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 (2.12-2.45GHz), WLAN (4.82-5.95GHz), 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 in 1975 [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. 0th, 1st and 2nd 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.

$$w = \frac{c}{2f_0} \sqrt{\varepsilon_r + \frac{1}{2}}$$  \hspace{1cm} (1)

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{1}{2}\left[1 + 12 \left(\frac{h}{w}\right)^{\frac{1}{3}}\right]$$  \hspace{1cm} (2)

$$L_{eff} = \frac{c}{2f_0} \sqrt{\varepsilon_{eff}}$$  \hspace{1cm} (3)

$$\Delta L = 0.412h \left(\frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258} \left(\frac{w}{h}\right) + 0.246\right)$$  \hspace{1cm} (4)

$$L = L_{eff} + 2\Delta L$$  \hspace{1cm} (5)

Where,
\(c\) = Velocity of light in free space.
\(h\) = Substrate height.
\(\varepsilon_r\) = Relative permittivity of the substrate.
\(W\) = Width of rectangular patch.
\(L\) = Length of rectangular patch.
\(L_{eff}\) = Effective length.
\(\varepsilon_{eff}\) = Effective dielectric constant.
\(f_{res}\) = Resonant frequency.
\(\Delta L\) = Length extension.
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.

### Table 1: Parametric values of proposed antenna

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameters</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ws</td>
<td>Width of Substrate</td>
<td>40 mm</td>
</tr>
<tr>
<td>2.</td>
<td>Ls</td>
<td>Length of Substrate</td>
<td>38.92 mm</td>
</tr>
<tr>
<td>3.</td>
<td>Wf</td>
<td>Width of Feed Line</td>
<td>0.60 mm</td>
</tr>
<tr>
<td>4.</td>
<td>Lf1</td>
<td>Length of Feed Line 1</td>
<td>17.77 mm</td>
</tr>
<tr>
<td>5.</td>
<td>Lf2</td>
<td>Length of Feed Line 2</td>
<td>13.96 mm</td>
</tr>
</tbody>
</table>

### 3. RESULT AND DISCUSSIONS

#### 3.1 Return loss

![Figure 5: Return loss plot for 0th iteration of proposed antenna](image5.png)

![Figure 6: Return loss plot for 1st iteration of proposed antenna](image6.png)
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 0th iteration of antenna operates on three frequencies, 1st iteration of antenna works on two frequencies and the 2nd 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 ($S_{11} = -10\text{dB}$). 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 $\leq 2$. Values of VSWR for all iterations at different frequencies are at acceptable level and are shown in Table 2. Simulated VSWR plot for 0th, 1st and 2nd iterations are shown in Figure 8, Figure 9 and Figure 10 respectively.

### 3.3 Gain
The simulated gain is also observed at every resonant frequency for all the iterations of proposed antenna. 0th 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. 1st iteration shows the value of gain as 2.84dB and 3.94dB for respective frequency bands such as 3.86GHz and 7.99GHz. Similarly, 2nd 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


