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Miniaturization of Antenna Using Fractals

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ABSTRACT

The wireless industry is witnessing an volatile emergence today in present era. Today antenna systems demand versatility and unobtrusiveness. Operators are looking for systems that can perform over several frequency bands or are reconfigurable as the demands on the system changes. Some applications require the antenna to be as miniaturized as possible. Fractal plays a prominent role for these requirements. Fractals have non-integral dimensions and their space filling capability could be used for miniaturizing antenna size and their property of being self-similarity in the geometry leads to have antennas which have a large number of resonant frequencies. Fractal antennas also have Multiband performance is at non-harmonic frequencies. Fractal Euclidean geometries could be applied to shape Fractal antennas have improved Impedance, improved SWR(standing wave ratio) performance on a reduced physical area when compared to non of fractal antenna to make it to resonate at different frequency.

In this paper Koch fractals with different iterations have been generated using MATLAB. Koch fractal of length 5.1c.m. With different iterations as a monopole antenna have been simulated using MATLAB and EZNEC code which is a MININEC code, and show the desirable advantages of fractal antennas. Different three iteration Koch fractal monopoles have been studied for GSM900 band.

Keywords: Fractals, Antenna Miniaturization, Koch Fractals, Iteration, IFS

1. INTRODUCTION

A fractal is defined as meaning broken, uneven: any of various extremely irregular curves or shape that repeat themselves at any scale on which they are examined. Although fractals are mainly discussed in mathematical forums, they exist in all parts of nature. For example Mandelbrot [5] discusses the basics of fractal theory as applied to the characteristics of a coastline(see Figure 1). The length of a coastline depends on the size of the measuring yardstick. As the yardstick we use to measure every turn and detail decreases in length, the coastline perimeter increases exponentially.

As the view of a coastline is brought closer, we discover that within the coastline there lie miniature bays and peninsulas. As we examine the coastline on a rescaled map, we discover that each of the bays and peninsulas contain sub-bays and sub-peninsulas. There is a self-similar trait observed as we look at the coastline at various resolutions. The numbers of microscopic structures begin to approach infinity. In fact, because of the large number of irregularities, the physical length of a coastline is virtually infinite.

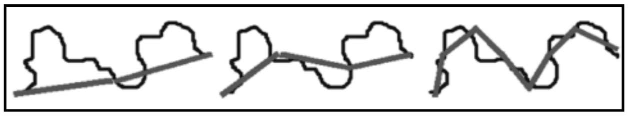

Fig 1: Coastline of Britain

These pictures represent an imaginary coastline of Britain. The red lines are rulers being used to measure the length of the coastline (L). These rulers are of the length S. Using the first ruler we see that it $L = 2 * S$. When we decrease the length of S the number of times that S is used increases. What these rulers illustrate is that as the size of the measuring device becomes smaller the accuracy of the measurements becomes more and more accurate. From this fact we can assume that eventually we will be able to get an exact measurement of the coastline. This statement is false. As we decrease the size of the measuring device the length that we have to measure becomes greater. We can see this by zooming in on the coastline. As we get closer and closer we will notice that it looks very similar to how it looked from a greater distance away. Only now we are much closer. These observations show the self similarity of the coastline. Therefore as we decrease the size of the measuring device the length of the coastline will increase without limit. Thus, showing us its fractal nature. Self similarity (seen in the coast example above) is defined by structures that look the same at variable magnifications. This recurring self-similarity is one of the many attributes of many fractals. Much like the coastline described above, any small part in a self-similar fractal is going to look exactly like the fractal as a whole. The example of coastline shows that the coastline has a dimension greater than 1 but less than 2.

2. OBJECTIVE

The objective of this paper is to generate Koch fractal for different iterations using MATLAB & to generate a Koch fractal monopole of length 5.1c.m. of zero, one, two iterations using MATLAB.To plot frequency versus impedance plot of fractal monopole with zero, one, two iterations for showing the multiband behavior at non-harmonic frequencies of fractals. In this paper antenna miniaturization can be done using Koch fractal GSM900 band.

3. PROBLEM OF DEFINING DIMENSIONS

The complexity of defining dimensions can be summarized in the following visualization depicted in figure2, of a microscopic fly flying towards a piece of paper[7].The fly starts out very far from the object in figure 2(a),thus it appears as a zero dimensional peck. As the fly gets closer, in figure 2(b), the speck begins to elongate into a one dimensional line. Upon flying over the line, in figure 2(c), the fly sees that it is actually a two dimensional plane. Flying even closer in figure 2(d). the fly sees that the plane has a depth to it. as well, forming a three dimensional prism, followed by flying closer still, sees only a two dimensional plane. Finally the fly flies into the piece of paper, seeing a one dimensional network of fibers.

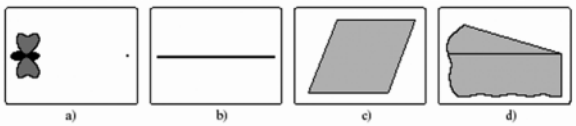

Fig 2: A Fly Flying Towards a Piece of Paper from Very Far Away Reveals the Problem of Defining Dimensions

Therefore there is a need for a geometry that handles these situations better than Euclidean geometry. Euclidean structures have whole number dimensions, such as one dimensional line or a two dimensional plane. Benoit Mandelbrot first defined the term "Fractal" meaning fractal dimensions in 1975 to handle geometries with dimensions that do not fall neatly into a whole number category.

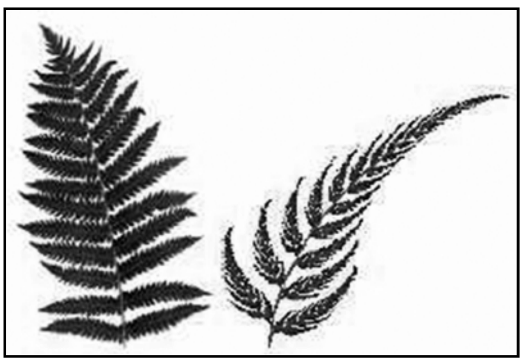

Fig 3: A Fern is a Common Example of a Geometry in Nature that is Easily Modeled using Fractal Geometry

One property of a certain class of fractals (as shown in the example of coastline),is the unique property that it can have an infinite length while fitting in finite volume. Fractals are structures of infinite complexity with a self similar nature.This means that as the structure is zoomed in upon the structure repeats .There never is a point where the fundamental building blocks are found . This is because the building blocks themselves have the same form as the original object with infinite complexity in each one. An example of this in nature can be seen in a fern, shown in figure.

4. SOLUTION METHODOLOGY

The intent of work is to use the fractal antenna, to minimize shape & size of Koch fractal antennas using random methodology.

Fractal curves have infinite length in a finite square of $R2$ [13]. To characterize the topological properties of fractal structures, usual length measurement is not adopted. In 1919 Hard off introduced anew definition of dimension based on the size variation of sets when measured at different scales [14]. Let S be a number N(s) of balls of radius s to cover S. If S is a set of dimension D, with a finite length (D=1), surface (D=2) or volume (D=3), then $N(s) = s^{-D}$ so $D = -\text{limit inf} \log N(s)/ \log(s)$, here s app 0.

It may be either finite or infinite. The simplest well known examples of fractal sets are koch curve and triadic cantor set. The former is obtained by recursively dividing each segment of length l in four segments of 1/3. Each subdivision increases length by 4/3.The limit of these subdivisions is therefore a curve of infinite length and its fractal dimension is D>1. We need $N(s)= 4^n$ balls of size $s= 3^{-n}$ to cover the whole curve, Hence

$$N(3^{-n}) = (3^{-n})^{\log4/\log3}$$

Therefore $D = \log4/\log3$

Function $y = F(x)$ is called fractal if its plot is a fractal set [15].

5. SIMULATION METHOD

There are a number of commonly available software packages which allow the simulation of antenna parameters known are SONNET, XFDTD, HFSS and various packages based on the NEC2 code. XFDTD and HFSS are excellent professional design tools which offer a great deal of simulation flexibility and analysis options. It uses the Mom technique to simulate 2D surfaces including traces on dielectric layers, which is essential for micro strip antenna modeling. The software is user-friendly and with some effort it can be used to model realistic structures despite the feature limitation. Software based on the NEC2 code is freely available. NEC2 uses 1D MoM, which allows modeling of wire structures. The geometry of the pre- fractal is first mathematically defined either by hand or using recursive loops in Mat lab. The geometry is then fed into a moment method code EZNEC code or MMANA code which is different versions of NEC. The modeling process is simply done by dividing all straight wires into short segments where the current in one segment is considered constant along the length of the short segment. These codes solve for the surface currents generated on perfectly conducting surfaces or thin wires or combinations of both. From these currents, the far field patterns and input impedances can be determined.

Simulation Results

To demonstrate the behavior of fractal antenna, a Koch fractal monopole antenna of 5.1c.m. length and with wire radius 0.1m.m.,up to two iteration has been simulated. Koch fractal with zero, one and two iterations has been generated by Mat lab and simulated using EZNEC code. EZNEC is based upon the method of moments in which the electromagnetic interactions between wire segments can be analyzed.

Figure below shows koch curves,fig 4 shows curve for zero iteration,fig 5 shows for one iteration, fig 6 koch curve for two iteration.

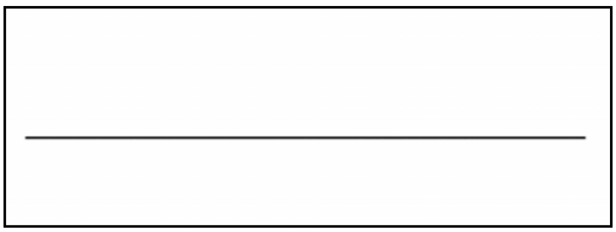

Fig. 4: Koch Curve with Zero Iteration

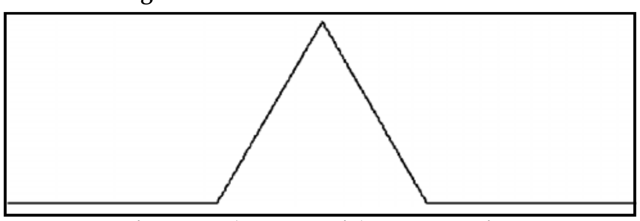

Fig. 5: Koch Curve with One Iteration

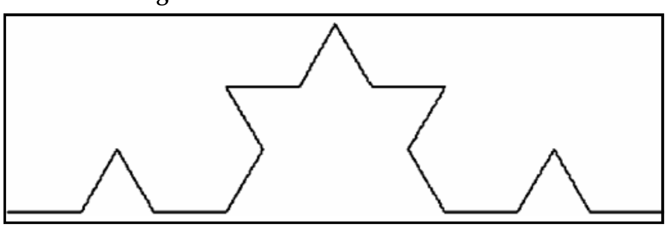

Fig 6: Koch Curve with Two Iterations

Fig 7 graph show the freq versus impedance plot for 5.1c.m.long Koch fractal monopole with zero iteration. As we increase the iterations number of resonant frequency increase, is obvious from the graphs that as iterations is increased the number of times Imaginary part of impedance becomes zero increases. This demonstrates that as number of iteration increases, more and more resonant frequency are there leading to a multiband antenna. This is due to the coupling between the wires. As more contours and iterations of the fractal are added, the coupling becomes more complicated and different segments of the wire resonate at different frequencies.

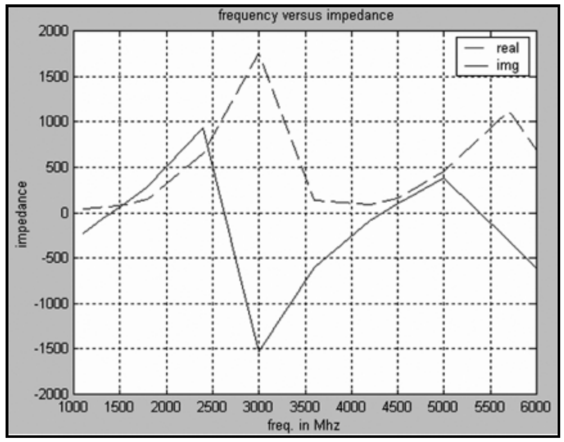

Fig. 7: Frequency Versus Impedance Plot for 5.1c.m. Long Koch Fractal Monopole with Zero Iteration

GSM900 operates at frequency range 890-915Mhz. for uplink communication and 935-960Mhz. for downlink communication. A monopole on a perfect ground having resonance at 925Mhz is required. The Koch monopole exhibits excellent performance at 925 MHz and has radiation properties nearly identical to that of traditional, straight-wire monopoles at that frequency. The radiation pattern is very uniform in all directions the greatest advantage of the Koch monopole the Koch monopole design is compactness. A size reduction of nearly 50% was achieved over the straight-wire,l / 4 free-space monopole. This is highly significant for applications such as monopole, it could GSM cellular phones Since it is half the size of the traditional easily be completely integrated within the case of the phone, eliminating the protruding monopoles commonly seen on many cellular phones.

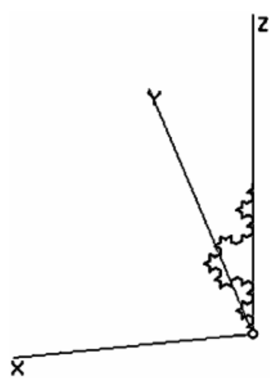

Fig. 8: Three Iteration Koch of Length 4.1cm.with Source at Bottom on a Perfect Ground

6. CONCLUSIONS

Fractal antenna incorporated into GSM handsets has been purposed. The project involves simulation of Koch fractal antennas. Several Koch fractal antennas have been simulated using MATLAB, EZNEC and MMANA codes. The results shows the Multiband performance of fractal antennas at non-harmonic frequencies, improved impedance, improved SWR(standing wave ratio) performance on a reduced physical area when compared to non fractal Euclidean geometries, Compressed Resonant behavior, broadband characteristic, improved reliability and the biggest advantage their size reducing capability, Size can be shrunk from two to four times with surprising good performance and with each iteration the number of resonant frequency increases. Perturbation could be applied to shape of fractal to make it to resonate at different frequency. Results shows that Koch fractal monopole are an excellent alternative to traditional antenna systems in mobile wireless receivers The Koch monopole exhibits excellent performance at 925 MHz and 1800Mhz and has radiation properties nearly identical to that of traditional, straight-wire monopoles at that frequency. The radiation pattern is very uniform in all directions. It is consistent with the classic doughnut shape characteristic of the straight wire l / 4 monopole, and consequently that of the l / 2 dipole. The greatest advantage of the Koch monopole design is compactness. The Koch monopole design has excellent impedance bandwidth, allowing some flexibility in Koch the types of applications where it could be used. Thus the monopole presents an excellent, compact solution to the traditional straight-wire monopole antenna.

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