Multiband Cross Dipole Antenna Based On the Triangular and Quadratic Fractal Koch Curve

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Abstract

This paper present the analysis and design a small size, low profile and multiband fractal cross dipole antenna. The proposed antenna design, analysis and characterization had been performed using the method of moments (MoM) technique. The new designed antenna has operating frequencies of 0.543 GHz, 2 GHz, and 6.5 GHz with acceptable bandwidth which has useful applications in communication systems. The radiation characteristics and reflection coefficient of the proposed antenna were described and simulated using 4NEC2 software package. Also, the gain of this proposed antenna is calculated and described in the three planes are XZ-plane, YZ-plane, and XY-plane, where the antenna placed in the free space.

Keywords: cross dipole antenna, Koch curve, multiband antenna

1. INTRODUCTION

In modern wireless communication systems and in other increasing wireless applications, wider bandwidth, multiband and low profile antennas are in great demand for both commercial and military applications. This has initiated antenna research in various directions. The telecom operators and equipment manufacturers can produce variety of communications systems, like cellular communications, global positioning, satellite communications, and others. Each one of these systems operates at several frequency bands. To serve the users, each system needs to have an antenna that has to work in the frequency band employed for the specific system. The tendency during last year's had been used one antenna for each system, but this solution is inefficient in terms of space usage, and it is very expensive [1].

The term fractal means broken (fragmented), was coined less than twenty-five years ago by one of history's most creative mathematicians, Benoit Mandelbrot, whose seminal work, "The Fractal Geometry of Nature" [2]. He shows that many fractals exist in nature and that fractals could accurately model certain irregularly shaped objects or spatially non uniform phenomena in nature that cannot be accommodated by Euclidean geometry, such as trees or mountains, this means that fractals operate in non-integer dimension. By furthering the idea of a fractional dimension, he coined the term fractal. Mandelbrot defined fractal as a fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced-size copy of the whole. In the mathematics, fractals are a class of complex geometric shapes commonly exhibit the property of self similarity, such that small portion of it can be viewed as a reduced scale replica of the whole. Fractals can be either random or deterministic [3]. Since the pioneering work of Mandelbrot and others, a wide variety of applications for fractals has been found in many branches of science and engineering. One such area is fractal electrodynamics [4-8], in which fractal geometry is combined with electromagnetic theory for the purpose of investigating a new class of radiation, propagation, and scattering problems. One of the most promising areas of fractal electrodynamics research is in its application to antenna theory and design.
Fractal antennas have improved impedance and voltage standing wave ratio (VSWR) performance on a reduced physical area when compared to non fractal Euclidean geometries.

In many cases, the use of fractal element antennas can simplify circuit design. Another beneficial of fractal antennas is that, fractal antennas are in form of a printed on the circuit board (PCB) [9].

2. GENERATION OF TRIANGULAR AND QUADRATIC KOCH CURVE GEOMETRIES

Generation of Triangular Koch Curve

The method of construction of the Koch curve is illustrated in (Figure 1). The Koch curve is simply constructed using an iterative procedure beginning with the initiator of the set as the unit line segment (step n = 0 in the figure). The unit line segment is divided into thirds, and the middle third is removed. The middle third is then replaced with two equal segments, both one-third in length, which form an equilateral triangle (step n = 1); this step is the generator of the curve. At the next step (n = 2), the middle third is removed from each of the four segments and each is replaced with two equal segments as before. This process is repeated to infinite number of times to produce the Koch curve. A noticeable property of the Koch curve is that it is seemingly infinite in length. This may be seen from the construction process. At each step n, in its generation, the length of the pre-fractal curve increases to $4/3L_{n-1}$, where L_{n-1} is the length of the curve in the preceding step [10].

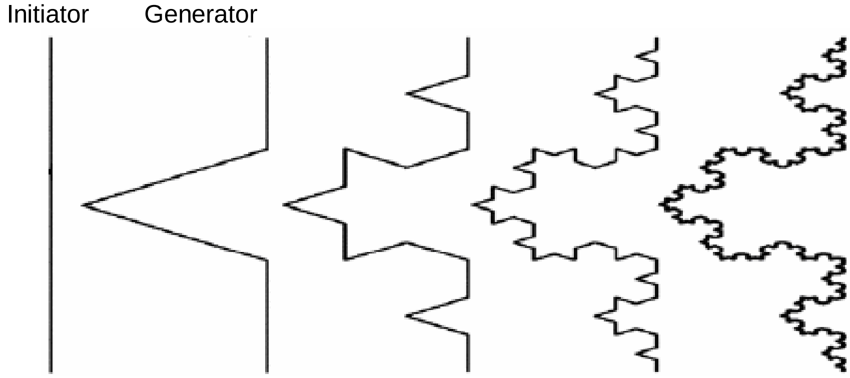


FIGURE 1: The first four iterations in the construction of the triangular Koch curve

Fractal dimension contains used information about the self-similarity and the space-filling properties of any fractal structures [10]. The fractal similarity dimension (FD) is defined as [11]:

$$FD = \frac{\log(N)}{\log(1/\varepsilon)} = \frac{\log(4)}{\log(3)} = 1.26186$$

Where N is the total number of distinct copies, and ($1/\varepsilon$) is the reduction factor value which means how will be the length of the new side with respect to the original side length.

Generation of Quadratic Koch Curve

(Figure 2) Contains the first three iterations in the construction of the quadratic Koch curve. This curve is generated by repeatedly replacing each line segment, composed of four quarters, with the generator consisting of eight pieces, each one quarter long (see Figure 2) [11]. Each smaller segment of the curve is an exact replica of the whole curve. There are eight such segments making up the curve, each one represents a one-quarter reduction of the original curve. Different from Euclidean geometries, fractal geometries are characterized by their non-integer dimensions. Fractal dimension contains used information about the self-similarity and the space-filling properties of any fractal structures [10]. The fractal similarity dimension (FD) is defined as [11]:

$$FD = \frac{\log(N)}{\log(1/\varepsilon)} = \frac{\log(8)}{\log(4)} = 1.5$$

Where *N* is the total number of distinct copies, and ($1/\varepsilon$) is the reduction factor value which means how will be the length of the new side with respect to the original side length.

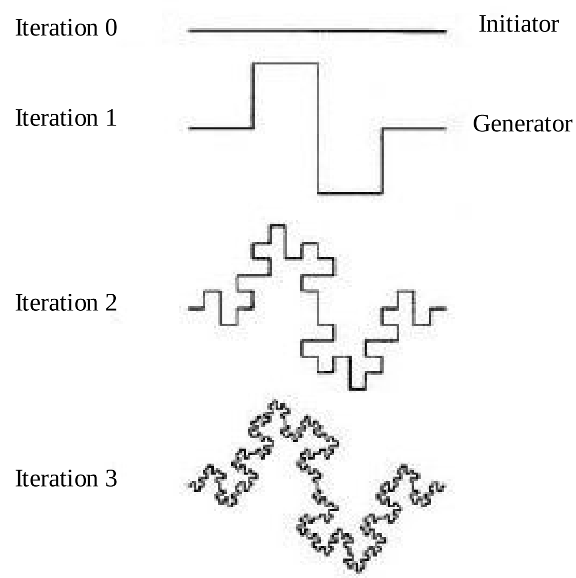
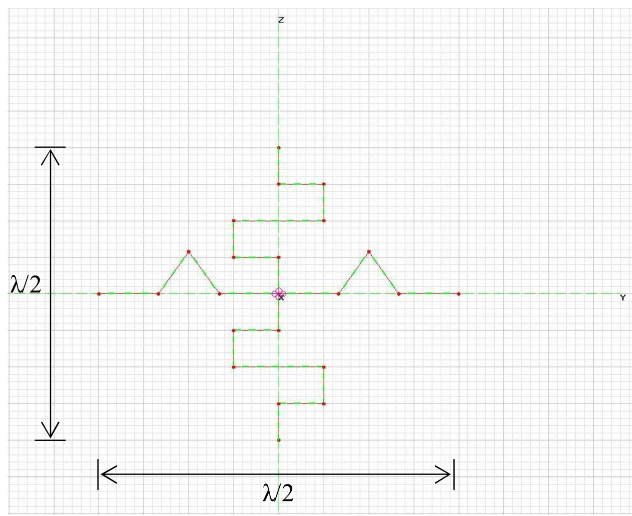


FIGURE 2: First three iterations of the construction of the quadratic Koch curve

3. PROPOSED ANTENNA DESIGN AND SIMULATION RESULTS

In this work, method of moment simulation code (NEC) is used to perform a detailed study of VSWR, reflection coefficient, and radiation pattern characteristics of the cross Koch dipole antenna in free space. The NEC is a computer code based on the method of moment for analyzing the electromagnetic response of an arbitrary structure consisting of wires or surfaces, such as Hilbert and Koch curves. The Method of Moment (MoM) is used to calculate the current distribution along the cross fractal Koch curve antenna, and hence the radiation characteristics of the antenna [12]. 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 [13]. The proposed antenna includes the replacement of each arm in the normal dipole crossed antenna in (Figure 3a) with first-iteration Koch curve geometry. The vertical arm in the normal dipole crossed antenna is replaced with quadratic Koch curve geometry while the horizontal arm in the normal dipole crossed antenna is replaced with triangular Koch curve geometry. The proposed antenna is shown in (Figure 3b). The proposed antenna is placed in YZ-plane with design frequency equal to 750 MHz. The feed source point of this antenna is placed at the origin (0,0,0), and this source is set to 1 volt. For the design frequency of 750 MHz, the design wavelength, λ_0 is 0.4 m (40 cm) then the length of the corresponding $\lambda/2$ dipole antenna length will be of 20 cm.
(Figure 4) shows the visualization of this cross dipole antenna geometry by using NEC-viewer software.

(a)



(b)

FIGURE 3: Cross Dipole Antenna (a) cross normal dipole antenna (b) proposed cross dipole antenna

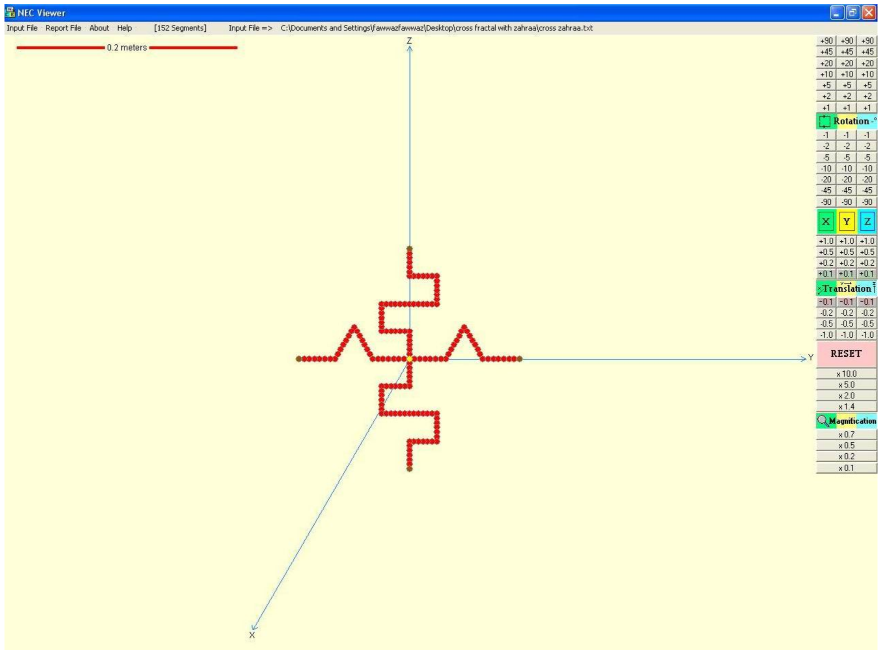


FIGURE 4: Visualization of the modeled cross fractal dipole antenna geometry

The reflection coefficient of the proposed antenna is shown in (Figure 5). it is found that the antenna has triple bands behavior at the resonance frequencies 0.543 GHz, 2 GHz, and 6.5 GHz with reflection coefficient < -10 dB.
(Table 1) shows these resonant frequencies and VSWR and reflection coefficients for each frequency, while (Table 2) shows the gain of each frequency in the three planes XZ-plane, YZ-plane, and XY-plane, where the antenna is placed in the YZ-plane.

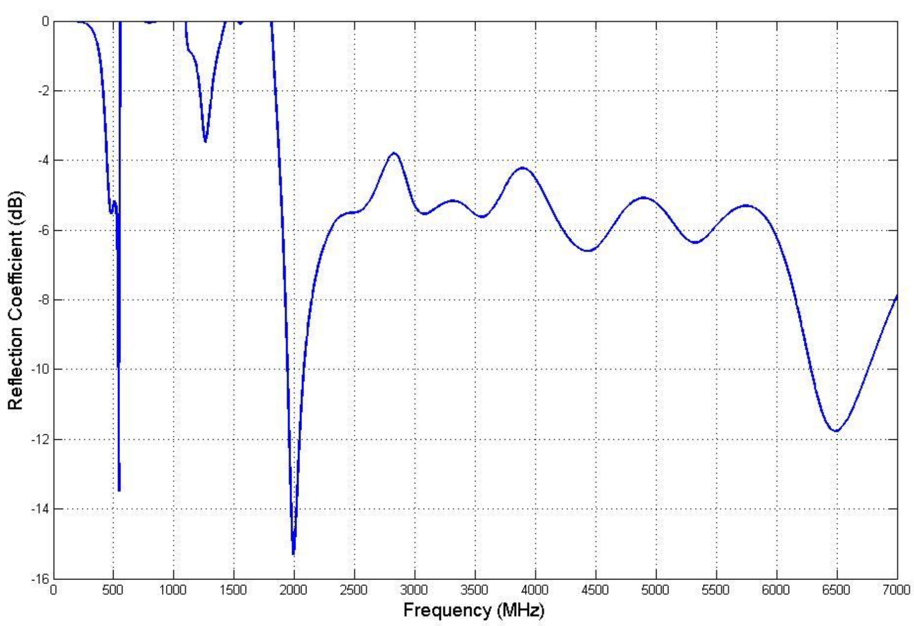


FIGURE 5: Reflection coefficients at the antenna terminals

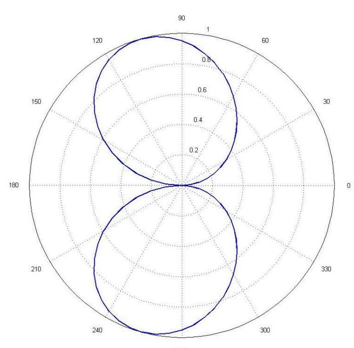
Frequency (GHz)	VSWR	Reflection coefficient (dB)	Bandwidth (GHz)
0.543	1.537	-13.487	0.009
2	1.4231	-15.159	0.14
6.5	1.696	-11.766	0.472

TABLE 1: VSWR and reflection coefficient of the Proposed Antenna

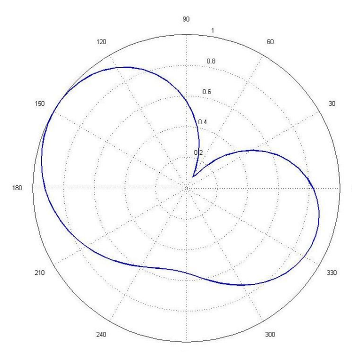
Frequency (GHz)	Gain (dBi)		
	XZ-plane (phi=0)	YZ-plane (phi=90)	XY-plane (theta=90)
0.543	2.04	1.6	1.78
2	1.85	4.42	5.1
6.5	3.57	1.74	4.75

TABLE 2: The Gain of the Proposed Antenna at the Resonant Frequencies in the Three Planes

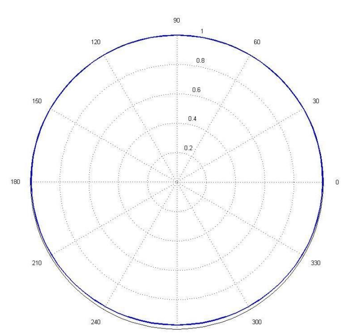
The radiation patterns at these resonant frequencies in the planes YZ-plane, XZ-plane, and XY-plane are depicted in (Figure 6), where the antenna is placed in the YZ-plane.



XZ-plane

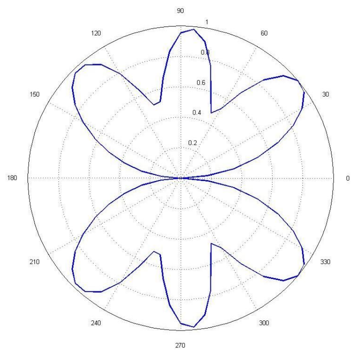


YZ-plane

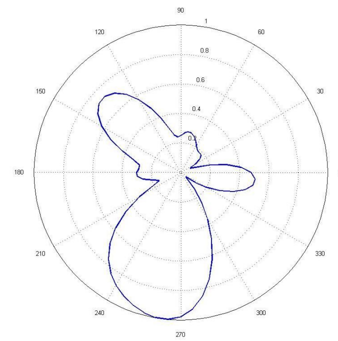


XY-plane

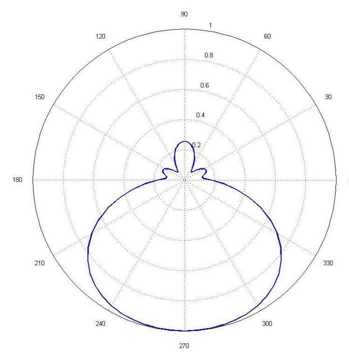
(a) f = 0.543 GHz



XZ-plane

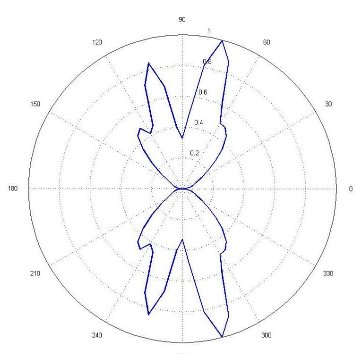


YZ-plane

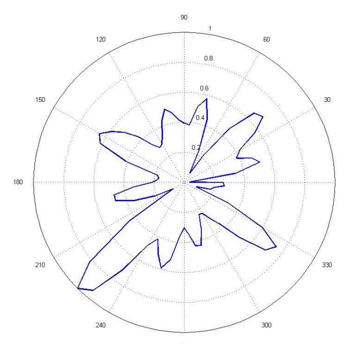


XY-plane

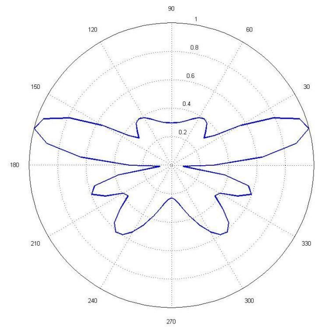
(b) f = 2 GHz



XZ-plane



YZ-plane



XY-plane

(c) f = 6.5 GHz

Figure 6 Radiation Patterns of the Modeled Antenna at Resonant Frequencies of (a) f = 0.543 GHz, (b) f = 2 GHz, (c) f = 6.5 GHz.

4. CONCLUSION

A novel small size multi-band cross dipole antenna based on a fractal first iteration quadratic and triangular Koch curve, has is presented. The analysis of the proposed antenna is performed using the method of moments (MOM), and the numerical simulations show that the proposed antenna has the ability to work as multi-band antenna at the frequencies 0.543 GHz, 2 GHz, and 6.5 GHz with acceptable bandwidth. In addition, this antenna has VSWR < 2 (reflection coefficient < -10dB) at all aforementioned resonance frequencies with high gain. The compact size of the antenna geometry makes it useful for wireless applications.

5. REFERENCES

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