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Design of Plus Shaped Fractal Antenna for Multiband Applications

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Abstract

A Plus shaped novel fractal antenna with Minkowsi geometry has been reported in this paper which operates on L, S, C and X bands. Proposed antenna is simulated and fabricated, Simulated antenna operates at seven distinguished resonant frequencies (1.82 GHz, 3.54 GHz, 4.09GHz ,5.09 GHz, 5.27 GHz, 6.45 GHz, 7.82 GHz).The designed antenna depicts minimum reflection coefficient -23.64 dB and the maximum gain 7.55dB. Whereas fabricated antenna works on six different frequency bands (1.82GHz, 3.7GHz, 4.68GHz, 5.383 GHz, 6.83GHz, 8.85GHz). The simulated and experimental results are in good agreement with each other. Proposed antenna can be used in Bluetooth, Wi-Max, High speed point-to-point communication, High speed wireless communications and Satellite Communication.

Keywords: MPA, Minkowski Geometry, Plus shape, Multiband Applications, Fractal.

1. INTRODUCTION

Microstrip Patch Antenna (MPA) contains radiating patch on one side of the dielectric substrate and ground on the other side of the substrate. Patch and feed line are inscribed on dielectric substrate [1][2][3]. For wireless communication, an antenna with high gain, multiband and wider bandwidth is required. Different antennas have been proposed by renowned researchers for wideband applications [4][5][6]. To fulfill these requirements, there is a need of fractal antennas. Fractal word derived from Latin word and invented by Benoit B. Mandelbort in 1995. Fractal geometry is used to achieve the multiband characteristics [7][8]. Fractal is formed from word “fractus” means fractured or broken fragment. .Number of fractal geometries had been discovered for wideband and multiband antenna [9]. Fractal geometry gives repetition of a particular scale for different iterations. Fractal antennas are self symmetrical and possess miniaturization, wideband and multiband [10][11][12]. Various types of Fractal geometries have been used by distinguished researchers to design antennas [13][14]. Most commonly used geometries are Sierpinski Gasket [15], Sierpinski Carpet [16][17], Koch curves [18], Minkowski Geometry [19], Meander [20], Giuseppe Peano [21], Hilbert curve [22], Hybrid Fractal Geometry [23]. Fractal geometries play vital role in miniaturization of antenna and multiband characteristics because of Space filling and self similarity properties [24][25][26].

2. DESIGN CONFIGURATION

In this proposed design, rectangular patch of length 39 mm and width 13mm has been taken. To design a proposed antenna, Initially, a plus shape slot has been taken out from rectangular patch e as shown Figure 1, and termed as iteration 1. Further, Sierpinski carpet geometry is used to make circles inside the plus shape geometry. Then the Minkowski geometry is applied as shown as shown in Figure 2, and named as 2nd iteration.. Similar procedure is used to derive the 3rd iteration by applying the Minkowski geometry to the 2nd iteration, as shown in Figure 3. Line feeding technique is applied to provide the excitation to antenna. The fabricated prototype of proposed Plus shaped Antenna is depicted in Figure 4.The following are the equations (1) to (6used to compute the dimensions of the proposed Antenna and also delineated in Table 1:

1. The width of the patch is calculated using:

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

2. Effective dielectric constant is calculated using:

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

3. The length of the patch is now to be calculated using:

$$L = \frac{1}{2f_r\sqrt{\varepsilon_o\mu_o}\sqrt{\varepsilon_{reff}}} - 2\Delta L \tag{3}$$

4. Effective Length is calculated using :

$$\Delta L = h \times 0.412\left[\frac{(\varepsilon_{reff} + 0.3)\left(W/h + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(W/h + 0.8\right)}\right] \tag{4}$$

5. The length and width of a substrate is calculated using :

$$L_g = 6h + L \tag{5}$$

$$W_g = 6h + W \tag{6}$$

Table 1: Parameteric values of Proposed Plus shaped fractal antenna

S. No.	Parameters	Values
1.	Length of Substrate	47mm
2.	Width of Substrate	47mm
3.	Height of substrate	2mm
4.	Length of Ground	47mm
5.	Width of Ground	47mm
6.	Length of patch(1,2)	39mm
7.	Width of Patch(1,2)	13mm
8.	Length of feed Line	2mm
9.	Width of Feed Line	4mm

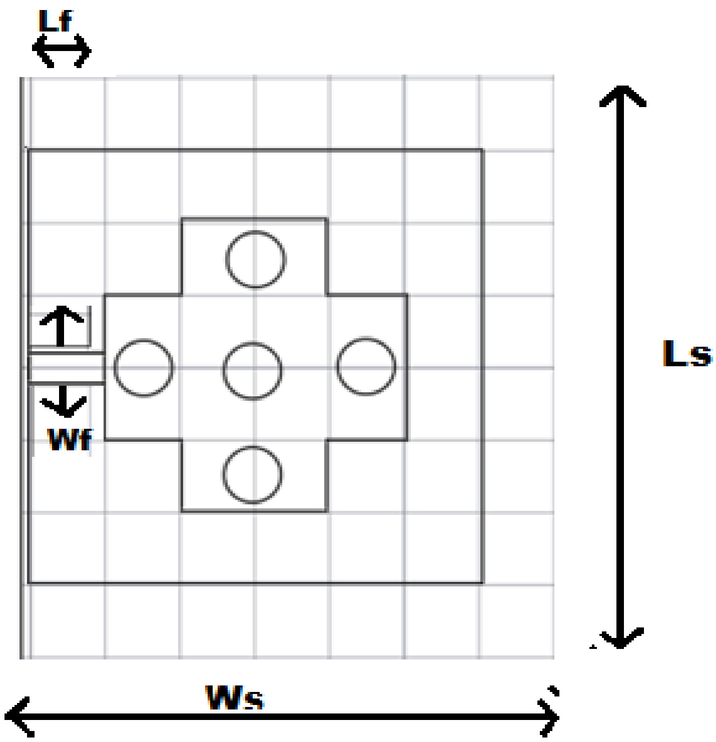

Figure 1: 1st Iteration of Proposed Antenna

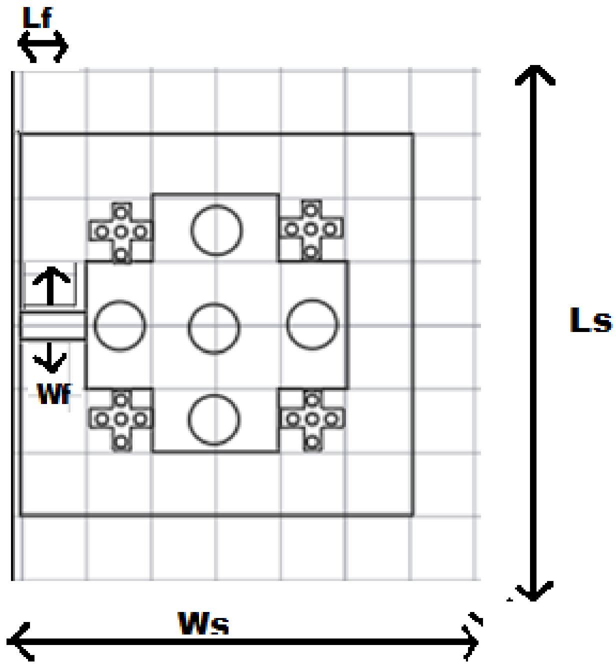

Figure 2: 2^{nd} Iteration of Proposed Antenna

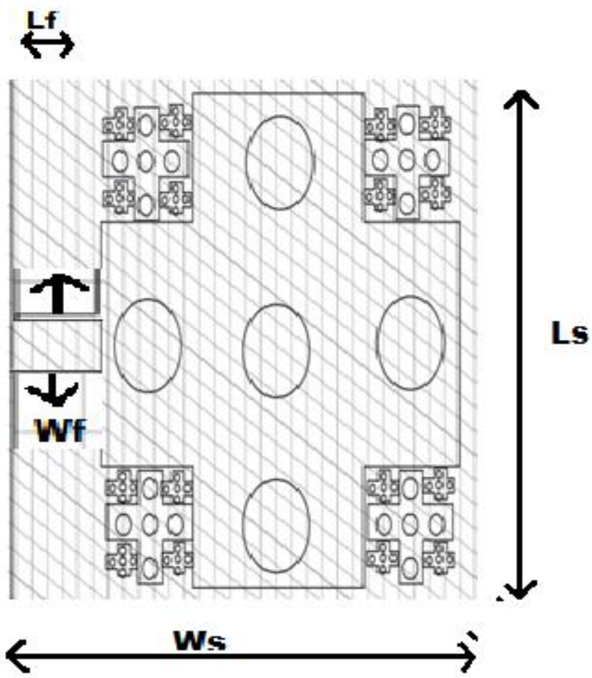

Figure 3: 3^{rd} Iteration of Proposed Antenna

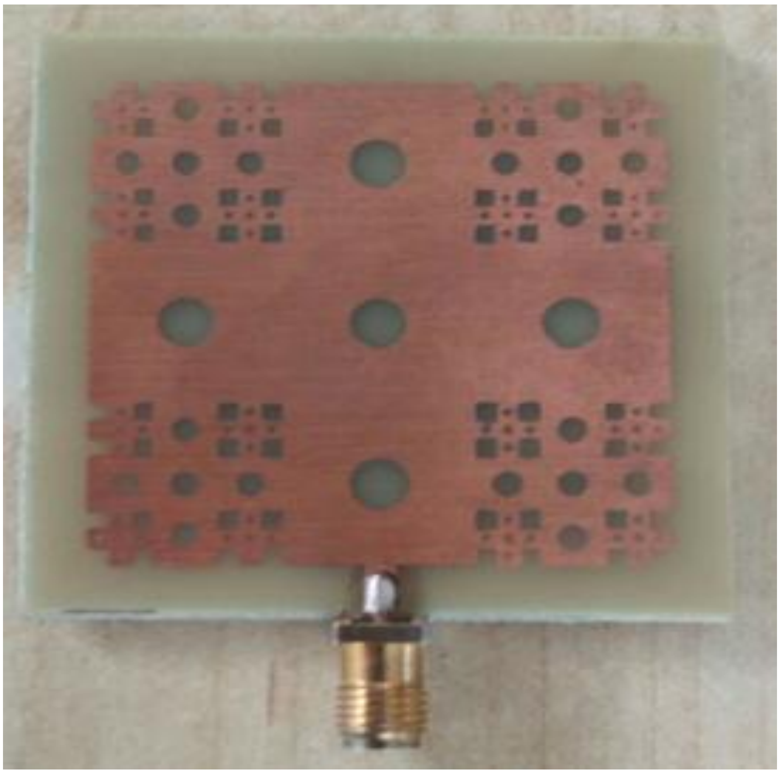

Figure 4: Fabricated Prototype of Proposed Antenna

3. RESULTS AND DISCUSSIONS

3.1 Reflection Coefficient

It is expressed in dB relative to the transmitted signal power [27]. The S_{11} characteristics of the simulated structures of designed antenna are shown in Fig. 4, Fig. 5 and Fig. 6 respectively. In results, it shows that the 1st iteration of antenna operates on four frequencies(4.18GHz, 4.90GHz, 7.09GHz, 9.18GHz), 2nd iteration of antenna works on six frequencies(1.82GHz, 3.36GHz, 4.63GHz, 5.36GHz, 7.27 GHz, 8.82GHz) and the 3rd iteration of antenna operates on seven resonant frequencies (1.82 GHz, 3.54 GHz, 4.09GHz ,5.09 GHz, 5.27 GHz, 6.45 GHz, 7.82 GHz). The values of the Reflection coefficient for all the frequency bands of designed antenna are at acceptable level ($S_{11} \leq$ -10dB). Simulated results of Reflection coefficient for all the iterations are reported in figures 5, 6 and 7 as Reflection coefficient versus Frequency plot and also delineated in Table 2.

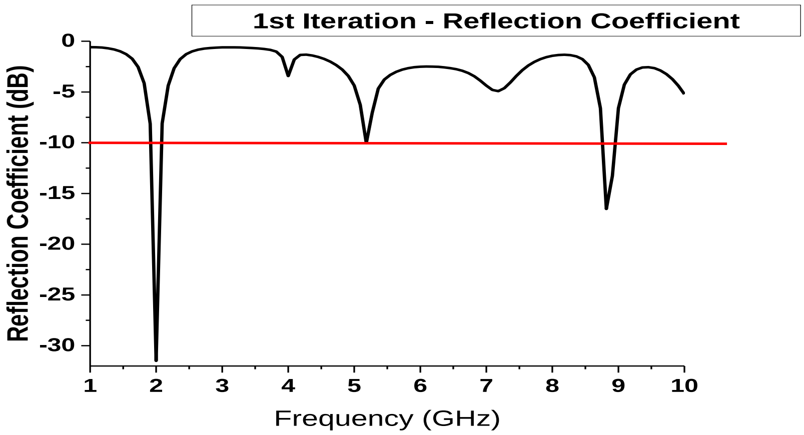

Figure 5: Reflection Coefficient v/s frequency plot – 1st iteration

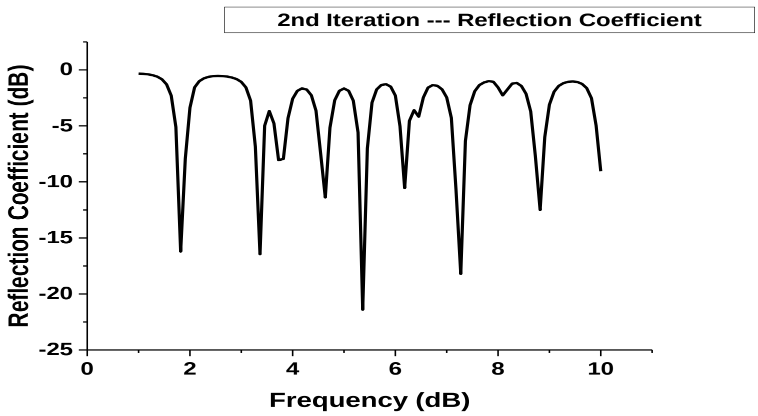

Figure 6: Reflection Coefficient v/s frequency plot – 2nd iteration

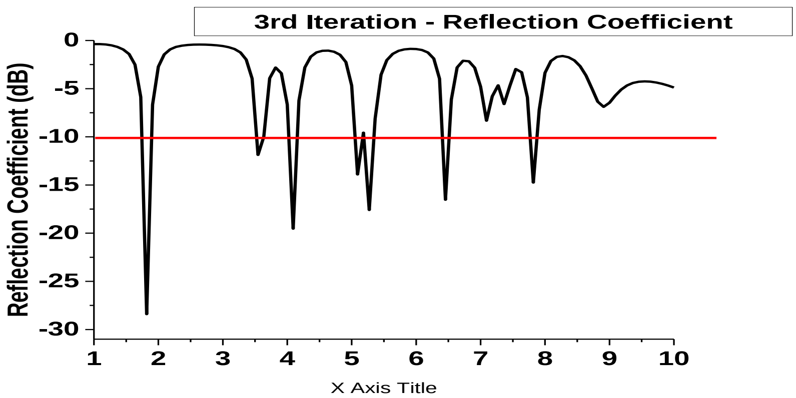

Figure7: Reflection Coefficient v/s frequency plot – 3rd iteration

3.2 Gain

Antenna gain is the ratio of radiation intensity at the peak of main beam to the radiation intensity in the same direction [28] .The simulated gain is also observed at every resonant frequency for all the iterations of proposed antenna. 1st iteration depicts the value of gain as 6.125 dB and their respective frequency band is 9.18 GHz . 2nd iteration exhibits the value of gain 7.55 dB and 4.76 dB for respective frequency bands 5.36GHz, 8.82GHz. Similarly, 3rd iteration demonstrates the value of gain as 2.8 dB and their respective frequency bands is 5.27 GHz. The Maximum value of gain is 7.55dB and 3D gain plot for all the iterations is delineated in Figure 8, Figure 9 and Figure 10 respectively.

Figure 8: 1st iteration – Gain

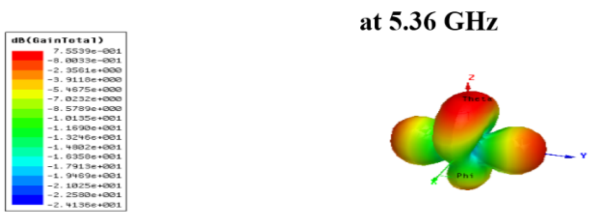

Figure 9: 2nd iteration - Gain

Figure 10: 3rd Iteration – Gain

3.3 Bandwidth

It is the range of usable frequencies in which the performance of the antenna conforms to a specified standard. It is the range of frequencies on either side of the centre frequency where the antenna characteristics like input impedance, radiation pattern, beam width, polarization, side lobe level or gain, are close to the values which are obtained at the center frequency [29]. Bandwidth of simulated results is elaborated in Table 2.

Table 2: Simulated Results of Designed Antenna

FREQUENCY (GHz)	Reflection Coefficient (dB)	GAIN (dB)	B.W.=(F2-F1)/Fc (MHz)	VSWR
1st ITERATION				
4.18	-16.60	-2.03	310	1.35
4.91	-16.23	1.95	260	1.37
7.09	-12.92	-3.38	84	1.58
9.18	-17.30	6.13	195	1.32
2nd ITERATION				
1.82	-15.70	-6.11	540	1.39
3.36	-22.88	-6.84	384	1.54
4.64	-11.92	-6.76	128	1.68
5.36	-15.34	7.55	203	1.41
7.27	-23.64	-1.60	230	1.14
8.82	-12.65	4.76	79	1.61
3rd ITERATION				
1.82	-27.48	-6.90	819	1.09
3.55	-11.60	-5.48	335	1.71
4.09	-19.55	-1.08	316	1.24
5.09	-13.72	-2.7981	252	1.52
5.27	-17.43	2.80	321	1.31
6.45	-15.63	-5.34	138	1.40
7.82	-14.80	-2.51	128	1.44

3.4 VSWR

A standing wave in a transmission line is the wave in which distribution of the current, voltage or field strength is generated by the superimposition of two waves of same frequency moving in opposite direction [6]. VSWR versus frequency plot for iterations 1st , 2nd and 3rd has been reported in Figure 11, 12 and 13, and VSWR for all the iterations also shown in Table 2. The value of VSWR is in the acceptable range (≤ 2) for all the resonating frequencies.

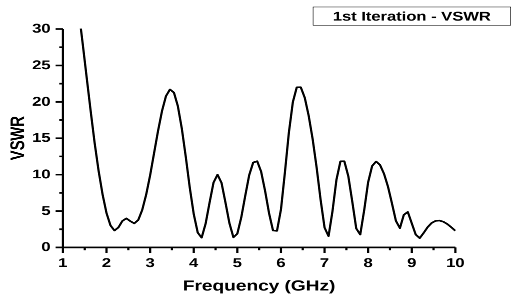

Figure 11: VSWR v/s Frequency Plot for 1st Iteration

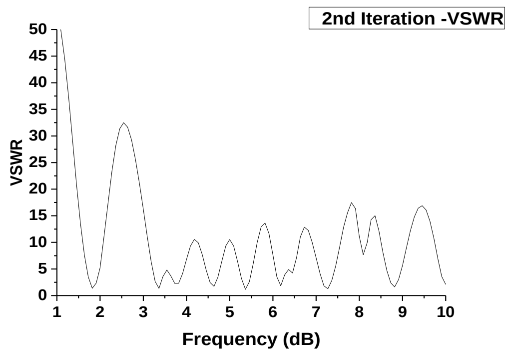

Figure 12: VSWR v/s Frequency Plot for 2nd Iteration

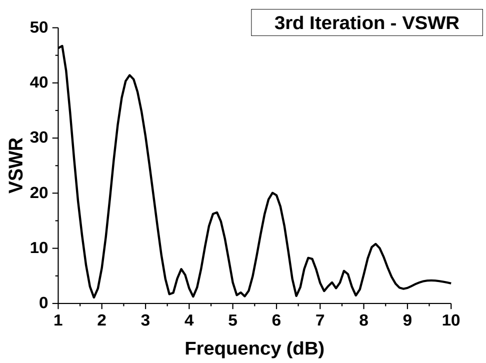

Figure 13: VSWR v/s Frequency Plot for 3rd Iteration

3.5 Comparison of Simulated and Fabricated Results

Reflection coefficient or Return Loss has been experimental measured on Vector Network Analyser and illustrated in Figure 14. It can be contemplated from the figure 15 (Comparison of Simulated and Measured Results) that Simulated and measured results are in good agreement with each other and variations of the results may be occurred because of the following reasons:

- Some vagueness in the electrical properties of Substrate
- Reflection from the SMA connector

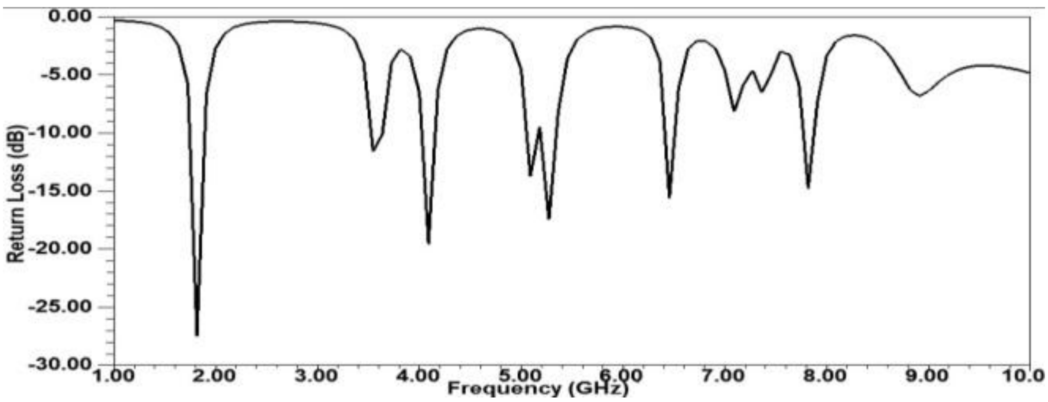

Figure 14: Measured result of return loss

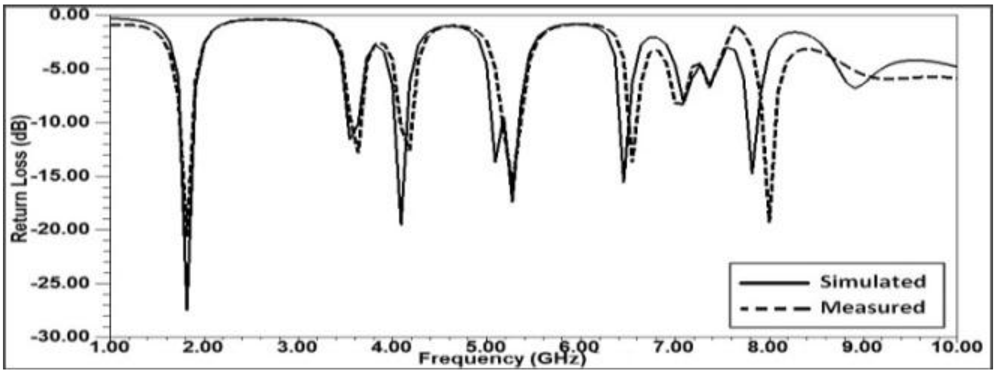

Figure15: Comparison of simulated and measured result of return loss

Measured and simulated results are also explained in Table 3.

Table 3: Comparison of simulated and measured Designed antenna

Frequency (GHz)	**Simulated Reflection Coefficient (dB)**	**Simulated Reflection Coefficient (dB)**
1.82	-27.48	-20.02
3.55	-11.60	-14.15
4.09	-19.55	-13.88
5.09	-13.72	-16.58
5.27	-17.43	-14.82
6.45	-15.63	-10.28
7.82	-14.80	-19.73

Proposed work is also juxtaposed with the existing work and reported in Table 4.

Table 4: Comparison of Proposed antenna with existing antennas

Ref. No.	**Antenna Size (mm^3)**	**Resonant Frequency (GHz)**	**Reflection coefficient (dB)**	**Band width (MHz)**	**Gain (dB)**
Propo-sed Antenna	47*47*2	1.82, 3.55, 4.09, 5.09, 5.27, 6.45, 7.82	-15.70, -22.88, -23.64, -27.48, -19.55, -17.43	195, 203, 79, 321	6.13, 7.56, 4.76, 2.80
[30]	50.5*83.5*1.524	1.1, 3.4, 5.8	-23.73, -38.9, -16.4	212.12,333.33, 363.6	2.09, 6.31, 4.33
[31]	45*70*8	0.69,1.88,2.5	-16.23, -22.27, -19.68	612, 367, 907	-7.25
[32]	50*50*1.59	2.42	-34.95	60	3.612
[33]	80*80*20	2.29	-29.5	62	7.29
[34]	85*75*1.5	2.6,4.2,6.2,8.1, 9.7	-19.8, -16.5, -15.1, -28.9, -25.3		

It can be contemplated from Table 4 that proposed design is compact in size and also better than existing designs in terms of antenna performance parameters like Reflection Coefficient, VSWR and Gain.

4. CONCLUSION

Novel design of fractal antenna using Sierpinski and Minkowski Geometry for wireless applications has been designed in this paper. Three iterations of proposed antenna have been designed to reduce the size of the antenna and also to improve the performance parameters in terms of reflection loss, VSWR , gain etc. The number of resonant frequencies of the antenna increases on increasing the antenna iterations. The gain of antenna is also observed which is acceptable at all the frequency bands of designed antenna This contemplate that the antenna can be useful for various wireless applications such as Bluetooth, WiMax, high speed wireless communication (5.92 - 8.5 GHz) and X-band for satellite communication (8-12 GHz).

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