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Design and Simulation of Koch Fractal Antenna for UWB Applications

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ABSTRACT: In this paper Koch fractal antenna has been designed to obtain multiband characteristics in ultra wideband which is having operating range of 3.1-10.6 GHz as per the authorized FCC (Federal communication commission). The proposed antenna consists of FR4 substrate having dielectric constant ε_r = 4.4 and height h=1.6mm and microstrip feed line. The dimension of the antenna is 21.45mm *17.89mm. The antenna structure simulated using CADFEKO 14.0 software. The antenna parameters such as reflection coefficient, gain and VSWR are analysed and presented. Koch fractal antenna with different iteration is simulated and compared which satisfies the needs of ultra wideband applications. The proposed fractal antenna gives dual bands with resonating frequencies 4.3GHz and 6.1GHz is applicable in off-body communication and LTE network communication.

KEYWORDS: Koch, Fractal antenna, Ultra wideband, FR4, CADEFEKO 14.0.

I. Introduction

Most wireless communication system requires antenna with small size and more bandwidth. The concepts of fractal were first introduced by Mandelbrot. The fractal antennas are different from traditional antennas because it is capable of operating at many different frequencies at a time. The key advantages of fractal antennas are reduced antenna size, support multiband and wideband operation with improved antenna performance. These can be achieved using fractal geometry like Hilbert, Sierpinski, Koch and Minkowski are the various types of fractal geometries. All these fractal geometries are used to design a small size multiband and wideband antennas.Fractal antenna design has created a major role due to its compactness as well as wider application in UWB application.

Related work

A small isosceles triangle is cut off from center of each side of the initial isosceles triangle, then the procedure iterates along the sides like Koch curve does as shown in fig.1 [1].Circle and square slot fractal technique is adopted to improve radiation characteristics of the antenna [2].Fractal antenna engineering represents a relatively new field of research that combines the attributes of fractal geometry with antenna theory and the fractal antenna geometries, applications and advantages of fractals have been discussed [3]. Koch fractal structure has been designed and the performance of the antenna shown in terms of radiation pattern and bandwidth and it is found to be suitable for UWB communication application [4].A small equilateral triangle is cut off from the center of the initial equilateral triangle.The second step was the introduction of two Koch-like curves (K1) as shown in fig.1 on two sides of the equilateral triangular patch [5].Current regulations and standards for wireless medical applications within the ITU-R, Canada, and some other countries required for medical implant communications systems, medical telemetry systems, ultra-wideband (UWB) medical radar imaging [6].The study of Ultra Wideband (UWB) technology to perform biomedical sensing and vital signs monitoring in humans. The research is pointed towards the developmentof a technique that can allow both, radar sensing and communications using the same UWB transceiver [7].Ultra wideband has wide applications in health monitoring area like health monitoring radar etc. Different applications of ultra wideband in health monitoring area increasing widely because of its advantageous and efficient features [8].This literature says that the fractal geometries are better for ultra wideband applications.

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II. PROPOSED FRACTAL ANTENNA

Koch Fractal Geometry

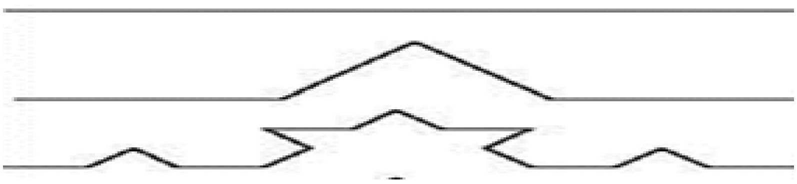

Fig.1 Geometrical Construction of Koch Curve

The relationship between total length and its generator length is as below
$L_n = L_0 \times (4/3)^n$(1)
L_n = Total length of the Koch curve
L_0 = Initial length of the Koch curve
n = Fractal dimension (Iteration times)
Using above relation Koch curve length is calculated.

III. ANTENNA DESIGN

The equilateral triangularpatch antenna is considered as conventional antenna and designed to operate at resonant frequency of 6GHz.The geometry of antenna is designed on FR4 substrate having relative permittivity 4.4 and thickness 1.6mm and loss tangent of 0.019.The side length of equilateral triangularpatch for resonating frequency 6GHz is calculated using below equation (2),

$$Wp = \frac{2 \times c}{3 \times fr \times \sqrt{\varepsilon_r}} \quad (2)$$

C= velocity of light (in mm/s)
f_r = resonant frequency(in GHz)
ε_r =relative permittivity

Table-1 Parameters of antenna-

Length of substrate (Ls)	21.45mm
Width of substrate (Ws)	17.89mm
Height of substrate (h)	1.6mm
Length of patch (Lp)	15.89mm
Length of ground plane (Lg)	0.925mm
Width of ground plane (Wg)	17.89mm
Length of Feed line (Lf)	6.9mm
Width of Feed line (Wf)	3.2mm

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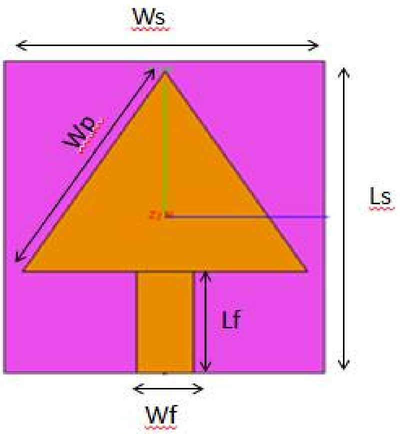

Fig.2 Top View of Triangular Patch Antenna

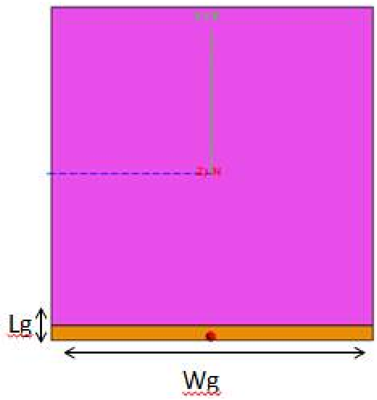

Fig.3 Bottom View of Triangular Patch Antenna

Feed line dimension is 3.2mmx6.9mm for fulfilment of characteristic impedance of 50 ohms. Substrate dimension is (Ws x Ls x h) 17.89mm x 21.45mm x 1.6mm and ground plane dimension is 17.89mm x0.925 mm.The partial ground plane with optimized feed gap method is found that it works better for achieving ultra-wideband characteristics [9][10].

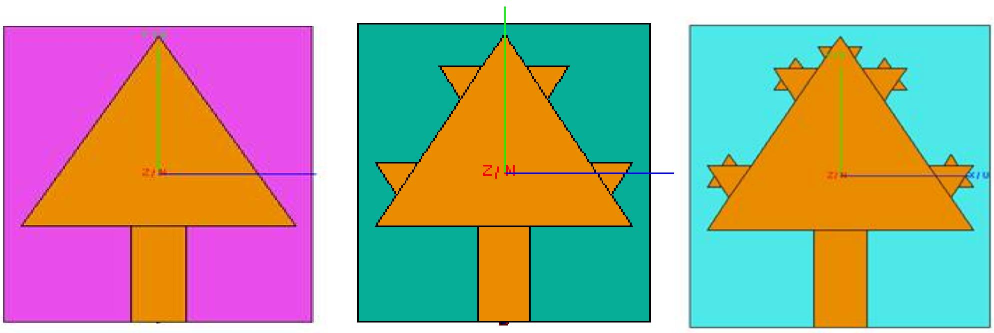

Fig.4 Basic Geometry of Antenna With 1st Iteration And 2nd Iteration of Koch Fractal

The geometry of proposed Koch fractal antenna and stages of iteration are shown in Fig.4.The fractals are the main radiating element. The characteristics of the antenna parameter depend on the fractal geometry. The antenna dimensions are calculated using transmission line model [11]. The most popular models for the analysis of microstrip patch antennas are the transmission line model, cavity model, and full wave model (which include primarily integral equations/Moment Method). The transmission line model is the simplest of all. The value of ε_{reff} is slightly lessthan ε_r because the fringing fields around the periphery of the patch are not confined in thedielectric substrate but are also spread in the air and the expression for ε_{reff} is given as:

$$\varepsilon_{reff} = \frac{(\varepsilon_{reff} + 1)}{2} + \frac{(\varepsilon_{reff} - 1)}{2}[1 + 12\frac{h}{W}]^{-1/2}$$

Where ε_{reff} = Effective dielectric constant

ε_r = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

$$\Delta L = 0.412h\left[\frac{(\varepsilon_{reff} + 0.3)}{(\varepsilon_{reff} - 0.258)}\right]\left[\frac{(W/h + 0.264)}{[(W/h + 0.8)]}\right]$$

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The effective length of the patch Leff :

$L_{eff} = L + 2\,\Delta L$

For a given resonance frequency f_0 ,the effective length is given by as:

$L_{eff} = c/(2f_0\sqrt{(\varepsilon_{reff})}$

The resonance frequency for any TM mode is given as:

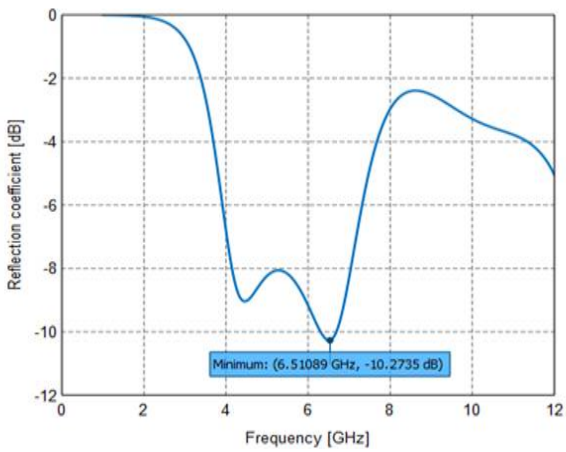
$f_0 = c/(2\sqrt{(\varepsilon_{reff})}[(m/L)2 + (n/W)2]1/2$

IV. SIMULATION RESULTS

The proposed Koch fractal antenna is simulated using CADEFEKO 14.0.The simulated results of gain, VSWR and reflection coefficient are studied and presented. It is well known that if the reflection coefficient value is more negative, the antenna performance will be better. To be specific a reflection coefficient below -10dB is sufficient for antenna radiation. The proposed design of antenna has resulted in a reflection coefficient value that are lower than -10dB. Therefore, the proposed antenna exhibits good radiation characteristics.

1] Conventional Triangular Patch Antenna (0^{th} Iteration)(K0)-

Reflection coefficient Gain



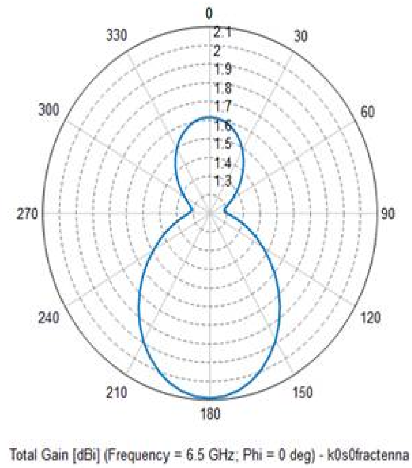


Fig.5Reflection coefficient vs frequency plot Fig.6 Gain of antenna at 6.5GHz

For conventional equilateral patch antenna simulated results shows reflection coefficient -10.27 dB at resonating frequency 6.5GHz and gain is 1.6dBi.

2] Comparison of 1^{st} and 2^{nd} iterations of Koch fractal antenna parameters (K1 vs K2)-

Reflection coefficientGain

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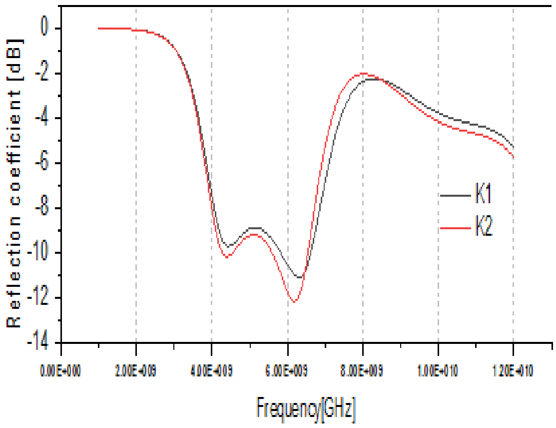

Fig.7 Reflection coefficient vs frequency plot

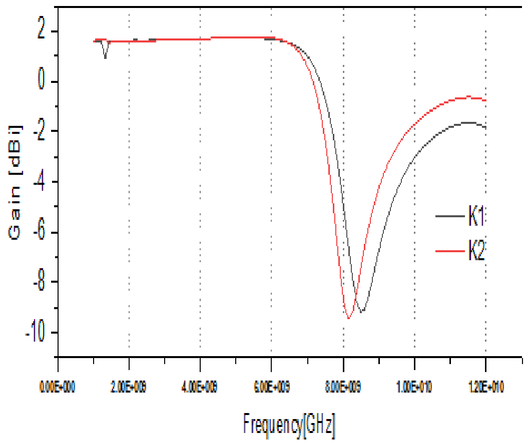

Fig.8 Gain vs frequency plot

Reflection coefficients and gain for first and second iterations K1 and K2 are -11.13dB, -10.19dB, -12.22dB, 1.59dBi, 1.71dBi and 1.68dBi at respective resonant frequencies 6.3GHz, 4.39GHz, 6.18GHz.

Impedance VSWR

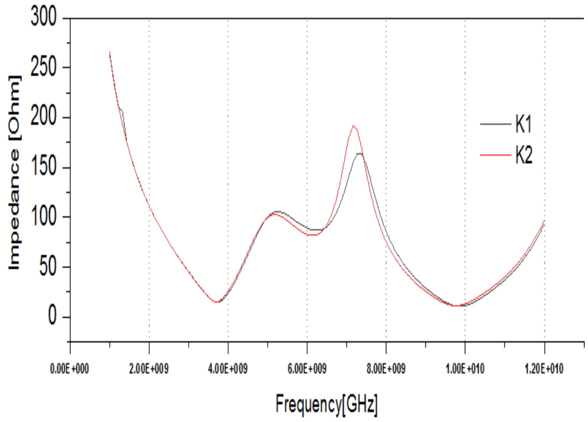

Fig.9 Impedance vs frequency plot

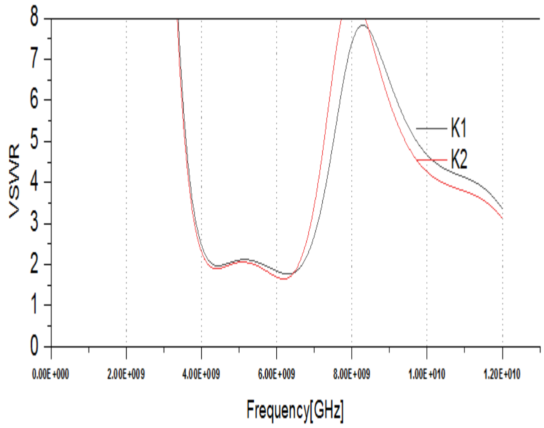

Fig.10 VSWR vs frequency plot

The VSWR is basically a measure of the impedance mismatch between the transmitter and the antenna. The higher the VSWR, the greater is the mismatch. The minimum VSWR which corresponds to a perfect match is unity. VSWR between 1 and 2 is accepted for practical applications.VSWR for K1 and K2 are 1.7682,1.8959 and 1.6499 at respective resonant frequencies 6.3GHz,4.39GHz and 6.18GHz.

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Table-2 Simulated parameters of Koch fractal antenna for 0^{th}, 1^{st} and 2^{nd} iteration-

Iteration number	Resonant Frequency (in GHz)	Reflection Coefficient (in dB)	Impedance (in Ohm)	Gain (in dBi)	VSWR	Bandwidth (in MHz)
0^{th} iteration (K0)	6.5	-10.27	89.58	1.6	1.8836	100
1^{st} iteration (K1)	6.3	-11.13	86.88	1.59	1.7682	738
2^{nd} iteration (K2)	4.39	-10.19	55.55	1.71	1.8959	136
	6.18	-12.22	81.74	1.68	1.6499	929

V. CONCLUSION

Ultra wideband has wide applications in wireless communication, radar applications and health monitoring.To meet the minimum requirements of ultra wideband applications fractal antennas are good because it gives better results.

In proposed work Koch fractal antenna up to second iteration K2 has been designed and antenna parameters are simulated in CADFEKO 14.0 simulation software. Comparing simulated parameters for each iteration of Koch fractal antenna like reflection coefficient, VSWR, gain with conventional triangular patch antenna, we can conclude that second iteration of Koch fractal gives dual resonant frequencies of 4.39GHz, 6.18GHz with reflection coefficient -10.19dB,-12.22dB than first iteration of Koch fractal K1, it gives one resonant frequency 6.3GHz with reflection coefficient -11.13dB.Bandwidth for Koch fractal structure's first iteration K1 is 738MHz at 6.3GHz resonant frequency and for second iteration of Koch fractal K2 is 136MHz at4.39GHz and 929MHz at 6.18GHz which is greater than 500MHz and satisfies the ultra wideband characteristics and also suitable for wireless medical applications.

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