IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 11, Issue 3, Ver. I (May-Jun .2016), PP 29-32
www.iosrjournals.org

Reconfigurable Koch Loop Fractal Antenna Using RF Switch

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Abstract: *A new reconfigurable koch loop fractal antenna model has been proposed and its properties discussed using HFSS software. The Patch version was figured using the first order Koch loop. By introducing patches of koch loop shapes, the antenna with different radiation patterns were formed using RF switches to switch between the configurations. The radiation pattern has been reconfigured. The proposed antenna will examine the reconfigurability of Koch loop for different resonant frequency.*

Keywords: *reconfigurable antenna, fractal antenna, Koch loop shape, RF switch.*

I. Introduction

The rapid expansion of wireless technology during the last years has led to increase in demand for small size, low-cost and multiband antennas for use in commercial communications systems. Fractal antenna [1] is one such category. These are composed of multiple iterations of a single elementary shape. They are used to describe a family of complex shapes that possess an inherent self-similarity and self-affinity in their geometrical structure. Such as Sierpinski fractal antenna, tree-shaped fractal antenna, snowflake fractal antenna, Koch fractal antenna etc.

The Koch fractal loop is one of the most well-known fractal shapes. Swedish mathematician Helge von Koch proposed the Koch curve in 1904 [2]. If Koch generator is applying to an equilateral triangle, after infinite iterations, a Koch snowflake structure is obtained which is smaller than other patch geometries [3].

Though these antennas reduce the size and cost, but in case of communication system many applications are used that works at different frequency band hence a single fractal antenna cannot be used to serve the purpose of the whole communication system. To resolve this issue reconfigurable antennas have been proposed. These antennas resonate at different frequencies at different time by using switches. They have remarkable characteristic of achieving diversity in operation, meaning that one or multiple parameters, including operating frequency, radiation pattern, gain and/or polarization, can be reconfigured a single antenna [4]. Compared to conventional antennas, reconfigurable antennas provide the ability to dynamically adjust various antenna parameters. By means of switches with compatible antenna elements the antenna and its feed structure can be physically reconfigured to provide radiation pattern, frequency band and polarization diversity so they have more advantage to compare with conventional antennas [5]. The most prevalent implementation about reconfigurable antenna is related to the operation frequency [3] since it might be the easiest feature to alter. Polarization and pattern reconfigurable antennas are also attractive since they can provide diversity features which leads to an increased signal to noise ratio and therefore a higher quality of service of whole systems [6-8].

The approach adopted in this paper combines koch loop fractal geometry and reconfigurability in order to come up with a new antenna design suitable for several wireless applications. This will help obtain a resonance at a lower frequency without increasing the overall antenna dimensions.

II. Fractal Geometries

Fractals are all around us. Fractals are self-similar objects and possess structure at all scales. Two examples of naturally occurring fractal geometries are snowflakes and boundary of geographic continents. Several naturally occurring phenomena such as lightning are better analyzed with the aid of fractals. One significant property of all these fractals is indeed their irregular nature. Some examples of fractals are given in Fig. 1.1.

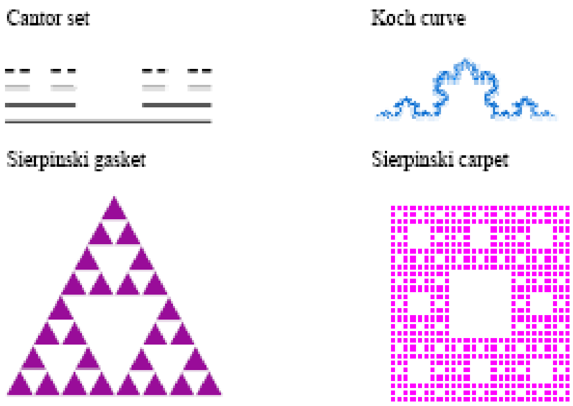


Figure: 1.1 some common examples of fractals

Most of these geometries are infinitely sub-divisible with each division a copy of the parent. This special nature of these geometries has led to several interesting features uncommon with Euclidean geometry. Fractal is defined as set F such that [39]:

* F has a fine structure with details on arbitrarily small scales,
* F is too irregular to be described by traditional geometry
* F having some form of self-similarity (not necessarily geometric, can be statistical)
* F can be described in a simple way, recursively, and
* Fractal dimension of F greater than its topological dimension

Dimension of geometry can be defined in several ways such as topological dimension, Euclidean dimension, self-similarity dimension and Hausdorff dimension. Some of these are special forms of Mandelbrot's definition of the fractal dimension. However the most easily understood definition is for self-similarity dimension. To obtain this value, the geometry is divided into scaled down dimension but identical copies of itself. If there is n such copies of the original geometry scaled down by a fraction *f*, the similarity dimension *D* is defined as:

$$D = \frac{\log n}{\log(1/f)}$$

For example, a square can be divided into 4 copies of ½ scale, 9 copies of ⅓ scale, 16copies of ¼ scale, or n^2 copies of $1/n$ scale. Although this approach is very convenient for many such geometries but all fractals are not suitable for this approach. Such is the case with most plane-, or space-filling fractals. In these cases more mathematically intensive definitions such as Hausdorff dimension are required. Many fractal geometries are self-similar, a property, which makes easier to compute accurately their Hausdorff dimension. Fractal geometries are generally infinitely sub-divisible. Self-similar sets defined by linear contractions are called Self-affine sets.

Koch curve is a good example of self-similar space-filling fractals which have been used to develop wideband/multiband and/or miniaturized antennas. The first four iterations of Koch curve are shown in Fig. 1. In [9], it was shown that self-similar fractals affect the electromagnetic properties of antennas created on the basis of these geometries, and that Koch fractal antennas are multiband structures. The authors of [10] related multiple resonant frequencies of Koch fractal antennas to their fractal dimension. In [11], a dual wide-band CPW-fed modied Koch fractal printed slot antenna, suitable for WLAN and WiMAX operations, was proposed.

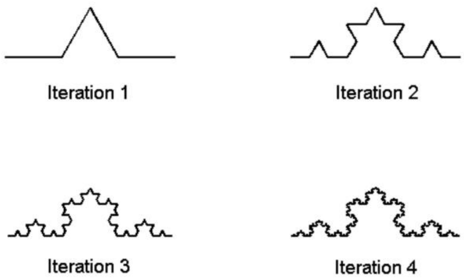
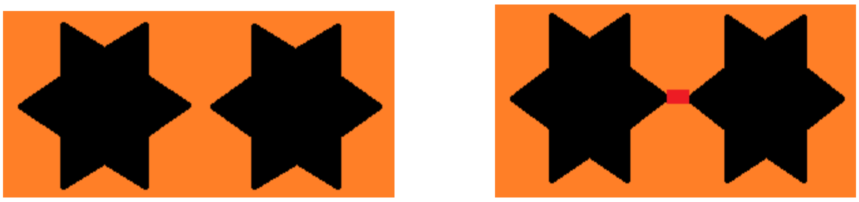


Figure 1. The first four iterations in the construction of the standard Koch curve.

In [12], Koch fractal dipoles were introduced as the basic structural elements of a planar Log-Periodic Koch-Dipole Antenna (LPKDA) array, thus replacing the full-sized Euclidean monopoles. Compared to the Euclidean LPDA, the proposed design revealed very similar characteristics, while achieving 12% less space. Another Koch-based antenna-size compacting scenario was proposed in [13]

III. Antenna Configuration

In this case, the reconfigurable patch module consists of a 1x2 array of koch loop patches connected together by the RF diodes switches as depicted in Fig.2. The *ON* state represents a short circuit, while the *OFF* state exhibits an open circuit. On one hand, when all switches are in the OFF state, the total radiation pattern is contributed from the pattern radiated by each small patch (Fig.1 (a)); as a result, the antenna resonates at a higher frequency band. On the other hand, when all switches are turned ON, the antenna effective area is the entire area of a 1x2 patch array. Accordingly, the antenna resonates at a lower frequency band (Fig.1 (b)). Further, it is found that the total radiation patterns are nearly identical between the two states of the switch operation.



(a) OFF Configuration (b) ON Configuration

Fig.1: Top views of a 1x2 patch antenna array fabricated on a substrate.

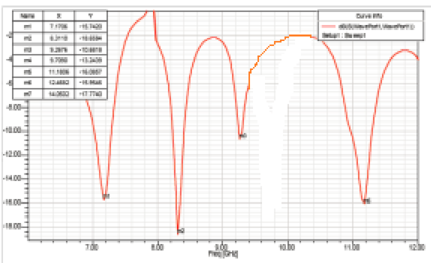
The koch loop patches are connected by the RF switches. The antenna operating frequency could be modified by activating the RF switches.

For the purpose of reconfiguration, four RF switches R_1-R_4 are used. Antenna is fed with a 50Ω coaxial cable. Reference Antenna used is designed on FR4 epoxy substrate having dielectric constant = 4.4, loss tangent δ=0.0025 and thickness = 1.3 mm. During modeling of RF switch, when switch is on, it is represented by copper strip (1mm×1mm) and when switch is off, no copper strip is used.

The proposed antenna has been studied in two modes- mode I (switch OFF) and mode II (switch ON). The goal is set to design a reconfigurable koch curve antenna that can operate at any frequency in the X-band as per requirement. In this application the bandwidth of the planar dipole is approximately 8.5%. The arms of the patches are connected with RF switches to additional patches. The basic function of the switches is to conductively couple the additional metallic patches thus extending on-demand each arm's length. When the switch is OFF, patches couple capacitively with the main arm. This increases the bandwidth. When the switch is ON, the patches are connected to the antenna's arms via the continuous metallic path that switch provides through its membrane. To avoid unnecessary discontinuities in the structure, the dipole is set to have the same width as the switches.

IV. Result And Discussion

Simulated results presented here are after HFSS software. The antenna has been optimized for two modes using different switch position. The resulting computed return loss plots are shown in Fig.2 and Fig.3.



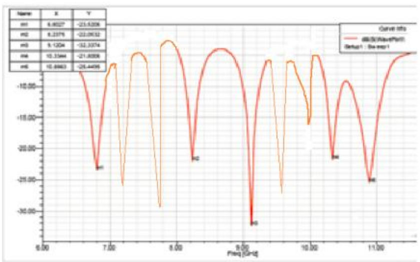


Fig.2. Performance of antenna at Mode I. Fig.3. Performance of antenna at Mode II

Incremental properties of koch loop gives increase in resonant frequency. The observed result is tabled in table 1.

Mode	Antenna Parameters				
	Resonant freq.(GHz)	VSWR	Return loss(dB)	Peak gain	Peak Directivity
I	7.17	1.4	-15	5.17	4.29
	8.31	1.26	-18	5.97	5.54
	11.18	1.3	-16	1.05	4.69
II	6.80	1.14	-23	12.6	6.38
	7.17	1.19	-24	5.17	4.29
	7.79	1.1	-27	5.18	4.58
	8.23	1.17	-22	2.96	6.94
	9.12	1.04	-32	6.91	6.8
	9.60	1.21	-26	7.8	7.5
	9.98	1.28	-16	5.4	8.45
	10.33	1.17	-21	2	8.73
	10.88	1.11	-25	1.60	5.95

Table 1: Antenna parameters in the two modes

V. Conclusion

A new type of koch loop reconfigurable antenna is discussed. Switch has been used to control the different resonant frequencies of the antenna. The resonant frequency changes with state of switch. The multiband behavior is obtained with improvement of the return loss due to change of switch operation. The bandwidth of the antenna also gets increased with different mode of operation. Improvement in VSWR is also observed. The radiator gives multiband properties to fractal geometry antenna with directive patterns.

The proposed hybrid reconfigurable fractal antenna is a novel compact, simple, multiband and reconfigurable. The antenna presents three resonant frequencies if non-reconfigurable fractal configuration is used, but by using reconfiguration concept this antenna can resonate at nine different resonant frequencies in mode II. The proposed reconfigurable antenna can be of great use in satellite communications, medical imaging, microwave imaging applications, vehicular radar applications and wireless industry applications.

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