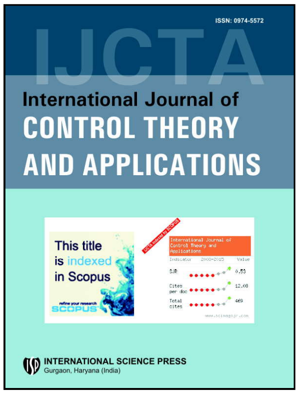

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Design of Microstrip Fractal antenna for GPS and Aircraft surveillance Applications

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Abstract: A fractal shaped antenna for GPS and aircraft surveillance applications is introduced in this paper. This design exhibits the behavior of multiband fractal geometry having acceptable value of Return Loss (RL), VSWR and Gain (G). Then geometry of proposed antenna is modified to have wideband, better gain, VSWR and radiation pattern. The proposed antenna has been investigated until good value of gain has not obtained at lower frequencies L1 (1.2 GHz) and L2 (1.575 GHz) which is suitable for GPS. Due to small in size antenna can used in handheld device like aircraft surveillance. Results of proposed antenna show multiband behavior and work on four resonant frequencies (3.1 GHz, 4.5 GHz, 7.1 GHz, 9.6 GHz). On other hand modified antenna covers two resonant frequencies (1.1 GHz, 6.9 GHz). The simulated result of modified fractal antenna shows 600 MHz bandwidth and 6.6 dB gain. The proposed antenna is simulated in High frequency Structure Simulator (HFSS) software tool.

Keywords: HFSS, Multiband, Return Loss, Gain, IFS

I. INTRODUCTION

The research on fractal antenna has tremendous effect in the area of engineering science and wireless technology [11]. There are many fields such as telecommunication, military and commercial applications which are affected by fractal antenna. Ongoing in past fractal antenna was discovered by French mathematician B. B. Mandelbort in year 1953 [1]. As a matter of fact, there are many different techniques to design a patch antenna but fractal antenna is the one of them is a most popular technique. The fractal geometries have invented for the improvement in the features of fractal design due to its self-similarity and space filling property [5], [8]. Due to these two properties, fractal antenna made compact in size, operating at different frequency bands, less in weight as compare to simple patch antenna [7], [13].

The performance of the fractal antennas is significantly different and much better results are obtained as compared to conventional design of antennas. Normally, traditional antennas are design for particular frequencies and more number of antennas is used for different frequencies but in fractal case, it can radiate multiple or wide range of frequencies according to the design of fractal antenna [10]. It is best suitable for wideband and multiple applications at small size antenna [8], [6]. There are no any passive component is used to alleviate the size of antenna [3]. The gain of fractal antenna can be achieved by making the array of fractal antennas on single patch. These antennas are mostly used in small handheld devices which is wireless [11].

The several fractal curves are developed but the length of these generator curves are not sufficient the space filling properties of fractal antenna and less number of segments are used [9]. To change the total length of fractal curve one method is by adding more number of segments in generator curve and another method is designed by adding two different fractal curves [6].

A new fractal shape of proposed antenna is designed from a straight line known as initiator curve. Then generator curve is made from initiator curve by dividing it into four parts and then two half polygons are added. First half polygon is added on upper side of initiator curve and other half polygon is added into lower side as shown in figure. 1(c). There are 10 segments in generator curve. The final geometry is obtained from repeating ten times on each segment of generator curve. The proposed antenna is designed up to second iteration. The initiator line, generator curve and proposed antenna are as shown in figure 1.

The generator curve is obtained by bending middle parts of initiator line in hut shape. Starting with continuous line firstly bending it 90^0 then bend 45^0 then bend again 45^0 and at last turn again 90^0 and then repeat it in bottom side proposed curve will be in shape. An Iterative Function System (IFS) is used to produce the generator shape of proposed fractal antenna. Various transformations required to produce the generator curve as shown in Figure.1 (b) are given below.

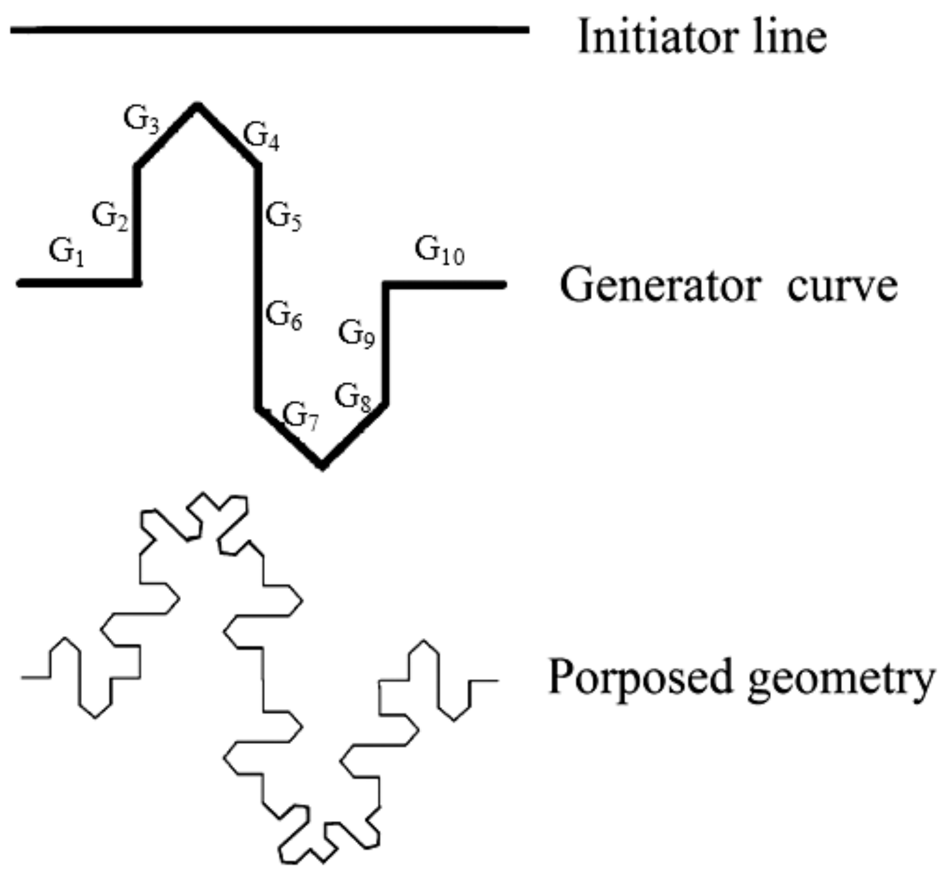


Figure 1: (a) Initiator line (b) 1st iteration and (c) 2nd iteration of proposed antenna

$$G_1=\begin{bmatrix}1/4 & 0\\ 0 & 1/4\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}0\\ 0\end{bmatrix},\ G_2=\begin{bmatrix}0 & -1/4\\ 1/4 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}1/4\\ 0\end{bmatrix},$$

$$G_3=\begin{bmatrix}1/8\sqrt{2} & -1/8\sqrt{2}\\ 1/8\sqrt{2} & 1/8\sqrt{2}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}1/4\\ 1/4\end{bmatrix},\ G_4=\begin{bmatrix}1/8\sqrt{2} & 1/8\sqrt{2}\\ -1/8\sqrt{2} & 1/8\sqrt{2}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}3/8\\ 3/8\end{bmatrix}$$

$$G_5=\begin{bmatrix}0 & 1/4\\ -1/4 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}1/2\\ 1/4\end{bmatrix},\ G_6=\begin{bmatrix}0 & 1/4\\ -1/4 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}1/2\\ 0\end{bmatrix}$$

$$G_7=\begin{bmatrix}1/8\sqrt{2} & 1/8\sqrt{2}\\ -1/8\sqrt{2} & 1/8\sqrt{2}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}1/2\\ -1/4\end{bmatrix},\ G_8=\begin{bmatrix}1/8\sqrt{2} & -1/8\sqrt{2}\\ 1/8\sqrt{2} & 1/8\sqrt{2}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}5/8\\ -3/8\end{bmatrix}$$

$$G_9=\begin{bmatrix}0 & -1/4\\ 1/4 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}3/4\\ -1/4\end{bmatrix},\ G_{10}=\begin{bmatrix}1/4 & 0\\ 0 & 1/4\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}+\begin{bmatrix}3/4\\ 0\end{bmatrix}$$

The generator curve is obtained using equation given below

$$G=G_1\cup G_2\cup G_3\cup G_4\cup G_5\cup G_6\cup G_7\cup G_8\cup G_9\cup G_{10} \tag{1}$$

The length increased after each iteration. The length according to iteration number can be determined by [2], [4]:

$$L=h\left(\frac{10}{4}\right)^n \tag{2}$$

where L = total length of the curve after n^{th} iteration

'h' is height of the curve

'n' is iteration number

The self-similarity is given from [4]

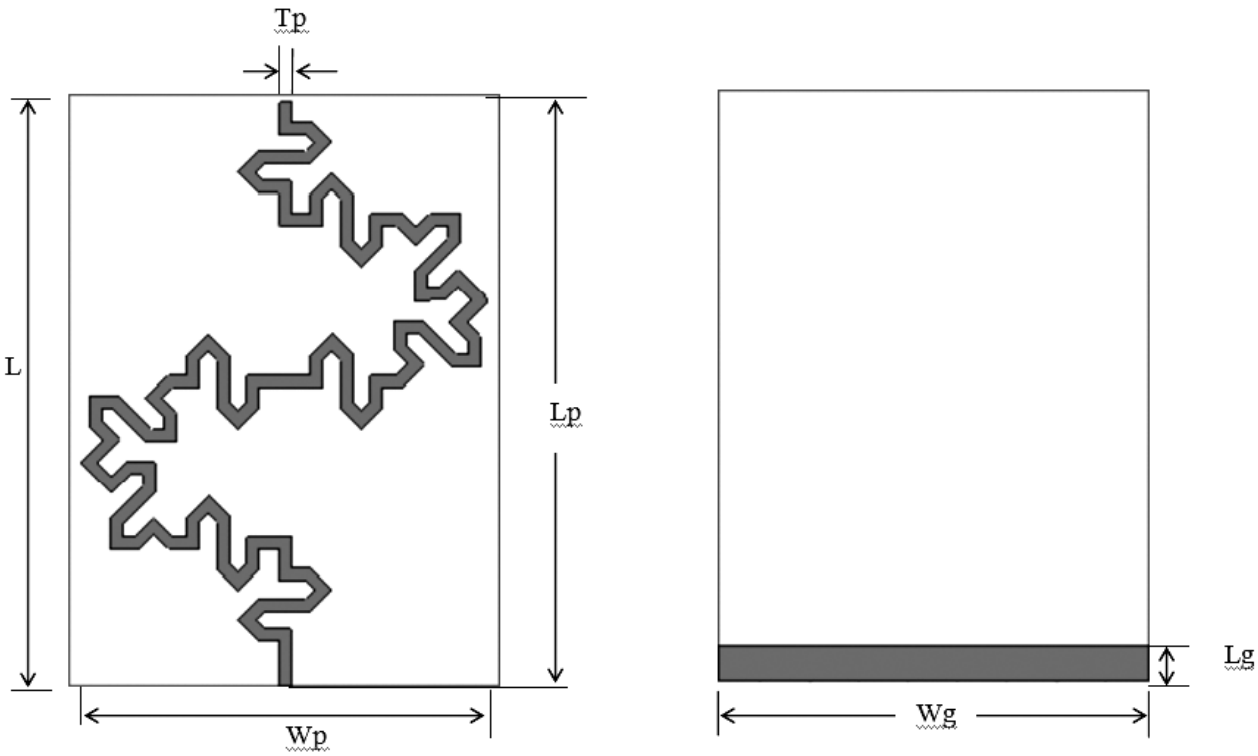
$$D=\frac{\log(N)}{\log(R)}=\frac{\log(10)}{\log(4)}=1.66 \tag{3}$$

Where N = total number of segments, R = number of parts in curve.

2. GEOMETERY OF PROPOSED ANTENNA

Proposed antenna is designed at second iteration of fractal geometry. The substrate used for proposed fractal antenna is FR4 epoxy material having dielectric constant $\varepsilon_r = 4.4$ and height of substrate h = 1.6 mm. The length of antenna substrate is L=24 mm and width is W=16.54 mm. By using defected ground results are calculated and effective dimensions of ground plane is Lg = 1.4 mm and width is same as substrate width Wg = 17.4 mm. The length of patch is Lp = 23.64 mm and Wp = 23.64 mm is the width of patch Tp = 0.5 mm shown in Figure. 2. The proposed antenna is excited by microstrip line feeding technique because it is simple to connect and easy to fabricate.

It is essential to take into consideration the size of designed fractal geometry should be as less as possible. Antenna dimensions are inversely proportional to frequency of antenna that means lower operated frequency



(a) **(b)**

Figure 2: Second iteration of proposed antenna (a) top view (b) bottom view

antenna has large in size [4]. The modified fractal design is obtained by using two new generator curves. The idea of designing two curves in single patch is adopted from author "Filipe M. Lopes" [2]. As per second iteration antenna is designed by drawing two generator curves having different in size originates from same point shown in Figure.3 (a) Both curves are parallel to each other and opposite in direction means it is mirror image of each other but differ in size.

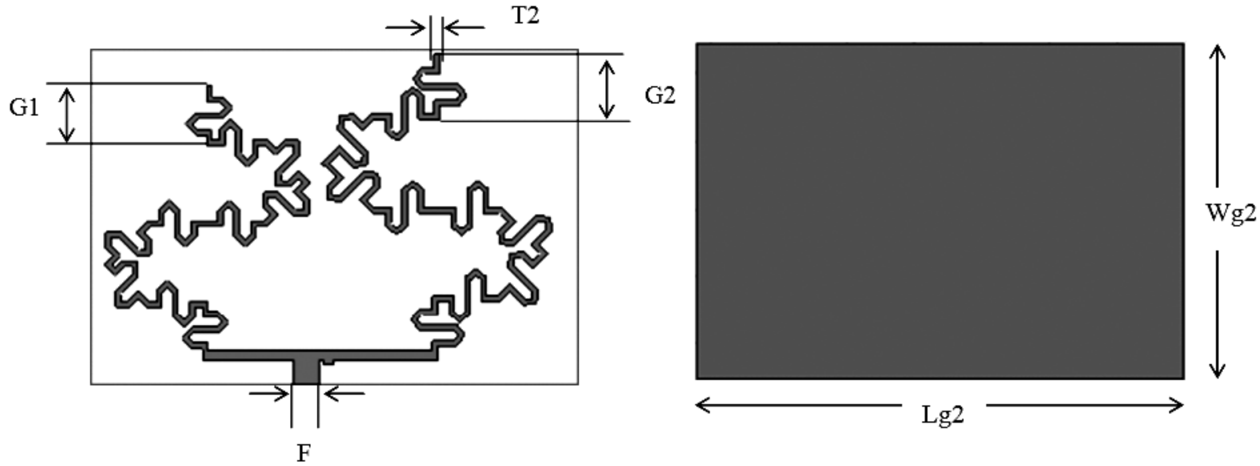
3. SECOND ITERATION OF MODIFIED FRACTAL ANTENNA

To achieve the self–similarity property it is used to repeat the same curve at each segment of generator curve. The results are also improved as further iterations applied to fractal geometry [3]. In this section, second iteration is applied on fractal geometry to improve result parameters of proposed antenna. The patch, substrate and ground dimensions are given in Figure.3.

The size of smaller curve G1 = 4.4 mm and dimensions of G2 = 4.8 mm. The width of both curves are T2 = 0.5 mm. The lumped port feeding technique is used for excitation and the width of feed line is F = 2 mm and 1.9 mm long for proper impedance matching. The position and width of feed line are changed to make better results and performance of antenna.

$$L = 20.32\left(\frac{10}{4}\right)^2 = 127 \text{ mm} \tag{4}$$

$$L = 22.66\left(\frac{10}{4}\right)^2 = 141 \text{ mm} \tag{5}$$



(a) **(b)**

Figure 3: Second iteration of modified fractal antenna (a) Top view of patch (b) Bottom view of ground

The ground plane has same dimensions as substrate Lg2 and Wg2 are 36*24 mm, respectively. Both geometries are separated by S = 16.6 mm gap space. The performance of antenna is judged using return loss, gain, VSWR, bandwidth which are simulated by HFSS softwere. In addition, the comparision of fractal antenna and various iterations of modified geometry of fractal antenna are also discussed.

4. RESULTS AND DISCUSSION

4.1 Return loss—The proposed fractal antenna is simulated by HFSS software. Return loss of proposed fractal antenna is observed by varying feed position and substrate material. The value of return loss should below then standard value which is -10dB. Return loss (S_{11}) parameters are not acceptable above -10 dB. There are four resonant frequencies at which proposed antenna works. The value of S_{11} parameter is -17.51 dB, -10.91 dB, -20.27 dB and -14.42 dB at frequency 3.1GHz , 4.5GHz, 7.1GHz and 9.6GHz, respectively as shown in Figure 4.

The return loss of modified fractal antenna is -17.59 dB at 1.2 GHz resonant frequency and -29.85 dB at frequency 6.9 GHz as shown in Figure 5.

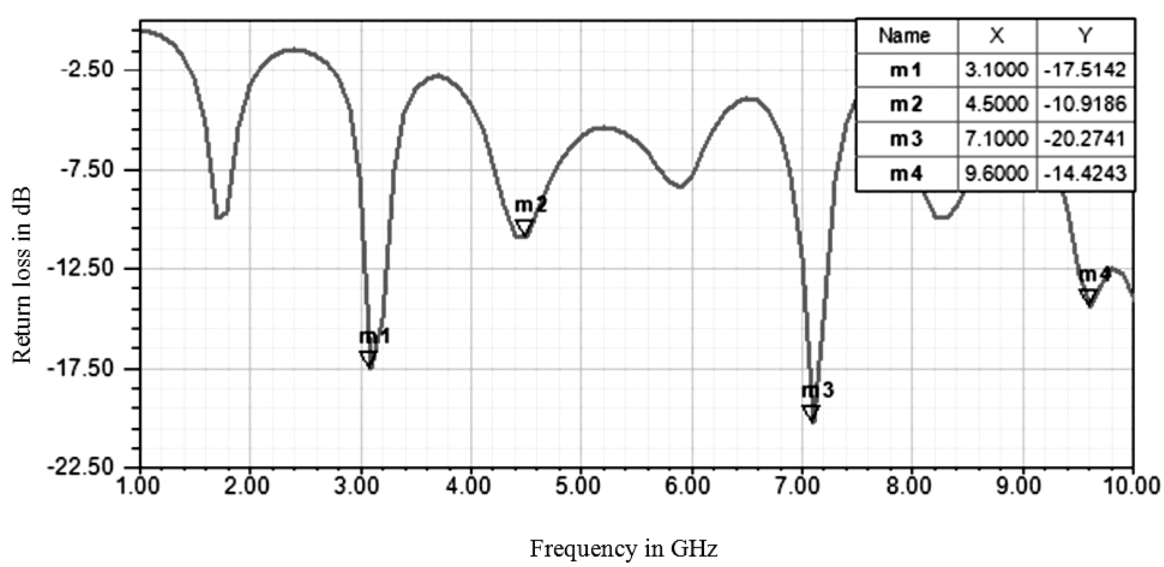


Figure 4: Return loss of second iteration of fractal antenna

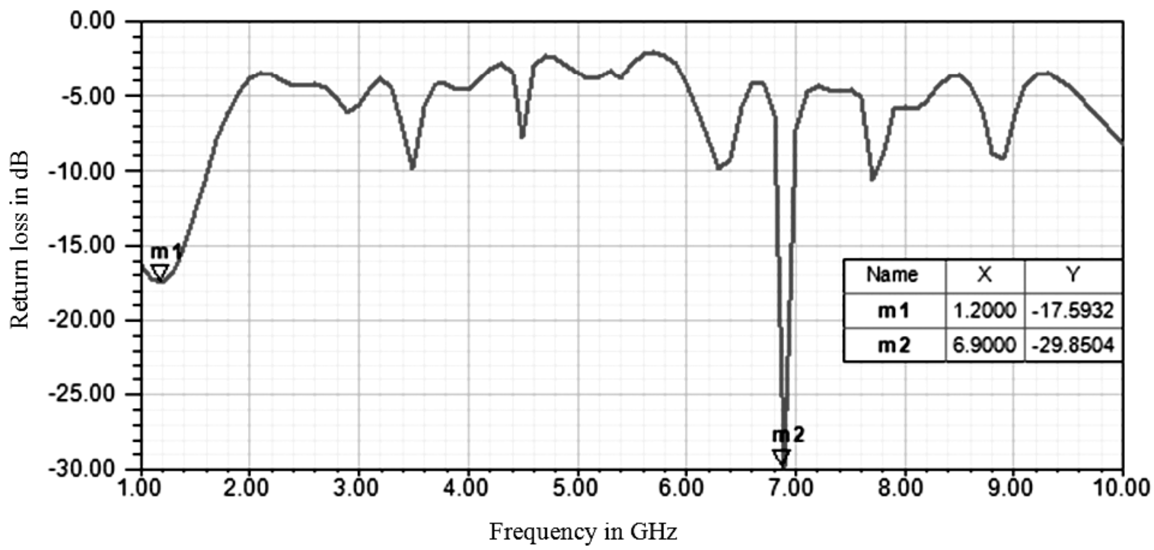
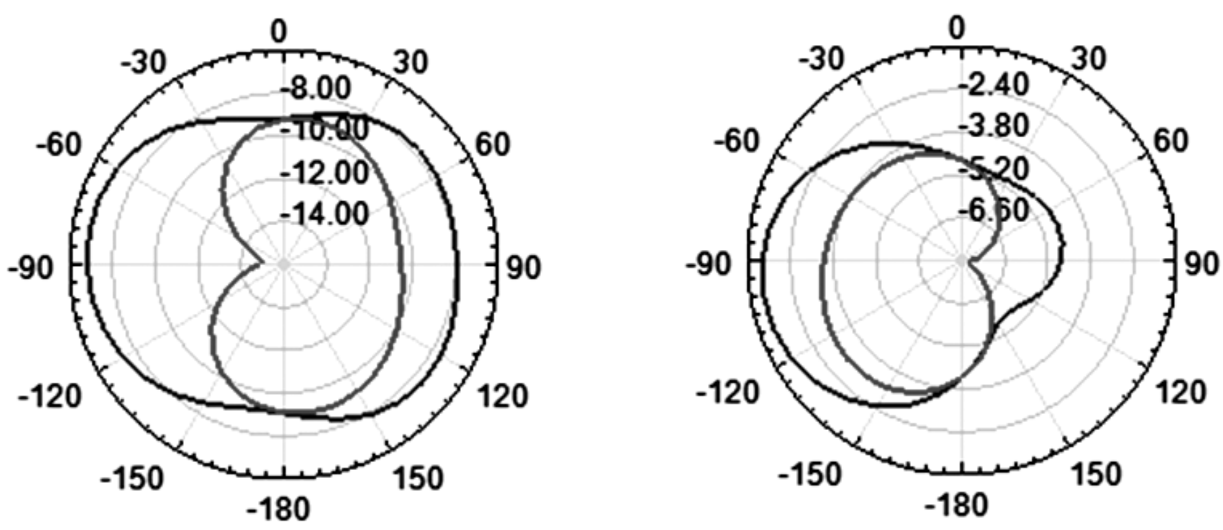


Figure 5: Return loss of modified fractal antenna

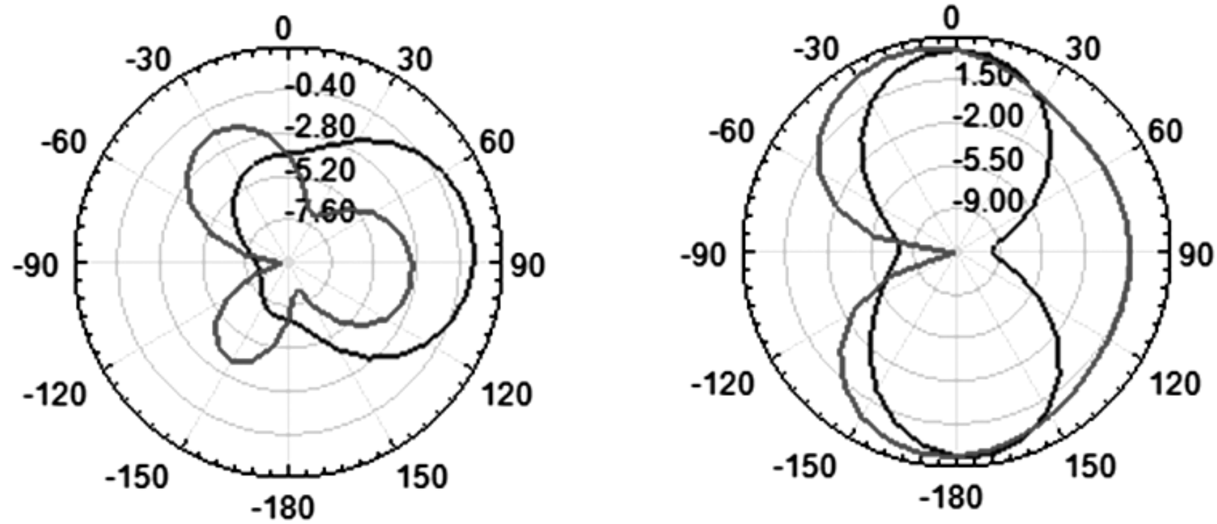
4.2. Radiation pattern

The radiation pattern is the graphical representation of propagation of electromagnetic waves from antenna in air. The pattern is constructed by measuring the energy which is radiated from antenna around the antenna. The two dimensional gain at $\Phi=0^0$ and 90^0 at resonant frequencies is shown in Figure. 6. The maximum gain of 5.4 dB is obtained at resonant frequencies 9.6 GHz. It is found that the characteristics of fractal antenna are improved by increasing the number of iteration. The results of second iteration are better than first iteration fractal antenna. The effect of second iteration is exhibited from return loss which indicates the proposed antenna is useful for low frequencies applications. This antenna operates on frequency range from 1.00 GHz to 1.60 GHz. The radiation pattern of proposed modified fractal antenna at 1GHz and 6.9GHz is shown in Figure.7

The proposed antenna is designed and simulated at different iterations and results are calculated. The comparison results of different iterations are shown in Table 1.

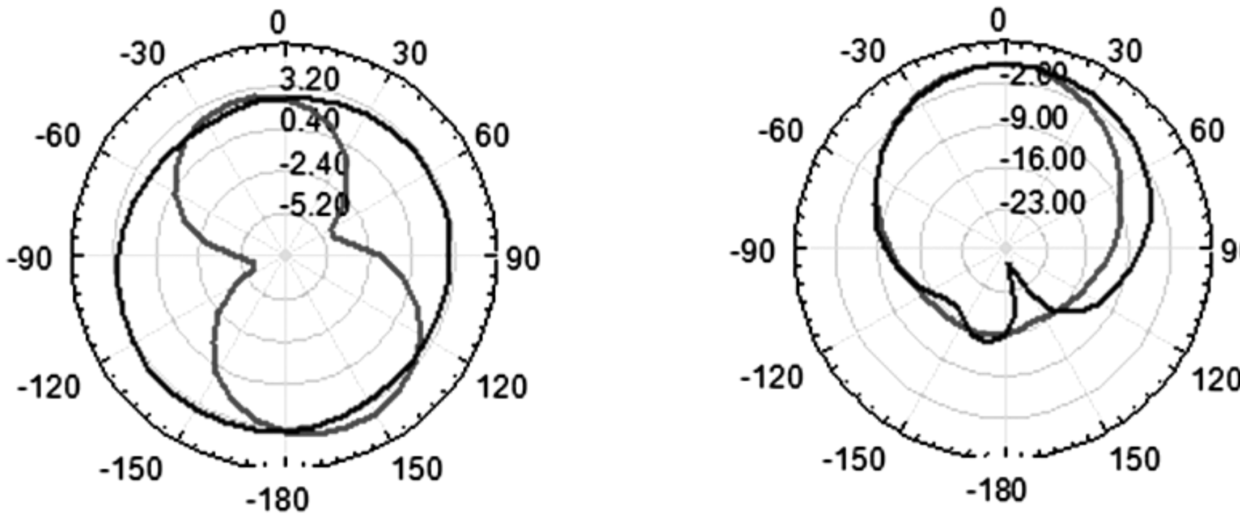


(a) **(b)**



(c) (d)

Figure 6: Radiation pattern of antenna at frequency (a) 3.1GHz (b) 4.5 GHz (c) 7.1 GHz (d) 9.6 GHz



(a) (b)

Figure 7: Radiation pattern of modified fractal antenna

Table 1
Comparison between 2nd iteration of geometry fractal,
1st iteration of modified fractal antenna and 2nd iteration of modified fractal antenna

S. no	*2nd iteration geometry of fractal antenna*			*1st iteration of modified fractal antenna*			*2nd iteration of modified fractal antenna*		
	Fc (GHz)	*Return loss*	*Gain (dB)*	*Fc (GHz)*	*Return loss*	*Gain (dB)*	*Fc (GHz)*	*Return loss*	*Gain (dB)*
1	3.1	-17.51	-6.2	5.5	-11.85	3.0	1.2	-10.24	4.4
2	4.5	-10.91	-1.0	8.0	-19.72	2.2	6.9	-29.85	1.2
3	7.1	-20.27	0.6						
4	9.6	-14.42	4.4						

4. CONCLUSION

It is clearly seen that fractal geometries are designed in HFSS software and FR4 substrate is used. The size of fractal geometry antenna is very small and antenna is useful for SHF band. Proposed fractal antenna operates on four resonant frequencies which fall under S, C and X bands. This antenna can be used for satellite TV LNB (9.75GHz). The modified fractal geometry is designed by two generator curves to increase the gain at low frequencies. The first iteration of proposed antenna can operates at C and S band with acceptable gain and can also be used for military satellite application (7.9GHz). But the gain and return loss are improved when second iterations is applied. The modified fractal geometry works in L band and having 600MHz bandwidth from 1.0 GHz to 1.6 GHz. The value of gain is also much better from previous design. Proposed antenna is useful for applications such as aircraft surveillance (1.09GHz), GPS (L1=1.227GHz). Modified fractal antenna founds its applications in L and C band of IEEE standard. So that proposed antenna meets requirement of various applications like Global positioning system (GPS), Aircraft Surveillance, Mobile services, Amateur radio, Digital audio broadcasting, World space satellite radio broadcasts, Astronomy radio.

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