An Overview of Fractal Antennas for Wireless Communication

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Abstract- In this paper, we provide overview of recent developments in the rapidly growing fields of fractal antenna engineering. Emerging applications of wireless communication system demand adaptability and unobtrusiveness in antenna system. Besides this the main constraint in advanced telecommunication systems are performances , size, weight, cost , ease of installation of antenna. One of the successful approach is " Fractal antenna".

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I. INTRODUCTION

There has been an ever-growing demand, in both the military as well as the commercial sectors for antenna design that possess the following highly desirable attributes.

1. Compact Size
2. Low Profile
3. Conformal
4. Multi-band or broadband

The term fractal means broken or irregular fragments, was originally coined by Mandelbrot [2] to describe a family of complex shapes that possess an inherent self-similarity or self-affinity in their geometrical structure. The original inspiration for the development of fractal geometry from in-depth study of the patterns of nature. For instance, fractals have been successfully used to model such complex natural objects as galaxies , cloud boundaries, mountain ranges, coastlines, snowflakes,trees,leaves,ferns,and much more. Mandelbrot and others,a wide variety of applications for fractals continue to be found in many branches of science and engineering. One such area is fractal electrodynamics [5-11], in which fractal geometry is combined with electromagnetic theory for the purpose of investigating a new class of radiation, propagation, and scattering problems.

These properties of fractal designs are utilized in fractal antenna designing for achieving wideband/multiband behavior. The fractal theory approach has been used as a size compression technique for all types of antennas such as dipoles, loops, patches and so on leading to the development of fractal antenna.

In this paper different fractal geometries such as Sierpinski fractal antenna, koch, Microstrip fractal antenna, Sierpinski Carpet antenna , their design issues are discussed regarding to Wireless communication is discussed.

Multi-band operation could be achieved by using multiple antennas only. Now a days, a single small fractal antenna can be used for multiband performance because of its self-similarity structure at different scales[ ]

A number of fractal shaped antennas have been developed like Sierpinski gasket, Sierpinski carpet, Koch loop, Cantor slot patch etc. In past years. Implementation of these fractal geometries to antenna arrays has proved to be very useful. In 1986, the thinned fractal linear and planar array, the first application of fractals to the antenna design was studied by Kim. After Kim, Werner worked on the same concept in 1996[3-6]. In 1995, Cohen designed the first antenna element using the Koch monopole and Koch dipole fractal geometry by bending the wire in a systematic way using the concept of fractals. Sierpinski gasket, fractal shape, named after Polish mathematician Sierpinski was desinged an antenna by Puente in 1998[7-8]. Hohlfeld demonstrated that the positions of frequency bands can be changed by changing the scale factor. Later on, Xu designed the fracta tree which could give better results as compared to Sierpinski gasket [10,11]. In 2001, Yeo and Gianvittorio studied some other applications of fractals concept to patch antenna design [12,13].

In 2002, Gianvittorio ans Sammii defined the fractlas as small space filling geometries, having electrically large length which easily fits into smaller areas. In 2004, Petko presented new design methdologies for fractal tree shaped antennas and studied their behavior.In 2005, the vrious characteristic of Silicon fabricated Sierpinski dipole antenna was studied by Kikkawa and Kimato. Lui introduced the printed fractal slot antennas [15-16], Sachendra Sinha considered a new fractal with self-affinity property in 2007. Ananth Sundaram implemented Koch recursion techniqueon foldd slot antenna[17-18].In 2008, Mahdi used Penta-Gasket-Koch approach to introduce a new planar monopole antenna with 3^{rd} iteration. Wen-Ling Chen successfully reduced the size of microstrip patch antennas by combining Sierpinski and Koch fratal shapes [19,20]. In 2009, Hatem Ramili designed a two dimentional irregular fractal antenna for multiband performance of the antenna measured over 1-30 GHz frequency range. Wen-Ling Chen enhanced the bandwidth of fractal slot antenna by giving microstrip line feed to it [23]. In 2011, Mima Bayatmaku designed a new E-shaped fractal

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antenna with probe feed for Mobile Communication application.

Javed proposed a modified fractal Pythagorean tree for Ultra Wide Band bow-tie antenna with the help of Koch like curve for better radiation t higher frequencies. Ham Byul Kim successfully impemented a two port fractal slot antenna as a gap filler antenna for communication [26,27].

Fractals are the class of geometrical shapes composed of multiple iterations of a single elementary shape. The fundamental building blocks of fractals are the scaled versions of the fractal shape. The application of fractals can be found in various fields such as image compression algorithms, weather prediction , integrated circuits, filter design, fractal electrodynamics and other disciplines. Fractal electrodynamics is one of the major applications of fractals in which fractal geometry is combined with electromagnetic theory to explore new class of radiation , propagation and scattering problems.Antenna theory and design have become one of the most promising areas of fractal electrodynamics research.

Among several properties that characterize fractals, self-similarity/ self-affinity and space filling properties are of interest in terms of antenna design. The image is reduced by same structure under different scales. The image is reduced by same factor in all directions in self- similarity but self-affine fractal has different scale factor for different directions.

II. FRACTAL GEOMETRIES

A. Some Useful Geometries for Fractal Antenna Engineering

This section will present a brief overview of some of the more common fractal geometries that have been found to be useful in developing new and innovative designs for antennas. The first fractal that will be considered is the popular Sierpinski gasket [9].

The first few stages in the construction of the Sierpinski gasket are shown in Figure 1. The procedure for geometrically constructing this fractal begins with an equilateral triangle contained in the plane , as illustrated in stage 0 of Figure 1. The next step in the construction process (see stage 1 of Figure 1) is to remove the central triangle with vertices that are located at the midpoint of the sides of the original triangle, shown in stage0.

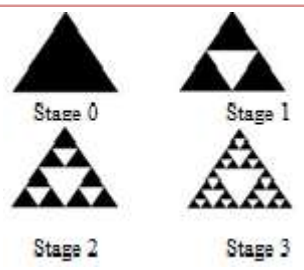

Figure 1. Several stages in the construction of a Sierpinski gasket fractal [42].

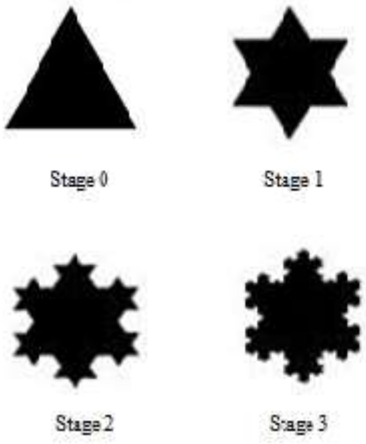

Figure 2. The first few stages in the construction of a Koch Snowflake [42].

This process is then repeated for the three remaining triangles, as shown in Stage 2 of Fig. 1. The next two stages (i.e. Stage 3 and 4) in the construction of Sierpinski gasket fractal are shown in Fig. 1. The Sierpinski gasket fractal is generated by carrying out this iterative process an infinite number of times. It is easy to see from this definition that the Sierpinski gasket is an example of a self-similar fractal. From an antenna engineering point of view, a useful interpolation of Fig. 1 is that the black triangular areas represent a metallic conductor, whereas the white triangular areas represent regions where metal has been removed[42].

Another popular fractal is known as the Koch snowflake[9]. This fractal also starts out as a solid equilateral triangle in the plane, as illustrated in Stage 0 of fig. 2. However, unlike the Sierpinski gasket , which was formed by systematically removing smaller and smaller triangles from the original structure, the Koch snowflake is considered by adding smaller and smaller triangles to the structure in an iterative fashion [42].

Some of the more common fractal geometries that have found applications in antenna engineering are depicted in figure 3. The self-similar structure of Sierpinski gaskets and carpets has been exploited to develop multi-band antenna elements.

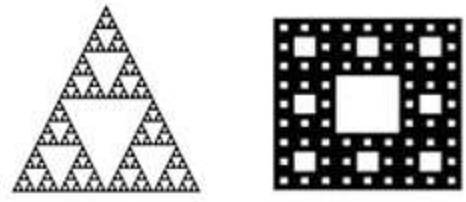

Figure 3. Some common fractal geometry found in antenna applications. Sierpinski gaskets and carpets , used in multiband antennas[42].

B. SIERPINSKI GASKET GEOMETRI

The Sierpinski gasket is named after the polish mathematician Sierpinski. He described the properties of this fractal design in 1916 [11]. The design is obtained by subtracting central part of the main triangle with an inverted triangle. After the subtraction, three equal triangles remain on the structure, each one being half of the size of the original one. Iterating the same subtraction procedure on the remaining traingles infinite number of times, the ideal fractal Sierpinski gasket is obtained. Fig. 1 shows the different iteration stages of Sierpinski gasket design. And Fig. 4 shows the design of Sierpinski monopole.

Description : An equilateral triangular Sierpinski gasket conductor structure is the main body of the antenna. The antenna is printed over a thin dielectric substrate (εr = 2.17, h=0.127 mm) and mounted upside-down over a 80 *

80 cm square conductor ground plane (Fig. 1). Such a monopole configuration is chosen because it greatly simplifies the antenna feeding scheme, which can be easily implemented by mounting a coaxial probe through the ground plane[42].

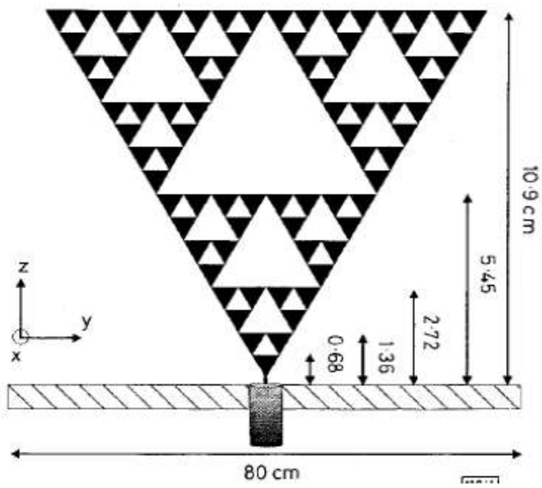

Figure 4 . Sierpinski Monopole [42]

The fractal shape is constructed with five iterations. That is, the Sierpinski triangle appears at five different scales within the main structure. There is a factor of two between scales, which means that the Sierpinski triangle heights are 10.9, 5.45,2.72,1.36 and 0.68 cm. This particular shape has been chosen owing to its similarity to the well known bow-tie antenna. Since the triangular like shape appears at five different scales. It could be expected that the Sierpinski antenna would behave similarly to a trinagular antenna but at five different bands[42].

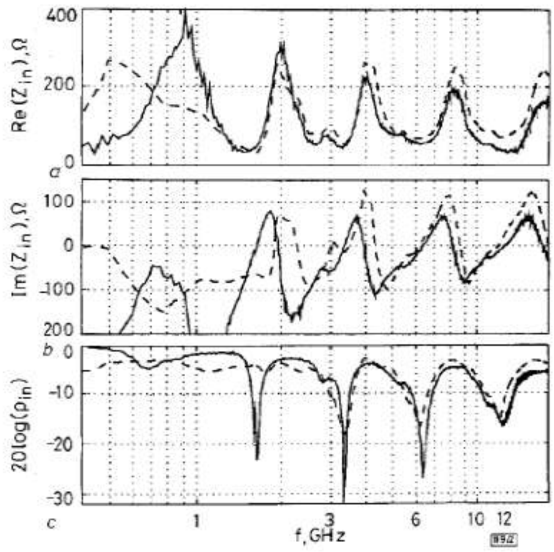

Fig. 5 . Input impedance and input reflection coefficient [42]

All three plots clearly show a log-periodic behaviour, and the log-period (ɗ) is a factor of two. In particular, the antenna is matched at five bands. 12.6,6.4,3.3,1.62 and 0.64 GHz. While pin is below one. Also , thsi band appears slightly shifted from its expected frequency position (0.64 GHz instead of 1.62/ ɗ= 0.81GHz). Both phenomena are also predicted by the numerical analysis and are likely caused by the truncation of the fractal shape, which can be implemented with an arbitrary number of scales and iterations. The truncation effect can also be related to the slight frequency shift and the worse matching of the upper band.

Advantages

Small in size

Better input impedance

Wideband/multiband support

Consistence performance over huge frequency range

Added inductance and capacitance without components

Disadvantages

Fabrication and design i little complicated.

Lower gain in some cases

Numerical limitations

Sierpinski gasket antenna is a representative fractal antenna. Usually , it is inverse triangle configuration upto three iteration. The material used for synthesis is FR-epoxy

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with permittivity (4.4) and dielectric loss tangent (0.02) is presented []. The capacitive feed is used in this study. These configurations cause alignment issues while assembling and hence may increase the production cost. The capacitive feed strip in the proposed antenna is optimized to a set of much smaller dimensions to improve the bandwidth and to reduce spurious radiations and also improves the return loss.

A capacitive feeding technique is used which is very common technique used for fractal antennas. The coaxial probe feed is the most popular one for electrically thick substrate; but the inductance of the probe may create the impedance mismatch which can be compensated by cutting slots on the patch, modifying the probe or by introducing a capacitive feed. It gives best performance having bandwidth and with good broadside radiation patterns throughout this band. Fig. 6 shows probe feeding mechanism.

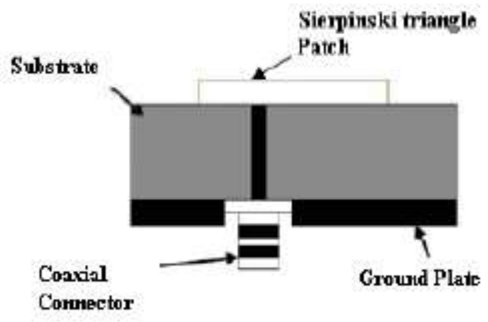

Fig. 6 Construction of Probe feeding mechanism [41]

The simulation analysis of small planar antennas using different antenna miniaturization technique presented [41] . These techniques are used to reduce the physical size but to increase the bandwidth and efficiency of antenna some approaches for antenna miniaturization are introduction of slots, slits, short meandering and novel geometries like fractals or by using higher dielectric constant. The effect of miniaturization in various antenna parameters like radiation efficiency , gain, bandwidth are discussed.

The operating frequency irreconcilability for sierpinski gasket fractal antenna presented [40,41] . This design may be a good candidate for RF over fiber (RoF) systems in which the built in optical systems have already been included. Doped silicon with a suitable laser light is considered as a switching component. The most efficient frequency reconfigurable method is using the optically controlled devices which do not require any interfering conducting lines carrying power control signals. illuminating points.

III. CONCLUSIONS

In case of triangular fractal antenna experimental and computed results on a novel fractal multiband antenna have been reported. The fractal antenna has shown a notable degree of similarly with five bands, the same number of scales over which the fractal structure appears similar. Thus, it can be concluded that the geometrical self-similarity properties of the fractal structure have been translated into its electromagnetic behavior. A set of Sierpinski triangle antennas using a coplanar capacitive feedstrip has been presented in this paper. This antennas gives best performance having bandwidth and with a good broadside radiation pattern throughout this band. In sum, the multiband fractal triangle antenna is a novel multiband antenna with broad prospect of application. It is used in mobile communication (2.4 GHz), RADAR (3-30 GHz), WLAN (2.4- 2.483 GHz) , UWB (3.1- 10.6 GHz). An analysis is performed to examine the parameters of antenna with a frequency range in between 1 GHz to 6 GHz.

A novel reconfiguration method for Sierpinski monopole antenna has been presented. The known advantages of fractal antennas have been further improved by utilizing the optical reconfigurability option.Optically re configurable Sierpinski gasket antenna is presented to obtain dynamically different resonance frequencies without changing the physical antenna dimension for RoF systems.

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