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An Improved Compact & Multiband Fractal Antenna Using the Koch Curve Geometry

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Abstract In this paper, we have achieved an compact & multiband fractal antenna using a Koch curve geometry. The simulation of the proposed antenna is done by CST Microwave Studio EM simulation software. The proposed Koch curve fractal antenna proves that it is capable to create multiband frequencies. The proposed fractal antenna is designed on FR-4 substrate with Ɛr= 4.4. The antenna is fed with the probe feed method. We got two resonant frequencies like 32.84GHz & 34.28GHz which shows multiband characteristics. Simulated results shows that the return loss is better than 15 dB, the VSWR is less than 1.3, the directivity is greater than 6dBi & the gain is more than 6dB in each band. So this fractal antenna can be suitable for the radio astronomy & space research applications.

Keywords: *fractal antenna, koch curve, CST, IFS, self similarity, self filling, multiband*

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1. Introduction

Now-a-days there is a need for more compact and portable communication systems. We know that antenna is an integral part of all the communication systems. So there is a demand for small antennas for portable communication systems [1].

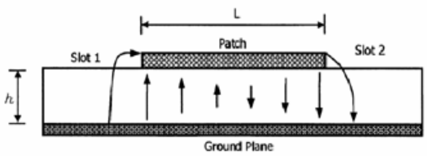
It is well known that the antenna dimension is a function of its operating wavelength (λ). i.e if the antenna size is less than the operating wavelength (λ), the antenna becomes inefficient as its characteristics like radiation resistance, directivity, gain & bandwidth are diminished [2]. Fractal geometry is a very good solution for this problem due to its two major characteristics like self similarity & space filling. so fractal geometry has become an important approach for designing multiband antennas [3,4].

A fractal is a rough or fragmented that can be sub-divided into parts, each of which is a reduced copy of whole. Therefore the basic property of a fractal shape is self similarity and structure at all scales [5].

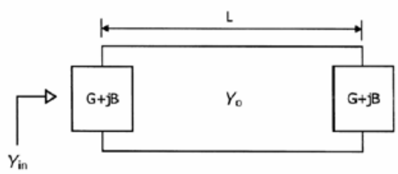
The goal of this paper is to design and characterize a fractal antenna with Koch curve geometry as it has the potential to provide multiband solution [6].

A koch curve is a famous fractal objects in mathematics [7]. These are low profile antennas with better return loss, VSWR, directivity and gain. So Koch curve can be made operative at multiple frequency bands and hence are multi-functional [8,9].

2. Antenna Design



RADIATING PATCH ANTENNA



EQUIVALENT CIRCUIT

$$G = \frac{w^2}{90\lambda_0^2} \; for \; W < \lambda_0$$

$$G = \frac{w^2}{120\lambda_0^2} \; for \; W < \lambda_0$$

$$B = \frac{k_0 \Delta l \sqrt{\varepsilon_{eff}}}{z_0}$$

$$Y_{in} = Y_{slot} + Y_0 \frac{Y_{slot} + jY_0 tan\beta(L+2\Delta l)}{Y_0 + jY_{slot} tan\beta(L+2\Delta l)}$$

Design Equations:

$$Z_0 = \frac{120\pi h}{W\sqrt{\varepsilon_{eff}}}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-1/2} = 2.14$$

$$\Delta l = 0.412h\left(\frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258}\right)\left(\frac{W/h + 0.264}{W/h + 0.8}\right)$$

$$f_r = \frac{c}{2\sqrt{\varepsilon_{eff}}\,(L + 2\Delta l)}$$

$$(L + 2\Delta l) = \frac{\lambda_g}{2} = \frac{\lambda_0}{2\sqrt{\varepsilon_{eff}}}$$

$$W = \frac{c}{2 f_r}\left(\frac{\varepsilon_r + 1}{2}\right)^{-1/2} (\text{not critical})$$

Here we have designed a 3 GHz antenna using the following parameters.

Substrate: FR4 (ε_r= 4.4, h=1.6 mm).

$$\lambda_0 = \frac{c}{f_r} = 10cm$$

$$W = \frac{c}{2 f_r}\left(\frac{\varepsilon_r + 1}{2}\right)^{-1/2} = 6mm$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-1/2} = 2.14$$

$$\Delta l = 0.412h\left(\frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258}\right)\left(\frac{W/h + 0.264}{W/h + 0.8}\right) = 0.04cm$$

$$L = \frac{c}{2\sqrt{\varepsilon_{eff}}} - 2\Delta l = 6mm$$

$$Y_{in} = 2G = \frac{1W^2}{45\lambda_0^2} = \frac{1}{R_{in}}$$

$$R_{in} = 288\Omega = input\ impendance$$

$$Z_{OT} = \sqrt{R_{in}.50} = 120\Omega$$

This proposed fractal antenna is an iterative model to a normal square patch as shown in Figure 2a with a generator of the shape shown in the following Figure 1.

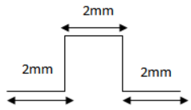


Figure 1. proposed generator

Figure 2a shows a normal wire square patch antenna in which the length of each side is 6 mm. Iteration 1 is produced by replacing each straight wire with the proposed generator shape as shown in figure 2b. Iteration 2 is produced from iteration 1 by using IFS (Iterated Function System) as shown in figure 2c [10,11].

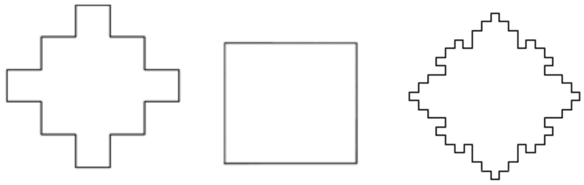


Figure 2. a. Iteration 0 Figure 2. b. Iteration 1 Figure 2. c. Iteration 2

Figure 2. Different iteration stages of the proposed Koch curve fractal antenna. Here One stage is generated by applying the affine transformation to the previous one

3. Simulation Setup & Results

CST Microwave Studio electromagnetic simulator software is used for design & simulation. Antenna is fed with probe feed. Results like Reflection coefficient (return loss), VSWR (voltage standing wave ratio), Variation of Impedance Z (real & Imaginary part), 2D radiation patterns, 3D radiation patterns are simulated [12,13]. Simulation results of iteration 1, iteration 2 & iteration 3 are summerised in Table 1, Table 2 & Table 3 respectively.

3.1. Simulated Results of Iteration 0

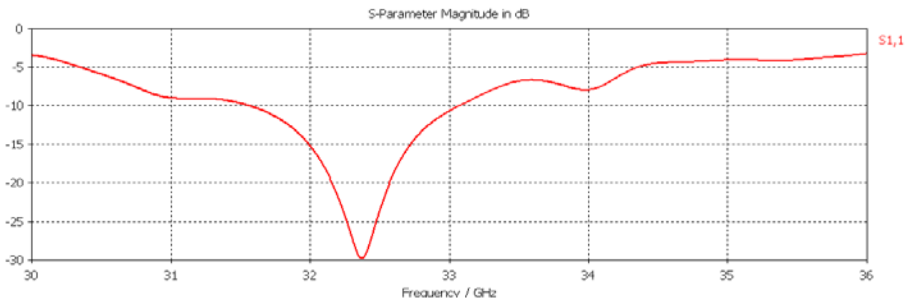


Figure 3. a. Variation of simulated reflection coefficient(S11)with frequency

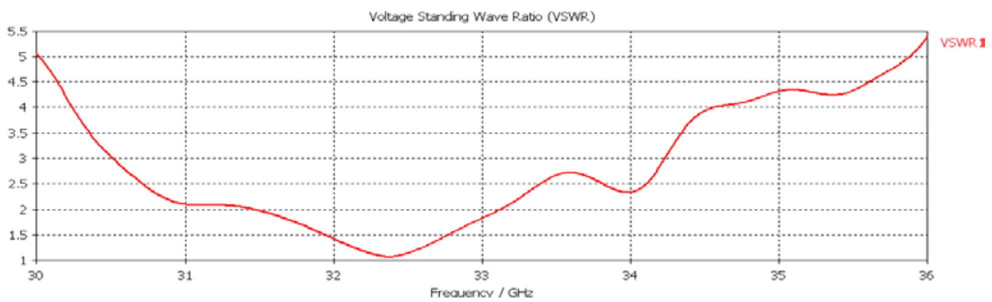


Figure 3. b. Variation of VSWR with frequency

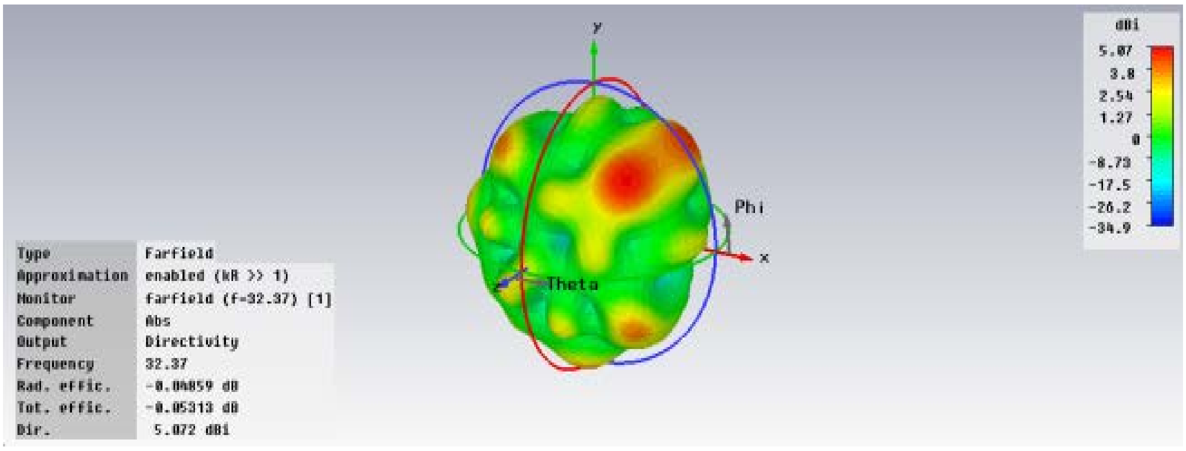


Figure 3. c. 3D Radiation pattern (Directivity) at Fr=32.37 GHz

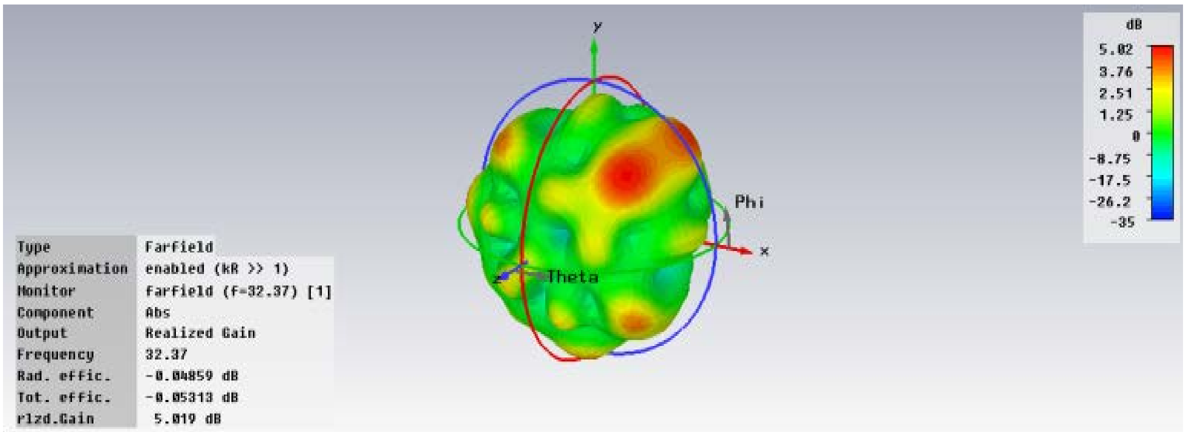


Figure 3. D. 3D Radiation pattern (Gain) at Fr=32.37 GHz

Table 1. The different results (1) are given below

Fr (GHz)	RL (dB)	VSWR	Directivity (dBi)	Gain (dB)
32.37	-29.814	1.006	5.072	5.019

3.2. Simulated Results of Iteration 1

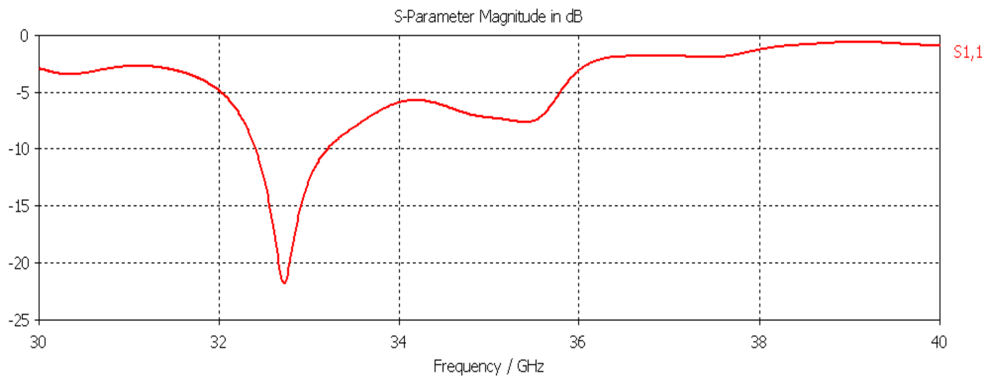


Figure 4. a. Variation of simulated reflection coefficient (S11) with frequency

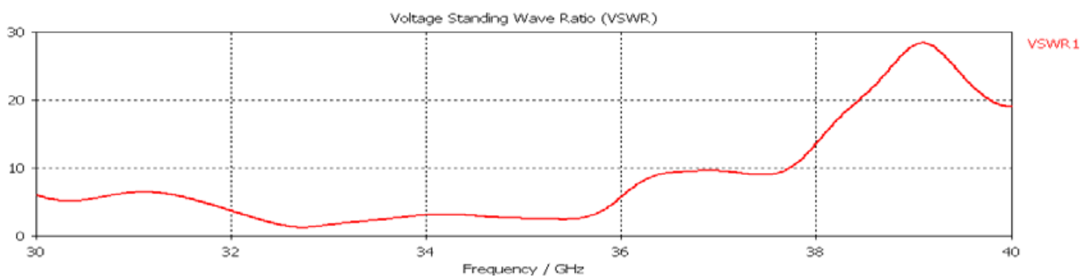


Figure 4. b. Variation of VSWR with frequency

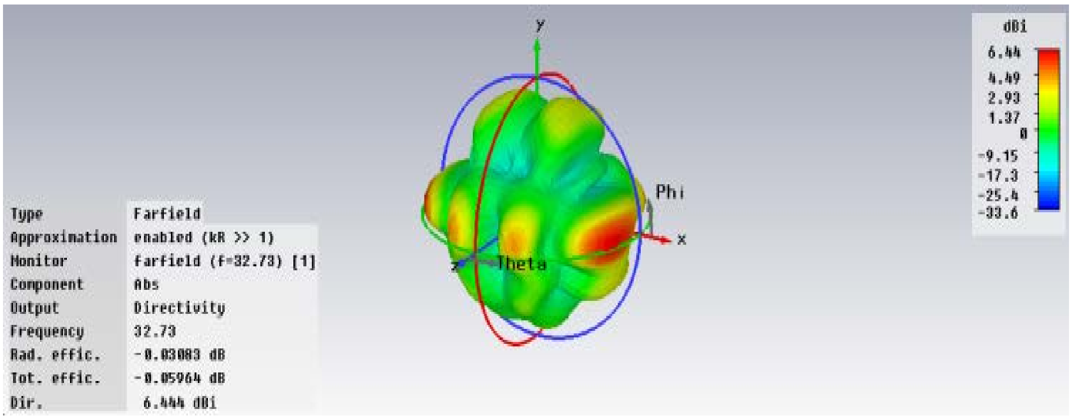


Figure 4. c: 3D Radiation pattern (Directivity) at Fr=32.73 GHz

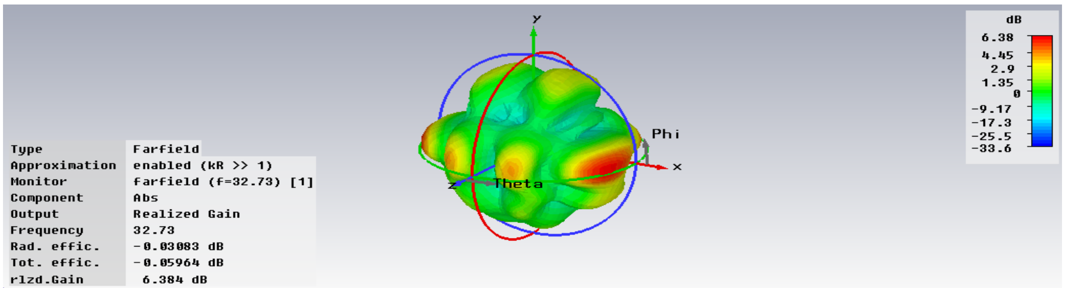


Figure 4. d. 3D Radiation pattern (Gain) at Fr=32.73 GHz

Table 2. The different results(1) are given below

Fr (GHz)	RL (dB)	VSWR	Directivity (dBi)	Gain (dB)
32.73	-22.14	1.07	6.444	6.384

3.3. Simulated Results of Iteration 2

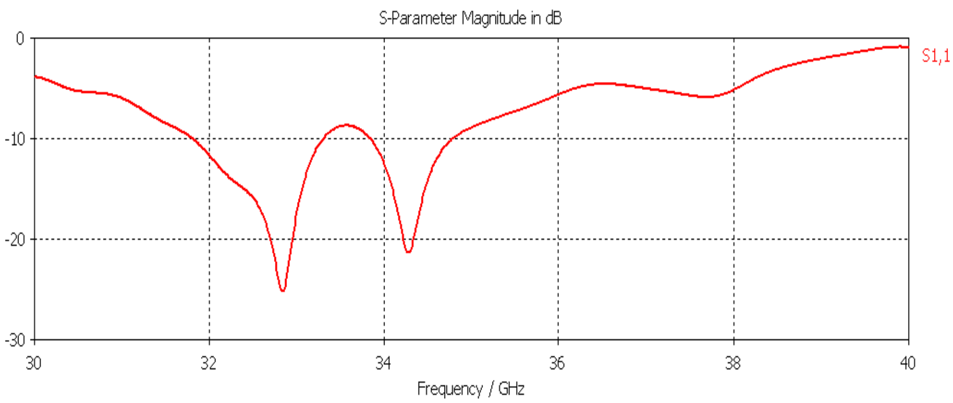


Figure 5. a. Variation of simulated reflection coefficient (S11) with frequency

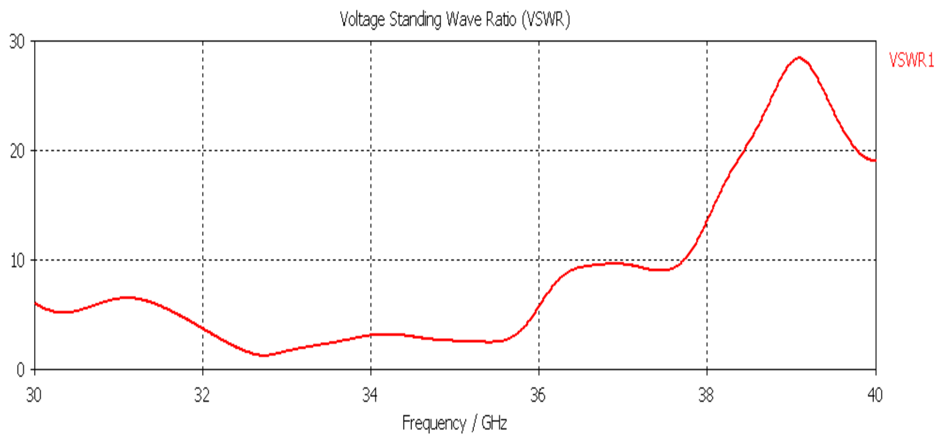


Figure 5. b: Variation of VSWR with frequency

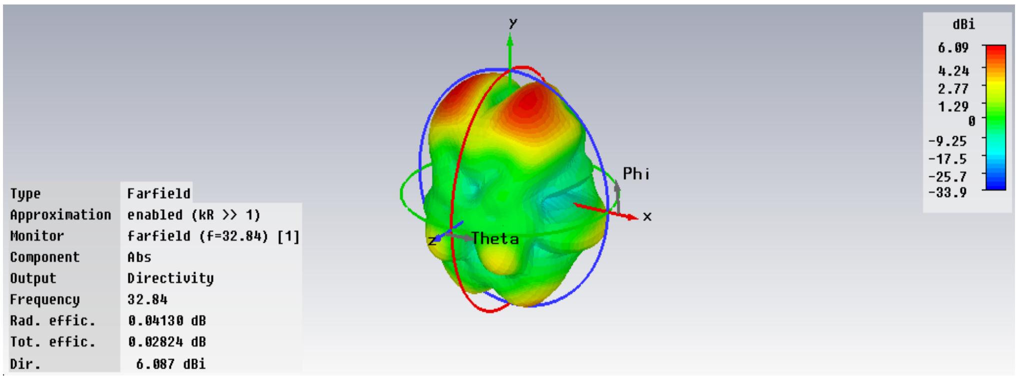


Figure 5. c. 3D Radiation pattern(Directivity) at Fr=32.84 GHz

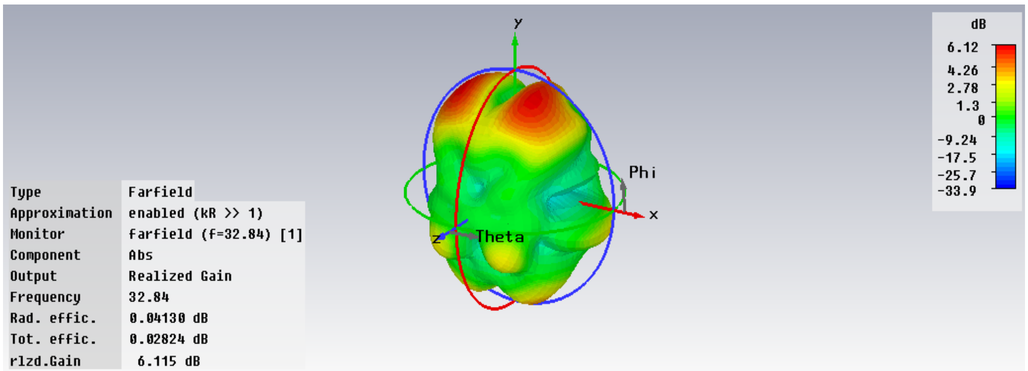


Figure 5. d. 3D Radiation pattern(Gain) at Fr=32.84 GHz

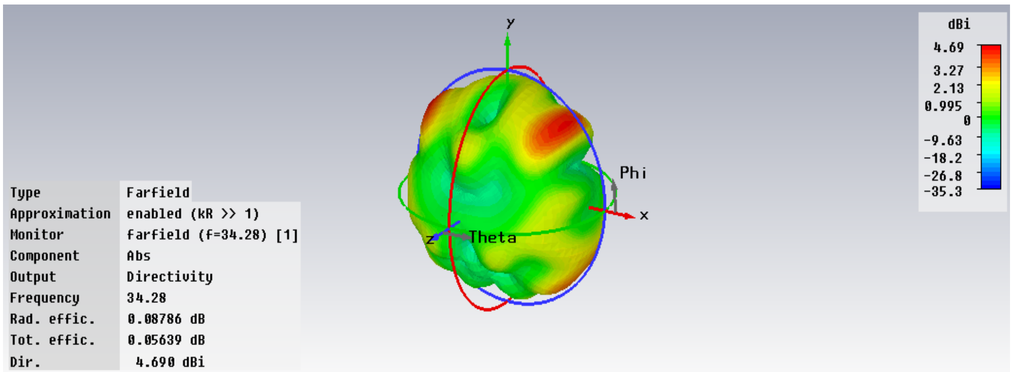


Figure 5. e. 3D Radiation pattern(Directivity) at Fr=34.28 GHz

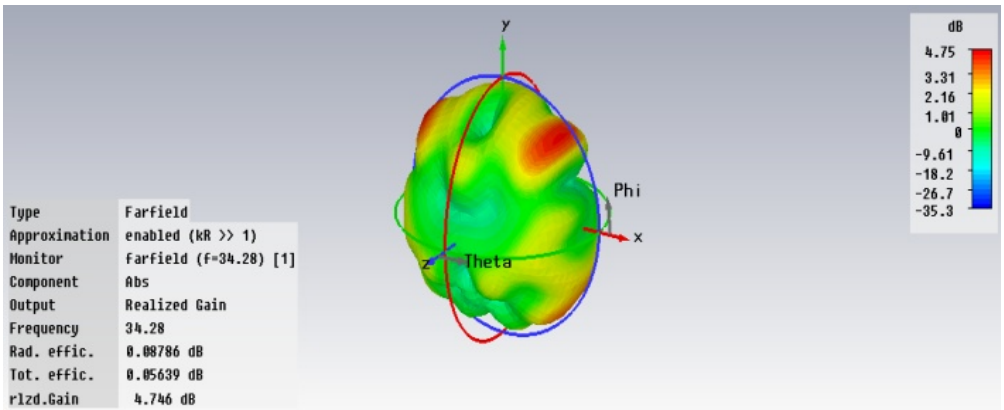


Figure 5. F. 3D Radiation pattern (Gain) at Fr=34.28 GHz

Table 3. The different results (9) are given below

Fr (GHz)	RL (dB)	VSWR	Directivity (dBi)	Gain (dB)
32.84	-25.1	1.1	6.087	6.115
34.28	-21.14	1.2	4.698	4.746

BW Calculation

1. For 0^{th} iteration

fc=32.37 GHz, f_L=31.67GHz & f_H=33.83GHz

So BW=$\left(\frac{fH - fL}{fc}\right)$ 100%=6.67%

2. For 1st iteration
fc=32.73 GHz, f_L =32.21GHz & f_H =33.19GHz

So BW= $(\frac{fH - fL}{fc})$ 100%=2.99%

3. For 2nd iteration
For 1st band
fc=32.84GHz, f_L=30.91GHz & f_H=33.41GHz So BW= $(\frac{fH - fL}{fc})$ 100%=7.61%

For 2nd band
fc=34.28GHz, f_L=33.92GHz & f_H=34.94GHz So BW= $(\frac{fH - fL}{fc})$ 100%=2.97%

Table 4. Comparision of different major parameters for multiple iterations

Multiple Parameters	0th iteration	1st iteration	2nd iteration
Return loss	-29.814	-22.14	-25.1 -21.14
VSWR	1.006	1.07	1.1 1.2
Directivity	5.072	6.444	6.087 4.698
Gain	5.019	6.384	6.115 4.746
Presence of multiband	Nil	Nil	Yes (2)
BWenhancement	6.67%	2.99%	7.61% 2.97%

4. Conclusion

A fractal antenna with Koch curve geometry is designed & characterized. The simulated results show that return loss is more than -15 dB, VSWR is less than 1.3, directivity is more than 6dBi, gain is more than 6dB. This antenna not only improve return loss, VSWR, directivity & gain, but also can Provide a compact size of radiating patch. Gain is enhanced with multiple iterations. Bandwidth enhancements for multiple iterations is compared. Antenna size is reduced by using fractal shapes with multiple iterations. After these comparisons, it is clear that the proposed fractal antenna is superior than the conventional rectangular patch antenna. It follows the multiband characteristics which enables to use a single antenna instead of many. So the proposed antenna is suitable for the radio astronomy & space research applications.

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