Novel Design of Fractal Antenna using Giuseppe Peano Geometry for Wireless Applications

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ABSTRACT
A novel design of fractal using Giuseppe Peano geometry for wireless applications has been presented in this paper. Low cost FR4 glass epoxy substrate with 1.6mm thickness and dielectric constant 4.4 is used to design proposed antennas. The resonant frequency used for calculating the dimensions of proposed antenna is 4GHz. Three iterations of proposed antenna are designed to achieve the miniaturization. Antenna is designed and simulated by using HFSS V13 software and different parameters such as return loss, VSWR, gain has been observed and analyzed. The proposed antenna is useful for different wireless applications as per FCC standards such as bluetooth (2.12-2.95GHz), WLAN (4.82-595GHz), high speed wireless communication (5.92GHz-8.5GHz) and X-band for satellite communication (8-12GHz).

Keywords
Giuseppe Peano, WLAN, FR4, VSWR, HFSS.

1. INTRODUCTION
Patch antenna is a conducting plate which consists over the top of a dielectric substrate and the ground plane at the bottom plane of the substrate. The radiator of these antennas is of different shapes and feed by various methods [4] [5]. Microstrip patch antennas are used in different wireless applications due to their compact size and low cost [8]. There are many disadvantages also faced by the microstrip antennas such as low gain, low efficiency, less number of operating frequency bands and less bandwidth [6]. But, the major disadvantage of antenna is that, while designing the antenna as the frequency of antenna decreases the size of patch increases. To overcome this problem the miniaturization techniques are employed to reduce the resonant frequency as well as the size of antenna [9]. The efficient way to reduce the size and resonant frequency of antenna is to introduce the slots in the geometry of patch or ground, use the defected ground structure and apply the different fractal geometries to the patch of antenna [10].

Fractal geometries are applied in the patch antennas to overcome the drawbacks of patch antennas as discussed above [1]. These geometrical shapes are self-similar and repeat themselves at different scales. B. Mandelbort proposed the fractal geometry in1975 [7]. Two types of properties are used to design the fractal geometries such as self-similarity and space-filling. These two properties make the antenna to work at more number of resonant frequencies with high value of gain [2] [3]. Fractal antennas can be useful for different wireless applications as per FCC standards such as WLAN at 5.15-8.825GHz, WiMAX at 3.3-3.7GHz, X-band for satellite communication at 7.25-8.395GHz etc [11].

2. ANTENNA DESIGN
Initially, a rectangular patch is used to design the geometry of proposed antenna. The dimensions (length and width) of the patch are calculated by using equation (1) to (5) and found to be 17mm and 23mm respectively. To draw the proposed fractal antenna, Giuseppe Peano geometry is applied along the length (L) and width (W) of the rectangular patch as shown in Figure 1. Line feeding technique is applied to provide the excitation to antenna. 0^{th}, 1^{st} and 2^{nd} iteration of proposed antenna is shown in Figure 2, Figure 3 and Figure 4 respectively. Parametric values of designed antenna are shown in Table 1.

$$w = \frac{c}{2fo\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

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

$$L_{efff} = \frac{c}{2fo\sqrt{\varepsilon_{reff}}} \tag{3}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.246\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \tag{4}$$

$$L = L_{eff} + 2\Delta L \tag{5}$$

Where,

c = Velocity of light in free space.

h = Substrate height.

ε_r = Relative permittivity of the substrate.

W = Width of rectangular patch.

L = Length of rectangular patch.

L_{eff} = Effective length.

ε_{eff} = Effective dielectric constant.

f_o = Resonant frequency.

ΔL = Length extension.

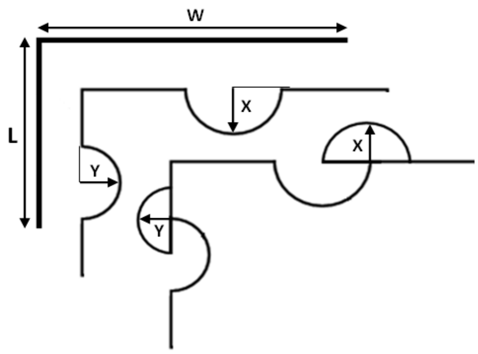

Figure 1: Procedure for designing the iterations of proposed antenna

0th iteration of the proposed antenna starts with the rectangular geometry with length (L=17mm) and width (W=23mm) as shown in Figure 2. The 1st iteration of antenna is designed by extracting the semi-circular slots along the length and width of the rectangular patch, with radius X=3.83mm and Y=2.83mm respectively as shown in Figure 3. 2nd iteration of proposed antenna is designed by taking the 1st iteration as a base geometry. The semi-circular elements with radius X=3.83mm and Y=2.83mm are united along the length and width of rectangular patch respectively as shown in Figure 4.

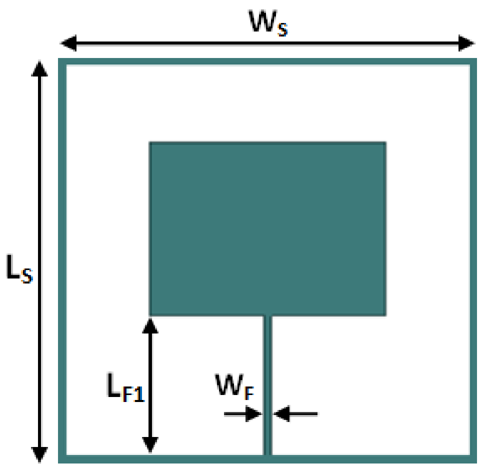

Figure 2: 0th iteration of proposed antenna

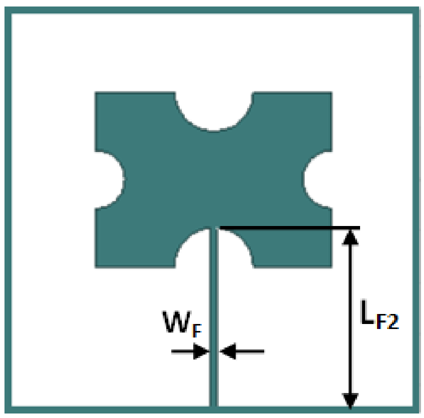

Figure 3: 1st iteration of proposed antenna

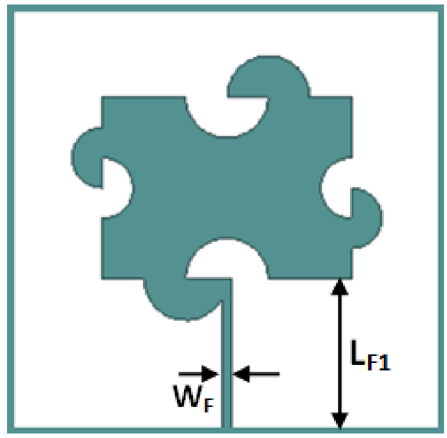

Figure 4: 2nd iteration of proposed antenna

Table 1: Parametric values of proposed antenna

S. No.	Parameters	Description	Values
1.	W_S	Width of Substrate	40 mm
2.	L_S	Length of Substrate	38.92 mm
3.	W_F	Width of Feed Line	0.60 mm
4.	L_{F1}	Length of Feed Line 1	17.77 mm
5.	L_{F2}	Length of Feed Line 2	13.96 mm

3. RESULT AND DISCUSSIONS

3.1 Return loss

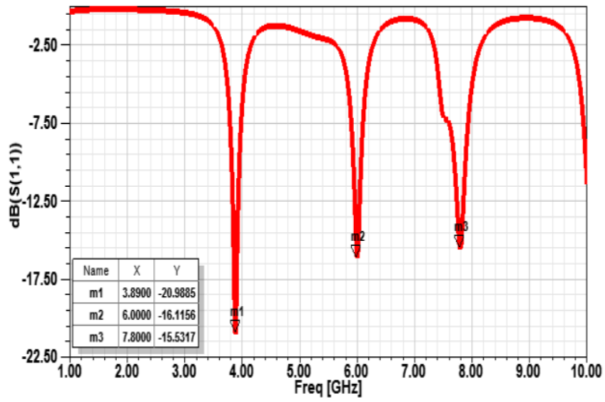

Figure 5: Return loss plot for 0th iteration of proposed antenna

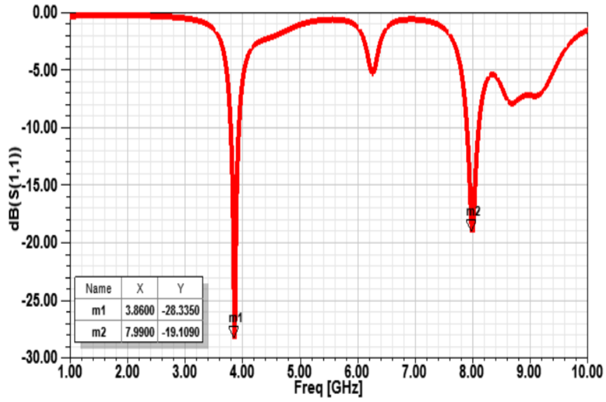

Figure 6: Return loss plot for 1st iteration of proposed antenna

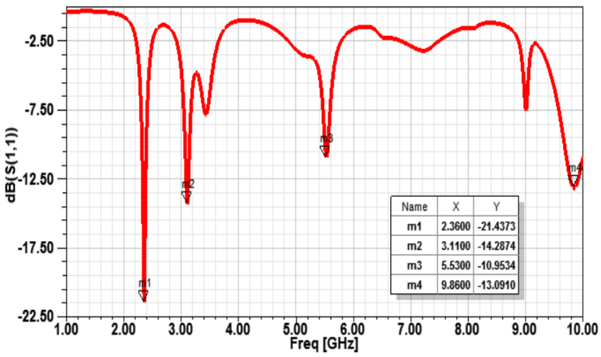

Figure 7: Return loss plot for 2nd iteration of proposed antenna

The S_{11} characteristics (return loss) of the simulated structures of proposed antenna are depicted in Figure 5, Figure 6 and Figure 7 respectively. For the results, it is evident that the 0^{th} iteration of antenna operates on three frequencies, 1^{st} iteration of antenna works on two frequencies and the 2^{nd} iteration of antenna operates on four resonant frequencies. The values of the return losses for all the frequency bands of proposed antenna is at acceptable level (S_{11}=-10dB). Simulated values of return loss for all the iterations are shown in Table 2.

3.2 VSWR

Voltage Standing Wave Ratio is the measure of mismatch between the patch and the feed line. More the mismatch means more value of VSWR. The acceptable value of VSWR for antenna to be used for practical application is ≤ 2. Values of VSWR for all iterations at different frequencies are at acceptable level and are shown in Table 2. Simulated VSWR plot for 0^{th}, 1^{st} and 2^{nd} iterations are shown in Figure 8, Figure 9 and Figure 10 respectively.

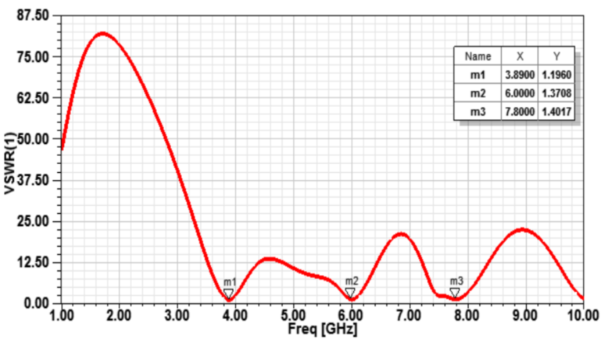

Figure 8: VSWR plot for 0th iteration of proposed antenna

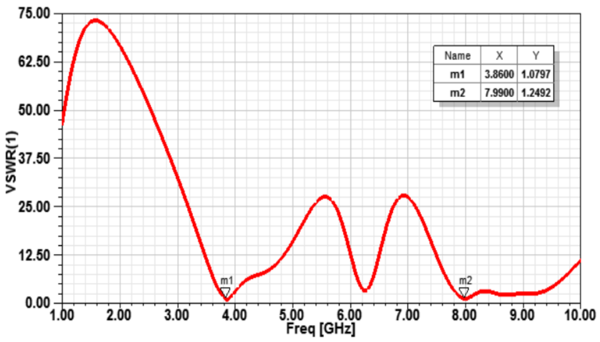

Figure 9: VSWR plot for 1st iteration of proposed antenna

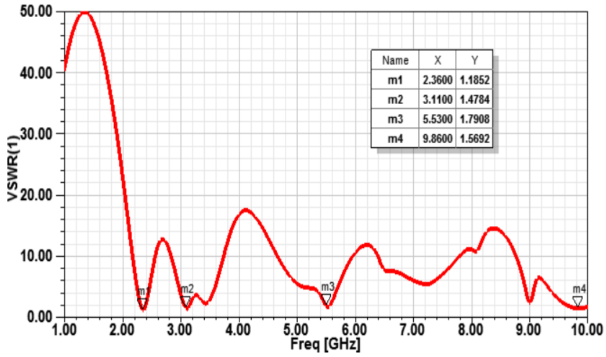

Figure 10: VSWR plot for 2nd iteration of proposed antenna

Table 2. Simulated results of proposed antenna

Iteration	Frequency in GHz	Return Loss in dB	VSWR
0th iteration	3.89	-20.98	1.19
	6.00	-16.11	1.37
	7.80	-15.53	1.40
1st iteration	3.86	-28.33	1.07
	7.99	-19.10	1.24
2nd iteration	2.36	-21.43	1.18
	3.11	-14.28	1.47
	5.53	-10.95	1.79
	9.86	-13.09	1.56

3.3 Gain

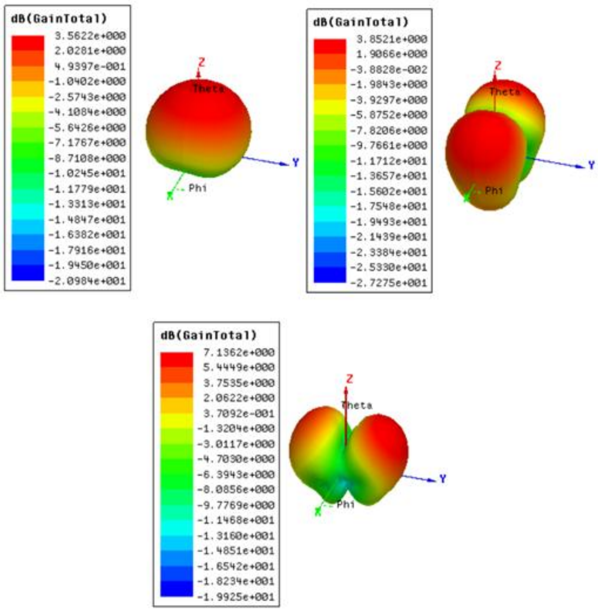

Figure 11: 3D gain plot of 0th iteration of proposed antenna

The simulated gain is also observed at every resonant frequency for all the iterations of proposed antenna. 0^{th} iteration shows the value of gain as 3.56dB, 3.85dB and 7.13dB and their respective frequency bands are 3.89GHz, 6GHz and 7.80GHz. 1^{st} iteration shows the value of gain as 2.84dB and 3.94dB for respective frequency bands such as 3.86GHz and 7.99GHz. Similarly, 2^{nd} iteration shows the value of gain as 3.19dB, 2.61dB, 3.44dB and 11.53dB and their respective frequency bands are 2.36GHz, 3.11GHz, 5.53GHz and 9.86GHz. The value of gain at every frequency band is at acceptable level and 3D gain plot for all the iterations is shown in Figure 11, Figure 12 and Figure 13 respectively.

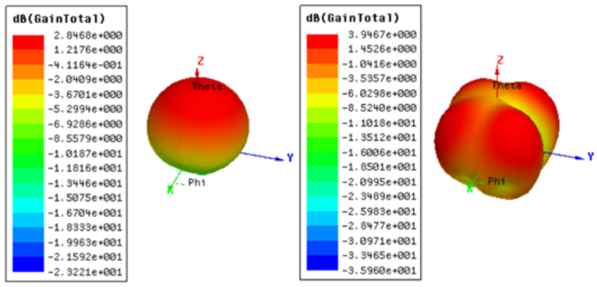

Figure 12: 3D gain plot of 1st iteration of proposed antenna

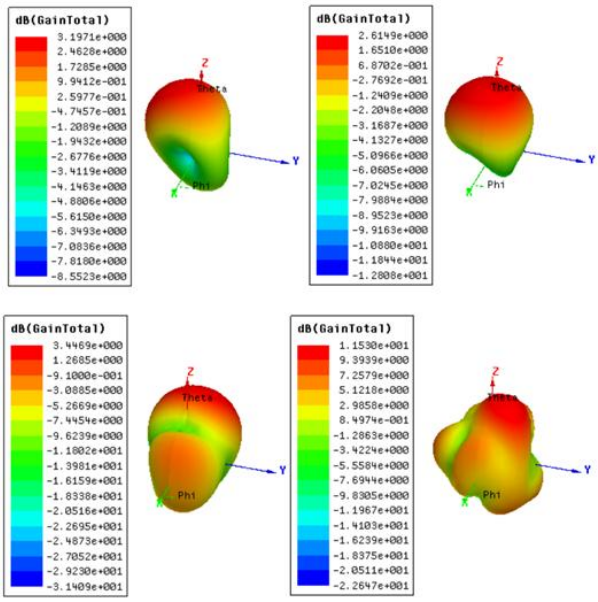

Figure 13: 3D gain plot of 2nd iteration of proposed antenna

4. CONCLUSIONS

Novel design of fractal antenna using Giuseppe peano geometry for wireless applications has been presented in this paper. Three iterations of proposed antenna have been designed to achieve the miniaturization of antenna. The operating frequency of the antenna decreases on increasing the antenna iterations as shown in Table 2. The gain of antenna is also observed at all the frequency bands of designed antenna. This shows that the antenna can be useful for different wireless applications such as bluetooth (2.12-2.95GHz), WLAN (4.82-595GHz), high speed wireless communication (5.92GHz-8.5GHz) and X-band for satellite communication (8-12GHz).

5. REFERENCES

[1] B. Roy, A. Bhatacharya, A. K. Bhattacharjee and S. K. Chowdhury, "UWB monopole antenna design in different substrate using sierpinski carpet fractal geometry," IEEE 2nd International Conference on Electronics and Communication System (ICECS), pp. 382-385, 2015.

[2] J. S. Sivia and S. S. Bhatia, "Design of fractal based microstrip rectangular patch antenna for multiband applications," IEEE International Advance Computing Conference (IACC), pp. 712-715, 2015.

[3] G. Bharti, S. Bhatia and J. S. Sivia, "Analysis and design of triple band compact microstrip patch antenna with fractal elements for wireless applications," International Conference on Computational Modeling and Security (CMS 2016), Elsevier Procedia Computer Science, Vol. 85, pp. 380-385, 2016.

[4] A. Kaur and N. Sharma , "A quad band circular patch antenna with fractal elements for S-band and C-band applications," International Journal of Computer Applications, Vol. 144, No. 3, pp. 1-4, 2016.

[5] S. Behera and D. Barad, "A novel design of microstrip fractal antenna for wireless sensor network," IEEE International Conference on Computation of Power, Energy, Information and Communication, pp. 0470-0474, 2015.

[6] A. S. Wadekar and S. V. Khobragade, "Design of multiband monopole triangular fractal antenna for GSM, bluetooth and wi-fi," IEEE International Advance Computing Conference (IACC), pp. 988-991, 2015.

[7] T. Sarkar, J. Chakravorty and R. Ghatak, "Broadband fractal slot planar antenna," IEEE, 2015.

[8] Y. Jia, Y. Liu and S. Gong, " Slot coupled broadband patch antenna," Electronics Letters, vol. 51, no. 6, pp. 445-447, 2015.

[9] A. R. Karade and P. L. Zade, "A miniaturized rectangular microstrip patch antenna using SSRR for WLAN applications," IEEE, ICCSP, pp. 1002-1004, 2015.

[10] I. Acharya and D. Upadhyay, "A novel ultra wideband antenna with dual band notches for wireless applications," International Conference on Electrical, Electronics, Signals, Communication and Optimization (EESCO), 2015.

[11] X. Hu, W. Yang, S. Yu and W. H. Liao, "Triple band notched UWB antenna with tapered microstrip feed line and slot coupling for bandwidth enhancement," 16th International Conference on Electronic Packaging Technology, pp. 879-883, 2015.