Design and Analysis of Koch Fractal Antenna for Wireless Applications

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Abstract: In this paper, Koch Fractal Antenna (KFA) focuses on the design strategy with resonant frequency of 1.35 GHz that is capable to hold the multiband behavior. The fabrication is done by using FR4 epoxy material for substrate whose relative permittivity 4.4 and the height of the substrate 1.6 mm. The dimensions of the proposed KFA antenna are 65 mm x 65 mm which is square in shape. The Koch fractal geometry is applied up to 3rd iteration in order to enhance the performance of the antenna. In this work, microstrip line feed is used to fed the antenna. The different antenna parameters such as gain, return loss, VSWR and radiation pattern are evaluated and analyzed. The High Frequency Structure Simulator (HFSS) software is used for analysis and simulation of the proposed KFA. This antenna works for multiband applications.

Keywords: Koch curve, Fractal Antenna, High Frequency Structure Simulator (HFSS), Multiband.

Introduction

Due to advancement in the technology, the need of wireless communication is increasing day by day. Antenna is the basic element of the communication system and has become the interest area for communication system. The demand of fabrication of many devices on a single chip has led to the discovery of integrated devices and to fulfill this requirement multiband antenna is best option which operates on multiple frequencies [3]. The Microstrip Patch Antenna (MPA) is a type of antenna which consists of very thin patch and a metallic ground plane and a substrate of some material with some dielectric constant is placed between the thin patch and metallic ground plane. The patch of the microstrip antenna is existed in a variety of forms such as triangular, square, circular, rectangular and elliptical or in some other profiles. This type of antennas are broadly used nowadays because of its small size, light weight and low profile[4].The available feed techniques to fed the microstrip patch antennas are microstrip line, coaxial probe, aperture coupling, proximity coupling. Fractals are the self similar shapes of the whole design. Some of its properties are complex structure, space filling, self similar and non integer dimension [2]. In literature fractal antennas are available in different shapes such as Koch, Hilbert Curves, Helix, Sieripinski Carpet and Gasket.

Antenna Configuration

The design of all three iterations of Koch Fractal Antenna is shown in figure 1. The thickness of the substrate is 1.6 mm. The frequency of 1.35 GHz is chosen as the design frequency Transmission line model is used to calculate the patch dimensions because it is simple and accurate model for rectangular or square patch antenna. According to the transmission line model, the width and length of the patch are calculated using equations (1) to (4). The steps for different iterations are given below.
Step 1: In the 0th iteration, According to the transmission line model, the width and length of the patch are calculated using equations (1) to (4). For calculating length and width of the patch, substitute dielectric constant (ϵ_r=4.4), resonant frequency(f_r=1.35 GHz) and height of substrate (h=.6mm).
Dimensions of square patch are calculated by using equations 1-4 which are given below.
The width of the patch is calculated by the following formula [1],

$$W = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}} \tag{1}$$

An effective dielectric constant is introduced to account for fringing effect, because some waves travel in the substrate and some in the air [2],

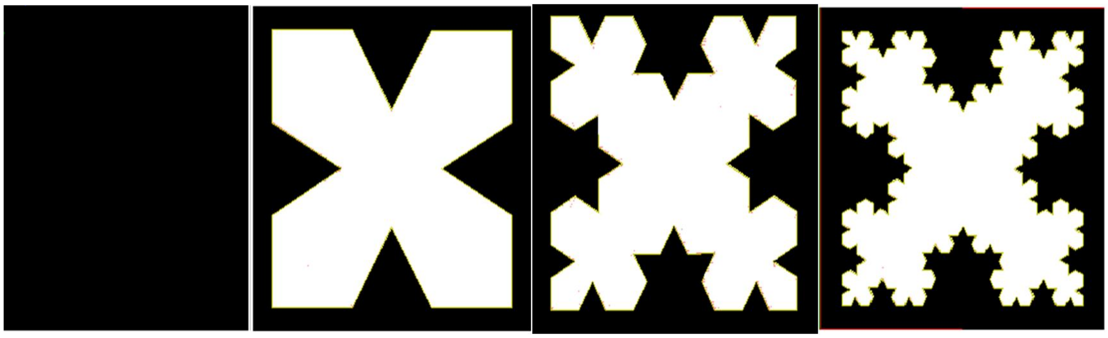


Figure 1 Design Of Kfa

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\frac{1}{\left[1+12\frac{h}{w}\right]} \tag{2}$$

Due to fringing effect, the dimensions of the patch are extended by ΔL on both sides [2],

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)} \tag{3}$$

The actual length of the patch is given by following formula [2],

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{4}$$

Where W, L, ε_{reff}, f_r, C and h are width of the patch, length of the patch, effective dielectric constant of the substrate, resonant frequency, speed of light in vacuum and height of substrate respectively.

Table 1 Dimensions of proposed antenna

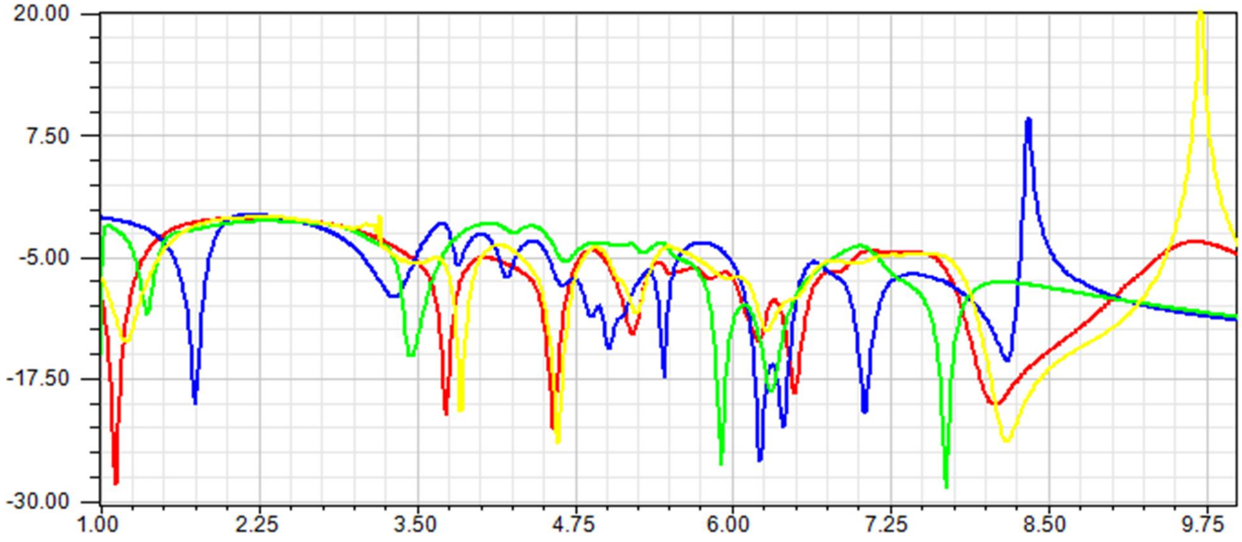
S.No.	Parameter	Dimensions
1	Length of the substrate	65 mm
2	Width of the substrate	65 mm
3	Length of the patch	54 mm
4	Width of the patch	54 mm
5	Length of the ground plane	50 mm
6	Width of the ground plane	50 mm
7	Length of feed line	18 mm
8	Width of the feed line	3 mm
9	Side of triangle in 1st iteration	18mm
10	Side of triangle in 2nd iteration	6mm
11	Side of triangle in 3rd iteration	3mm

Step 2: In the 1st iteration start with each line and this straight line is divided into three equal parts. Then an equilateral triangle is drawn by taking the middle part as base and erases the middle part. There are 4 sides of the square and this method is applied on the 4 sides of the square so draw four triangles in the middle and erases it to have the desired design.
Step 3: In 2nd iteration the above method is applicable for the remaining 12 sides of the geometry to obtain the further design of the Koch fractal antenna.
Step 4: In 3rd iteration again the same method is applied for the remaining 26 sides of the design to get the required geometry shape. All the calculated dimensions by using above steps are mentioned in table 1.

Result and Discussion

Simulated results

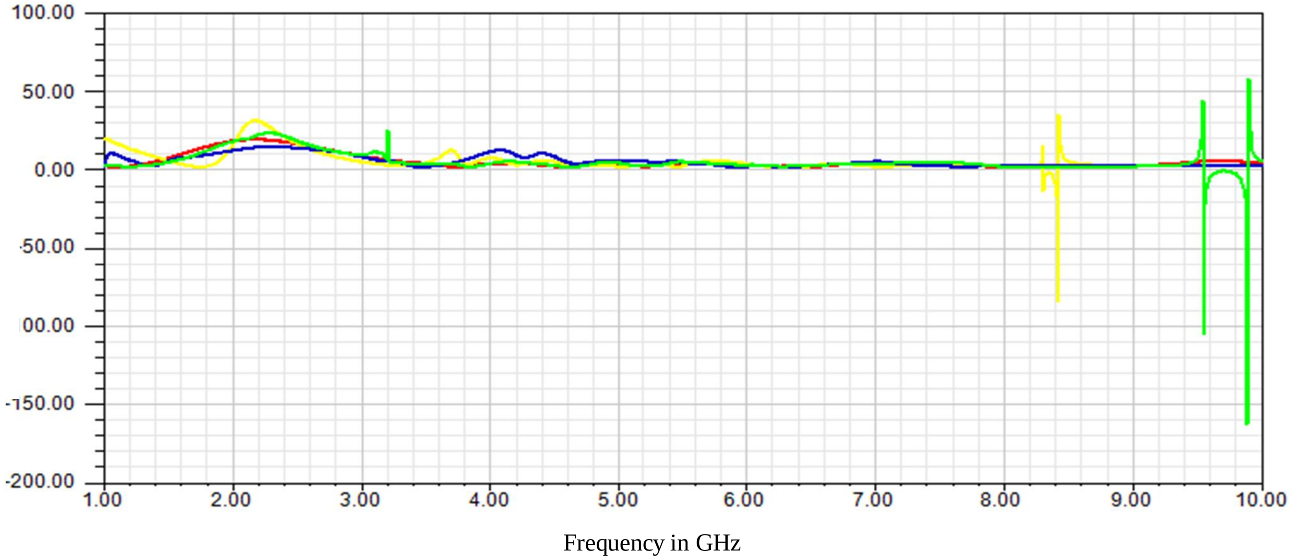
The comparisons of the return loss v/s frequency plot of all the iterations of the proposed antenna are shown in figure 3. It is perceived that the size of the antenna decreases with increase of the iteration order. The resonant frequencies shift to the lower side as the iteration order increases.



Frequency in GHz

Figure 2 Return losses Vs Frequency of iteration 0, iteration 1, iteration 2 and iteration 3.

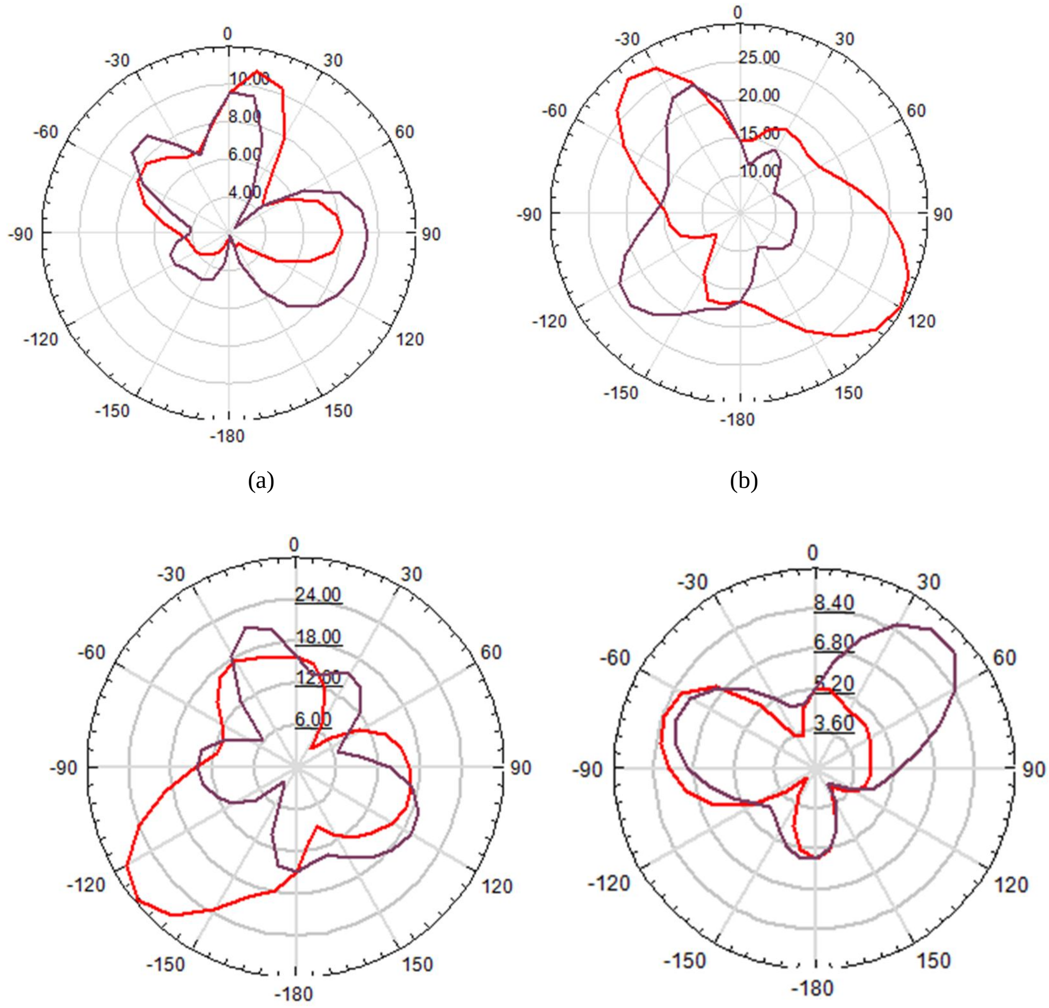
VSWR v/s frequency plot of 0th, 1st, 2nd and 3rd iterations of the proposed antenna are shown in figure 4. The value of VSWR is less than 2 at the resonant frequency of each iteration.



Frequency in GHz

Figure 3 VSWR Vs Freq. of iteration 0, iteration 1, iteration 2 and iteration 3

The radiation patterns of the proposed antenna at a frequency 1.35 GHz of 0th, 1st, 2nd and 3rd iteration are shown in figure 4.



(a) (b)

(c) (d)

Figure 4 Radiation Patterns of the proposed antenna at 1.35GHZ for 0^{th}, 1^{st}, 2^{nd} and 3^{rd} iterations have stable radiation patterns.

It is evident from the above discussion that Return loss are above -10 db , gain is more than +3 db and VSWR is lie between 1 and 2 of the proposed antenna KFA all iterations which are the acceptable values of an antenna. The detail of all the parameters of proposed antenna is given in table 2.

Table 2. Performance parameters of proposed antenna

Iteration	Freq. (GHz)	Lower Freq(GHz)	Upper Freq(GHz)	Gain(dB)	BW (MHz)	Return Loss(dB)	VSWR
0^{th}	1.75	1.6785	1.8061	12.10	127.6	-19.98	1.22
	6.22	6.1181	6.4990	5.02	380.9	-25.71	1.10
	7.05	6.9464	7.1609	8.78	214.5	-20.95	1.19
	8.17	7.9213	818.24	10.77	320.5	-15.63	1.39
1^{st}	1.37	1.3489	1.3901	15.25	41.2	-10.88	1.79
	3.45	3.3866	3.5619	12.43	175.3	-15.19	1.42
	5.91	5.8245	6.0768	3.87	252.3	-26.13	1.10

	6.31	6.1061	614.47	6.49	365.3	-18.76	1.26
	7.69	7.5373	7.8269	11.59	289.6	-28.43	1.07
2nd	1.21	1.0930	1.3057	12.79	212.7	-13.63	1.52
	3.85	3.7908	3.9045	9.33	113.7	-20.65	1.20
	4.61	4.5065	4.7031	4.14	196.6	-24.00	1.13
	5.23	5.1964	5.2618	4.69	65.4	-10.77	1.81
	6.27	6.1966	6.3905	4.16	193.9	-12.61	1.61
	8.18	7.9087	9.1933	8.59	1284.6	-23.79	1.13
3rd	1.12	1.0197	1.2228	20.3	203.1	-28.17	1.08
	3.73	3.6538	3.7997	4.59	145.9	-21.13	1.19
	4.58	4.4780	4.6669	4.31	188.9	-22.45	1.16
	5.20	5.1280	5.2619	3.57	133.9	-12.87	1.58
	6.20	6.0901	6.2973	5.12	207.2	-13.56	1.53
	6.49	6.3678	6.5996	5.84	231.8	-18.85	1.25
	8.06	7.8051	8.9446	8.06	1139.5	-20.07	1.22

Measured Results

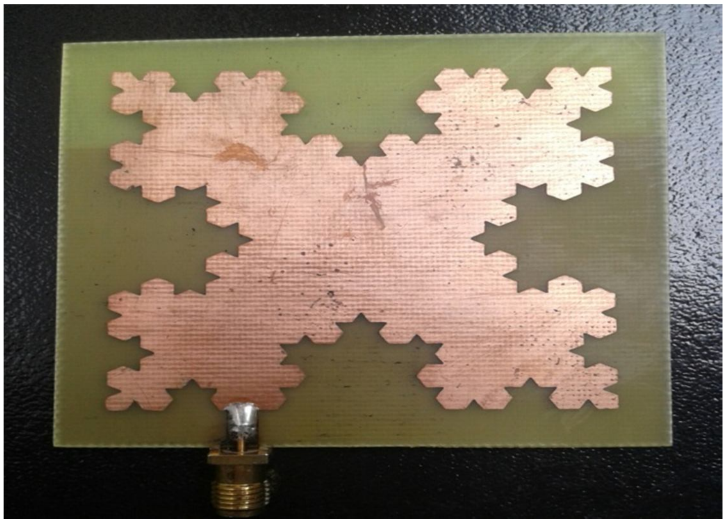


Figure 5**.** Fabricated Koch fractal antenna

The result of the proposed antenna of 2nd and 3rd iteration are shown in table 5.2.It is clear from the table that the return loss of the iteration 2nd is less than -10 dB at resonant frequencies 3.93 GHz, 4.79GHz,5.52,6GHz.51,6.78GHz and 8.59GHz and VSWR lie between 1 and 2

The iteration 3rd of proposed antenna has return loss at 1.27 GHz, 1.58 GHz, 3.84 GHz, 4.50 GHz, 4.84 GHz, 5.56 GHz, 6.74 GHz and 8.46GHz respectively and VSWR lie between 1 and 2.

Comparison of Simulated and Measured Results

The comparison between the simulated results of return loss and measured results of return loss of iteration 2 and 3 of the proposed antenna are shown in figure 6.19 and 6.20 respectively. The compared values are shown in table 6.3.

Table 3. Measured results of proposed antenna

Iteration No.	Frequency(GHz)	Return loss(dB)	VSWR
2nd	3.93	-14.80	1.63
	4.79	-28.80	1.18
	5.52	-36.60	1.07
	6.51	-12.70	1.62
	6.78	-18.20	1.28
	8.59	-26.20	1.10
3rd	1.27	-10.20	1.96
	1.58	-12.10	1.65
	3.84	-16.20	1.50
	4.50	-11.60	1.79
	4.84	-17.10	1.35
	5.56	-13.70	1.54
	6.74	-20.30	1.21
	8.46	-30.70	1.07

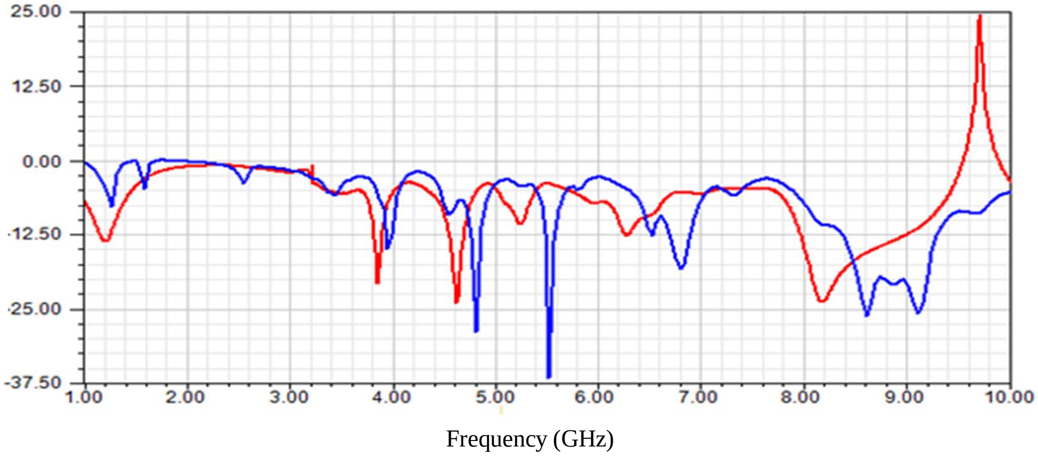


Figure 6.19 Simulated and Measured Return Loss of Iteration 2 of KFA

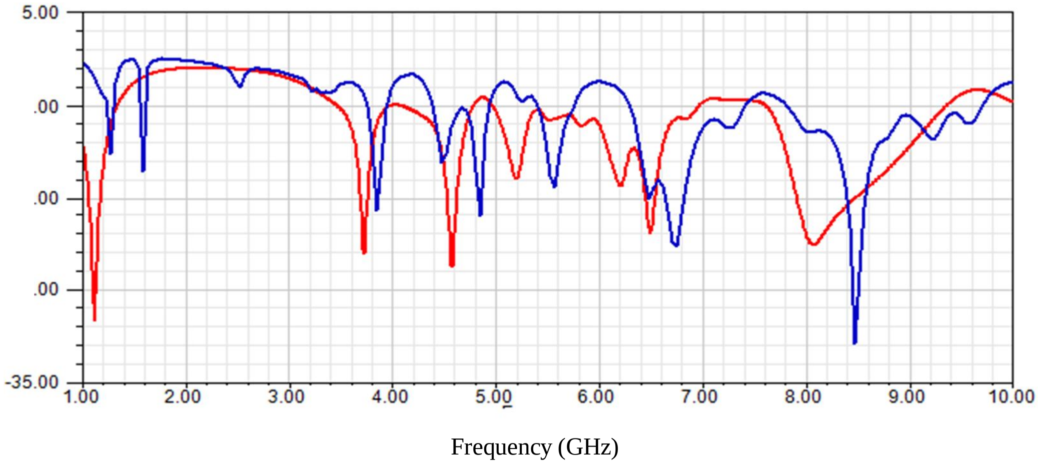


Figure 6.20 Simulated and Measured Return Loss of Iteration 3 of KFA

Table 4. Comparison between simulated and measured results of KFA

Simulated Results			Measured Results		
Iteration No.	Frequency(GHz)	Return loss(dB)	Iteration No.	Frequency(GHz)	Return loss(dB)
2nd	1.21	-13.63	2nd	3.93	-14.80
	3.85	-20.65		4.79	-28.80
	4.61	-24.00		5.52	-36.60
	5.23	-10.77		6.51	-12.70
	6.27	-12.61		6.78	-18.20
	8.18	-23.79		8.59	-26.20
3rd	1.12	-28.17	3rd	1.27	-10.20
	3.73	-21.13		1.58	-12.10
	4.58	-22.45		3.84	-16.20
	5.20	-12.87		4.50	-11.60
	6.20	-13.56		4.84	-17.10
	6.49	-18.85		5.56	-13.70
	8.06	-20.07		6.74	-20.30
				8.46	-30.70

Conclusions

In this research, Koch Fractal Antenna is designed for Multiband application. This antenna resonates at different seven frequencies therefore applicable for multi tasking equipments that need many services on a single device like cell phone. The reduction in size and improvement in performance is seen by using 4 iterations.

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