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Research paper

Multi-band hybrid fractal shape antenna for X and K band applications

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Abstract

Fractal shapes has unusual properties. These unique features will affect antenna parameters when designed in fractal shapes. Two fractal shapes combined together to generate new fractal shape dipole antenna. Seirpinski and modified Koch fractal shapes allow this antenna to operate at too far apart frequencies lies in X and K band. Fractal dimension of modified Koch is found to be 1.08 which led the antenna to be electrically small. This is explaining the resonant points at higher frequencies. Uniting X and K band in single antenna will make the possibility of combining the applications of these two bands in one device. Good results have been obtained from calculating antenna parameters.

Keywords:

1. Introduction

In the past, antennas had simple shape based on Euclidean geometry and operate on single specific frequency [1]. Its parameters will change when operating on different frequencies. By the time the swift growth of the wireless mobile technology, show need to small wide band and multi band antennas [2]. A multiband antenna is designed to operate on several bands to avoid using two antennas. These antennas many times use designs where part of it is active for one band, and another part is active for other band [3]. Microstrip patch antenna is a promising choice for the future technology because of its advantages like light weight and low profile [4-6]. Fractal geometry deals with self-similar shapes that remain unchanged under different scales [7]. Combine fractal geometry with electromagnetic theory have led to access of new shapes in antenna designs [8]. The term fractal antenna is used to describe those antenna that are based on such mathematical concepts that enable one to obtain a new generation of antennas with new features [9].

In this paper, a new fractal shape dipole antenna design is proposed. The design is created by combining Sierpinski and modified Koch fractal shapes. New features obtained from this antenna shape. It exhibits a multiband behavior that is a property of Sierpinski triangle shape. The principal frequency located at X -band while the other resonant points located at k-band, which means that the antenna is electrically small so it operates at higher frequencies. This property is obtained from modified Koch fractal shape. Good computation results we get using
commercially available finite element code HFSS [10].

2. Iterated Function System (IFS) and Antenna Structure

Iterated function systems (IFS) represent a method for constructing a wide variety of fractal structures [11]. It is based on the use of a series of affine transformations (w). Mathematically written as:

w (x, y) = (ax+ by+ e, cx+ dy+ f) (1)

Where, the coefficients (a, b, c, d, e, f) are real numbers responsible for movement of fractal element. The coefficients (a, d) are responsible for scaling and (b, c) are responsible for rotation and (e, f) responsible for linear transmission. The iterated function system (IFS) of Sierpinski triangle and Koch curve has been published in literatures vastly [8]. IFS of modified Koch fractal shape that is used in our model is represented by:

$$\left.\begin{array}{l} w_1 = [\frac{1}{3}x;\ \frac{1}{3}y] \\ w_2 = [\frac{1}{12}x - \frac{\sqrt{3}}{12}y + \frac{1}{3};\ \frac{\sqrt{3}}{12}x + \frac{1}{12}y] \\ w_3 = [\frac{1}{6}x + \frac{5}{12};\ \frac{1}{6}y + \frac{\sqrt{3}}{12}] \\ \qquad\qquad\qquad\qquad\qquad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)} \\ w_4 = [\frac{1}{12}x + \frac{\sqrt{3}}{12}y + \frac{7}{12};- \frac{\sqrt{3}}{12}x + \frac{1}{12}y + \frac{\sqrt{3}}{12}] \\ w_5 = [\frac{1}{3}x + \frac{2}{3};\ \frac{1}{3}y] \end{array}\right\}$$

The generated shape of modified Koch is shown in Fig.1.

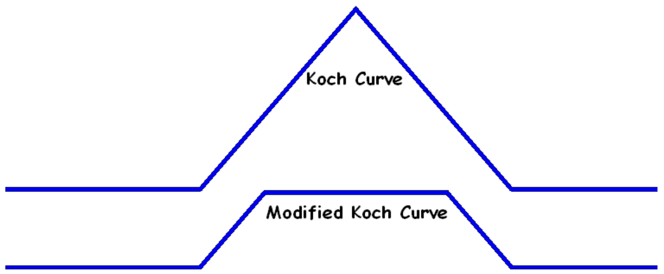

Fig.1. Modified Koch fractal shape

3. Fractal Dimension

Fractal dimension is an infinite dimensions lies between Euclidean 0, 1, 2, and 3 dimensions. It is a measure of how complicated a self-similar figure is [12]. The in between dimensions are inherent character of fractal shapes. Fractal antenna parameters are found to be related to fractal dimension value. Sierpinski triangle fractal dimension is equal to 1.58 and Koch fractal dimension is 1.26 [13]. Fractal dimension is calculated with the following equation [14]:

$$D_f = \log \frac{N}{1/E} \quad (3)$$

Where N is the number of copies and 1/E is similarity ratio
Modified Koch fractal dimension is calculated using equation (3) to be 1.08.It is obvious that whenever fractal dimension decrease, the electrical size of the antenna decrease too which led the antenna to operate at higher frequency.

4. Results and Discussion

New fractal shape obtained by combining second iteration of Seirpinski triangle and modified Koch curve. Calculations are done with HFSS code. Antenna shape is illustrated in Fig.2 and its feeding configuration by using coupling aperture is illustrated in Fig.3.

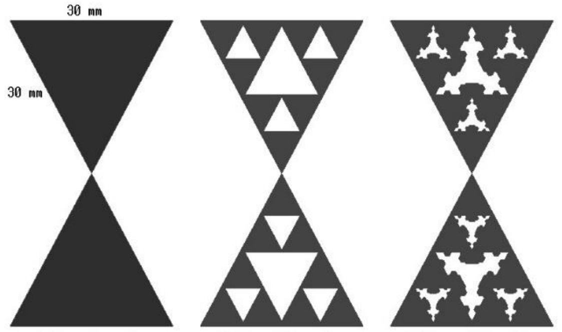

Fig.2. Antenna fractal shape: Second iteration of Seirpinski combined with modified Koch.

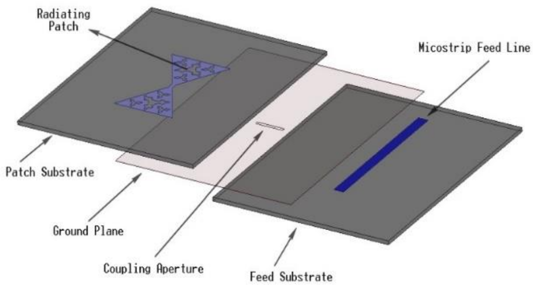

Fig.3. Feed configuration of the antenna.

The calculated return loss which represents the matching points of the antenna are shown in Fig.4.

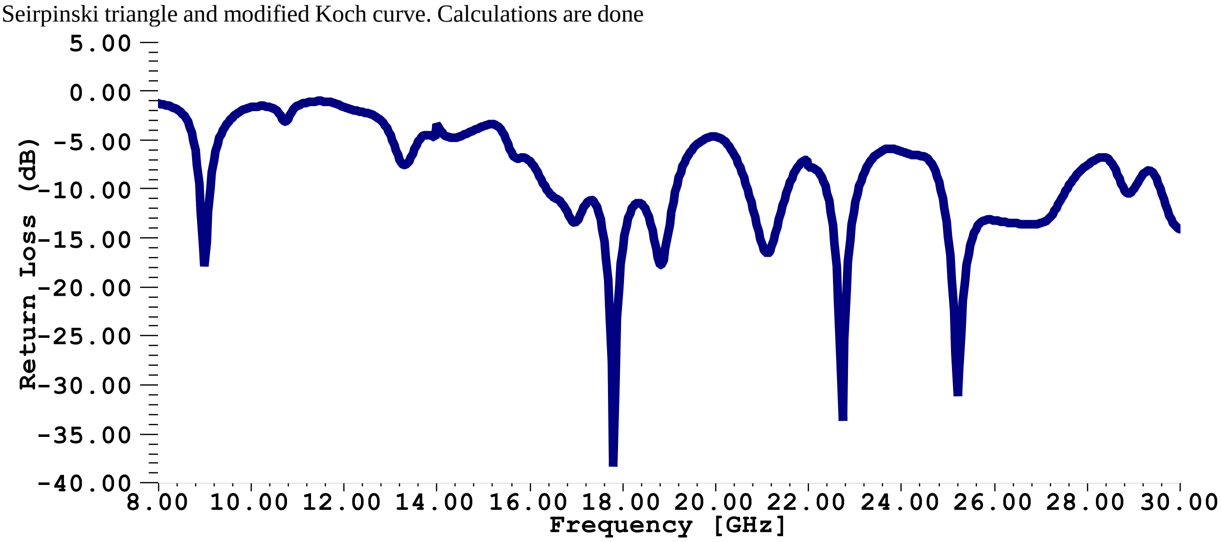

Fig.4. Return loss of the antenna.

It is obvious from this figure, the principal frequency located at 9GHz and the other matching points located at frequencies of k-band. This property of uniting too far apart bands in one single antenna makes it very useful in future wireless devices.
The resistance of the feed line of the antenna is set to 50 ohm. Resistance versus frequency is shown in Fig.5.

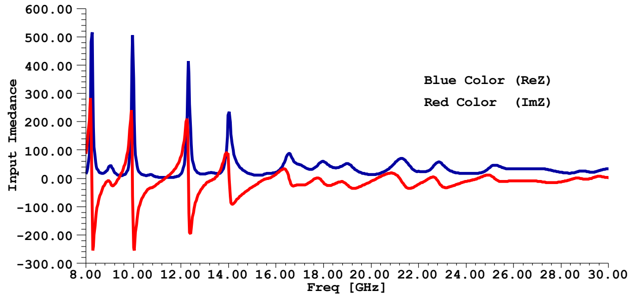

Fig.5. Resistance versus Frequency.

This model of antenna has acceptable values of gain; this is shown in Figures 6 and 7.

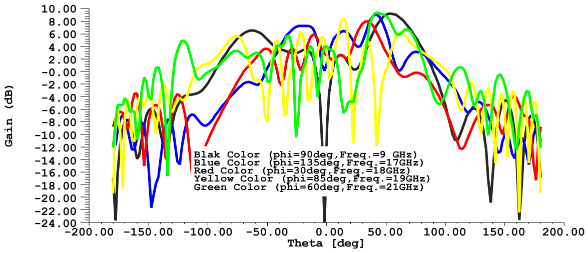

Fig.6. Gain of antenna for the frequencies (9 GHz-21 GHz)

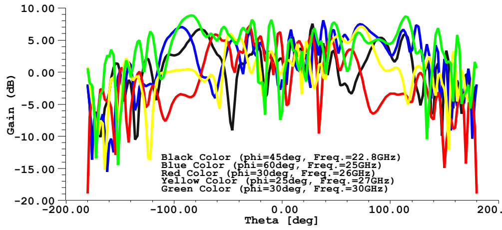

Fig.7. Gain of antenna for the frequencies (22 GHz-30 GHz).

Summary of calculated results obtained include input impedance, gain, directivity, and efficiency are listed in table 1.

Table.1. antenna parameters.

Frequency (GHz)	Return Loss (dB)	VSWR	Input Impedance(Ω)	Gain (dB)	Directivity (dB)	Efficiency
9	-17.7	1.29	45	9.22	9.29	99%
17	-13.4	1.54	49.39	9.08	9.40	95%
18	-38.3	1.02	50.15	8.40	8.44	99%
19	-15.7	1.43	49.15	8.23	8.55	96%
21	-16.5	1.35	50.81	9.29	9.55	97%
22.8	-33.5	1.04	51.78	8.43	9.57	88%
25.2	-31.1	1.05	47.32	8.04	8.90	89%
26	-13.1	1.56	33.48	7.68	8.14	93%
27	-13.4	1.53	34.75	8.57	11.52	73%
30	-14.1	1.48	34.73	9.15	13.73	66%

Three directional patterns of antenna are shown in figure 9.

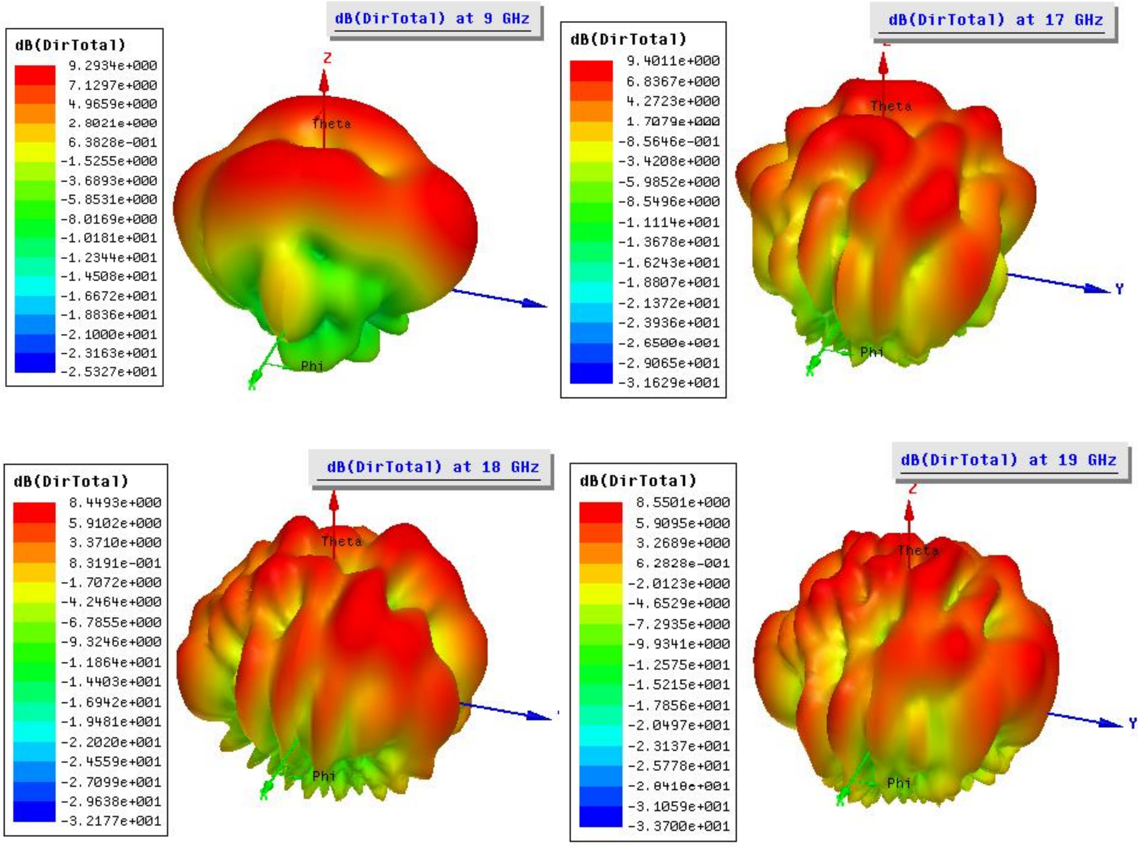

Fig.9. Three dimensional pattern of the antenna.

5.Conclusion

New fractal shape of antenna design has been presented in this paper. Combine two fractal shapes, Seirpiniski and modified Koch, has led to generate new features in this antenna model. IFS of modified Koch is calculated to generate the fractal shape. Also, fractal dimension of modified Koch is calculated, it is equal 1.08. Low value of fractal dimension makes the antenna electrically small and resonate at higher frequencies. The antenna is operate at too far apart frequencies lies in X and K band. This could make the potential of combining the applications of the two bands in one device. Good results obtained from calculating antenna parameters like gain and efficiency.

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