of feeding techniques but the mostly used are CPW, micro strip feed, coaxial feed line. And after that we discuss about the effect of thickness of fractal antenna.

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