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# Design of a Modified Slotted Monopole Fractal Antenna for Wideband Applications

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***Abstract*— This article presents a slotted circular monopole fractal antenna dedicated to wideband wireless applications. The proposed antenna comprises of a fractal monopole radiator with a defected ground structure fabricated on a low cost FR4 epoxy substrate. A prototype has been fabricated to verify the 2.74 GHz – 7.33 GHz wide operating band of the proposed design. The simulated 2D radiation patterns exhibit omnidirectional characteristics throughout the wide operating band. The proposed design is having the dimension of $0.32\lambda \times 0.2\lambda \times 0.014\lambda$ ($\lambda$ represents the wavelength at 2.74GHz). The proposed design is having realized gain more than 2.5 dBi and can be suitable for ISM band, WLAN, C-band, and S-band applications.**

***Keywords — Monopole Antenna, Fractal, ISM band, Wideband, Multiband***

## I. INTRODUCTION

The usage of wireless communications have been rapidly increased in the recent years. The wireless communication system can also be witnessed in the cost effective and fast accessed equipments like tablets and cellular devices. The broadband systems are designed with an advanced technology and transfer the data at high rate. Designing a compact sized, beneficial antenna is in great demand for the effective use of portable devices. The printed slot antennas are one of the techniques for obtaining wide operating bandwidth [1]. Microstrip patch antenna are also broadly engaged in practical applications keeping aside its limitations such as low efficiency and narrow bandwidth. The microstrip patch antenna is considered to be the good choice for the low profile such as weight, cost, size [2].

When the electrical length of an antenna is smaller than the operating wavelength then the antenna becomes highly inefficient and it is difficult to acquire good radiation properties. However, size constraints can be overcome in this case by incorporating fractal geometry [3]. In fact, to reduce antenna's physical size, fractal geometry technique is contemplated as a hopeful solution. The first fractal geometry was put forward by Mandelbrot in the year 1975. A fractal is a shape, in which each part will be similar to the whole structure [4]. Fractals are found in nature. Fractals appear irregular, yet have underlying order and possess structure on all scales. Actually, various technologies like antennas and radiators, make use of fractal geometries. Recently, the fractal technique is introduced in antenna design.

The reduction in the size of the antenna, optimization of antenna gain, multiband and wideband characteristics can be attained by using fractal geometry [5]. Monopole antennas are prominent because of their pleasing characteristics such as good radiation properties, simple structure, wide frequency and ease of fabrication [6]. Monopole antennas are half the size of their dipole counterparts, and hence are agreeable when a smaller antenna is needed [7].

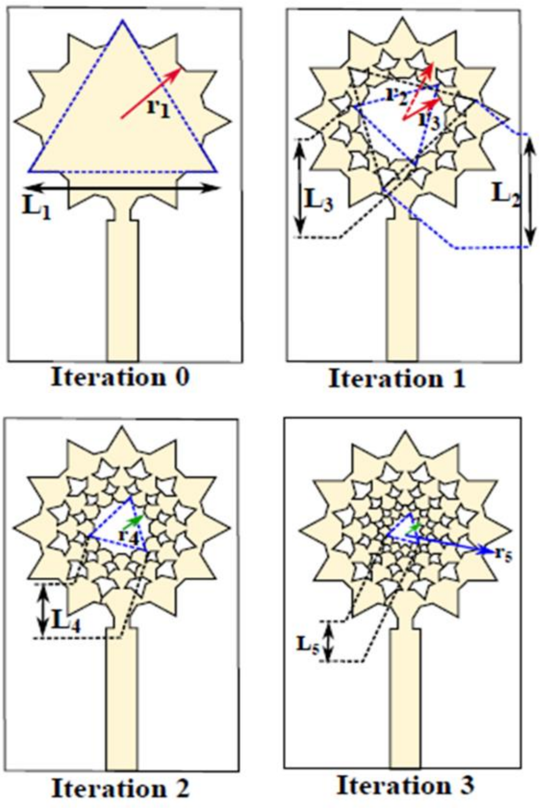


Fig. 1. Development of the proposed antenna.

In view of this paper, a slotted circular fractal monopole antenna with a microstrip line feeding technique is presented. A prototype of the antenna has been designed and fabricated. The proposed design incorporates the fractal design with the third iteration at the main radiator. The full wave simulation results show a wide operating bandwidth of 2.74 GHz – 7.33 GHz. This wideband antenna can be suitable for wireless applications in the wide frequency range.

Table I. Dimensions of Antenna

| $L_s$ | $W_s$ | $L_f$ | $W_f$ | $L_g$ | $r$ |
|---|---|---|---|---|---|
| 36mm | 22mm | 14.6mm | 3mm | 14.6mm | 5mm |
| $W_1$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_5$ |
| 1.5mm | 18mm | 12.8mm | 8.5mm | 5.6mm | 3.3mm |
| $r_1$ | $r_2$ | $r_3$ | $r_4$ | $r_5$ | L |
| 8mm | 6.15mm | 4.21mm | 2.66mm | 1.45mm | 3.3mm |

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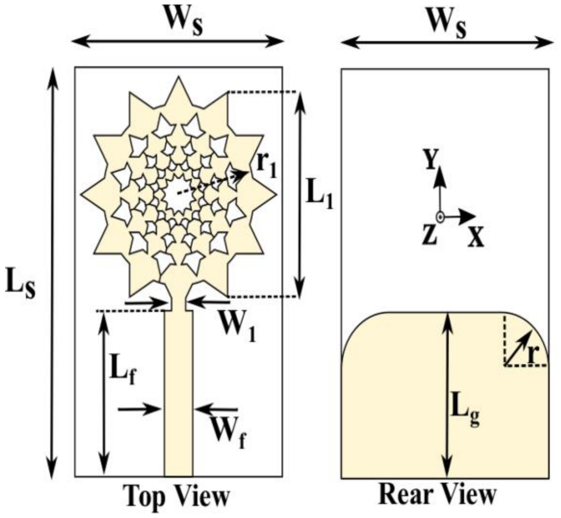


Fig. 2. Geometry of the proposed antenna.

Antenna geometry and design of the propound structure have been presented in section II. Simulated results with analysis are studied in section III succeeded by the conclusion in section IV and references.

## II. Antenna Geometry and Design

The proposed design is a monopole antenna with a fractal geometry based radiator. The development process of the antenna is demonstrated in Fig. 1. It indicates the iteration values from $0-3$. The zeroth iteration of the proposed antenna is designed through the integration of a circular shaped patch and four triangles. The first iteration consists of dual modified circular and triangular patches, subtracted from the integration of circular shape and four triangular patches. This procedure is repeated up to 3 iterations leading to the proposed fractal geometry.

The geometry of the proposed design with all the dimensional details is shown in Fig. 2. The antenna is etched on the cost effective FR4 substrate of height $h_S = 1.6$ mm having relative permittivity ($\varepsilon_r$) of 4.4 and loss tangent ($\tan\delta$) of 0.02. The monopole antenna is designed on the substrate with the overall dimension of $L_s \times W_s \times h_S$.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+12\left(\frac{h}{W}\right)}} \quad (1)$$

$$Z_0 = \frac{1}{\sqrt{\varepsilon_{reff}}} \frac{120\pi}{\left[\frac{W}{h}+1.393+0.667\ln\left(\frac{W}{h}+1.444\right)\right]}, \frac{W}{h} \geq 1 \quad (2)$$

The proposed antenna has been fed using microstrip line feeding with 50Ω impedance value. The width of the feed line is calculated using the conventional formulas as shown in (1) and (2) [7]. The ground has been designed with the dimensions of $L_g \times W_s$, on the bottom side of the substrate. The defected ground has been modified at the two corners with a radius $r$. The final dimensions of the proposed antenna design is shown in Table I. The full wave simulation of the proposed antenna has been accomplished using ANSYS-HFSS version-18 EM simulator.

The implementation of the proposed antenna can be further explained in terms of surface current distribution plot as shown in Fig. 3. The plot indicates the magnitude response of the surface current distribution at four different

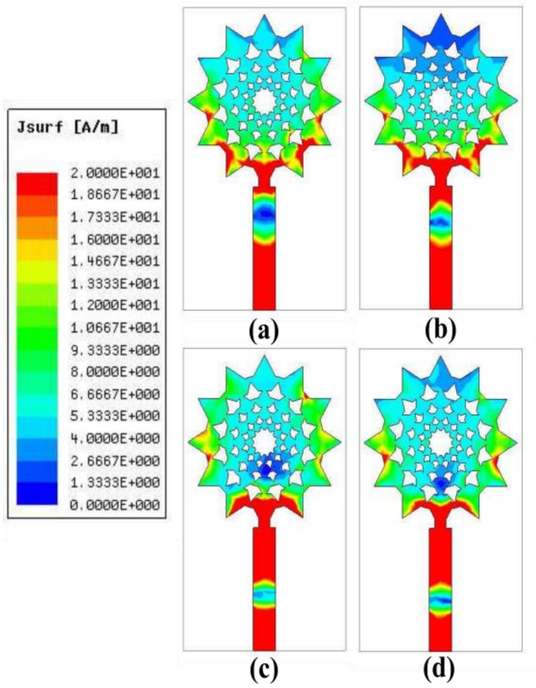


Fig. 3. Simulated surface current distribution of the proposed antenna at (a) 3.13 GHz, (b) 4.14 GHz, (c) 5.8 GHz, and (d) 6.4 GHz.

operating frequency values i,e. at 3.13 GHz, 4.14 GHz, 5.8 GHz and 6.4GHz respectively. It clearly demonstrated that at lower frequencies the surface current is maximum throughout the radiator (Fig. 3(a), (b)), whereas at higher frequencies the surface current is limited to the lower part of the radiator or to feed line only (Fig. 3(c), (d)). This satisfies the concept of the decrement in resonating frequency for the increment of the electrical length.

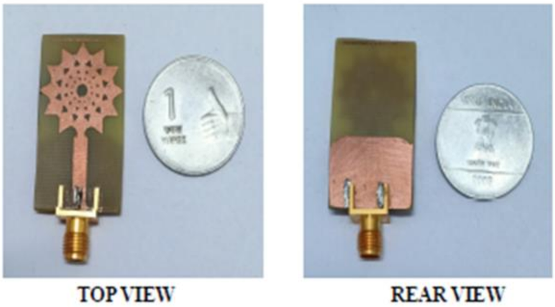


Fig. 4. The fabricated prototype of the proposed antenna.

## III. Results and Discussion

The fabricated prototype of the proposed design is shown in Fig. 4. The reflection coefficient versus frequency response of the proposed design is demonstrated in Fig. 5. It shows that the antenna has a wide operational bandwidth in the frequency range of 2.74 GHz – 7.33 GHz. The measurement of the reflection coefficient ($S_{11}$) versus frequency was accomplished by key-sight performance network analyzer (Model: N5222B). The simulation and the measured results were in good agreement and the small variations observed might be due to the fabrication tolerances.

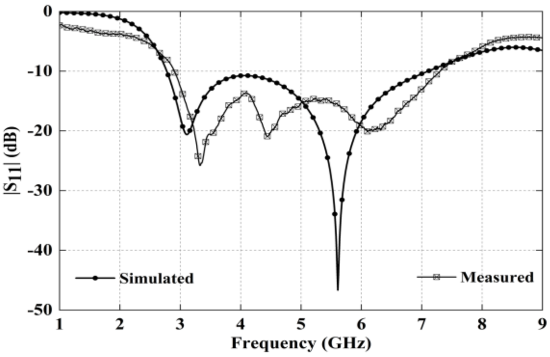


Fig. 5. Reflection coefficient versus frequency response of the proposed antenna.

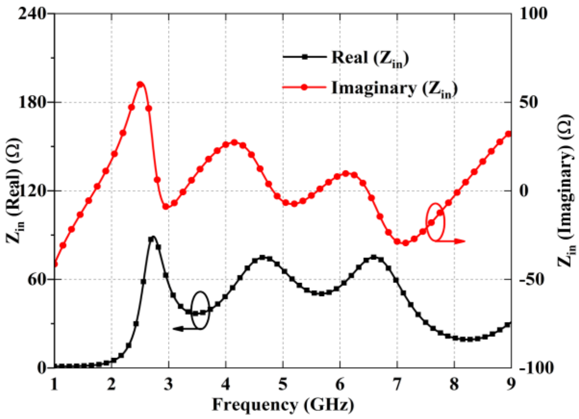


Fig. 6. Simulated input impedance versus frequency response of the proposed antenna.

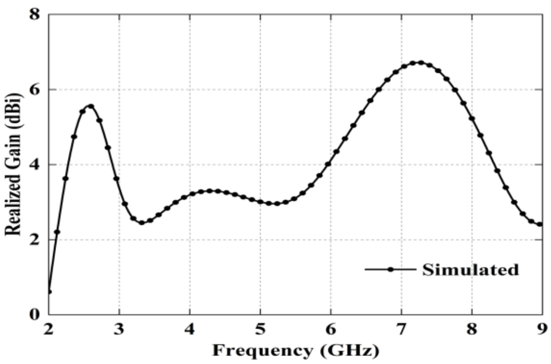


Fig. 7. Simulated realized gain versus frequency plot of the proposed antenna.

The simulated input impedance versus frequency response of the proposed design is demonstrated in Fig. 6. It clearly indicates the real part of input impedance around 50Ω with approximately zero imaginary value in the entire operating frequency range.

Fig. 7. indicates the variation of realized gain with different frequency values. At the operating frequency of 3.13 GHz, 4.14 GHz, 5.8 GHz and 6.4 GHz, the achieved realized gain values are 2.74 dBi, 3.27 dBi, 3.61 dBi and 5.28 dBi respectively. The omnidirectional pattern with the standard realized gain can be essential in wireless applications.

The simulated 2D radiation patterns at different frequencies throughout the band of the proposed antenna are shown in

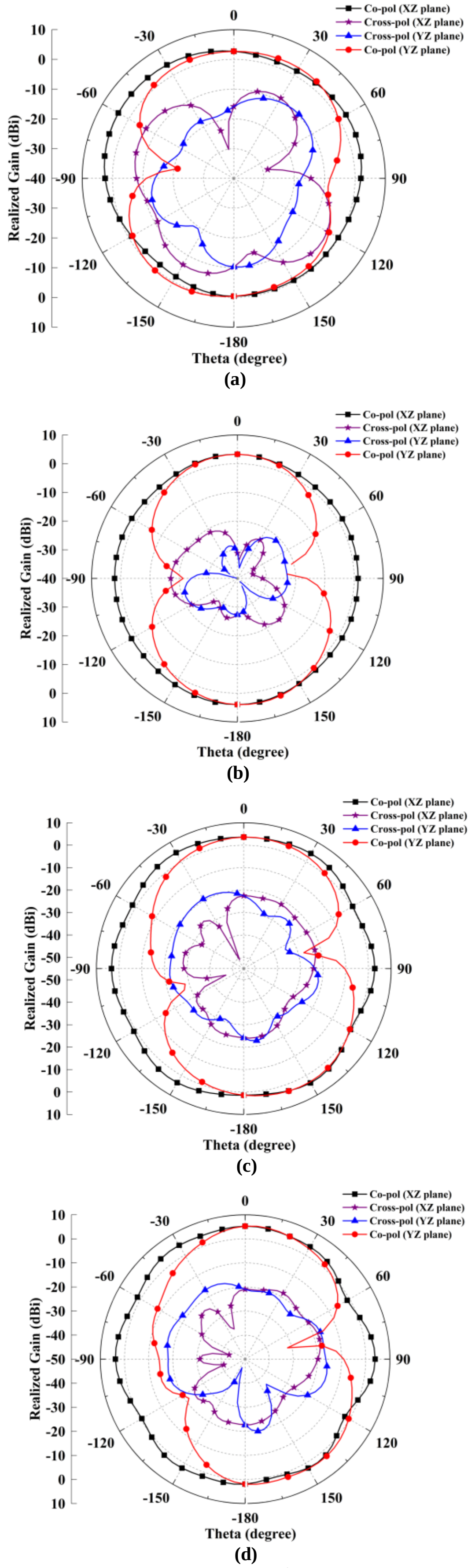


Fig. 8. Simulated 2D radiation pattern of the proposed antenna at (a) 3.13 GHz, (b) 4.14 GHz, (c) 5.8 GHz, and (d) 6.4 GHz.

the Fig. 8. It is obvious from the figure that, the proposed antenna shows omnidirectional characteristic in the entire operating frequency range. The cross-polarization values are approximately 25dB below the co-polarization level in both XZ and YZ plane having a beam width of 60°.

A comparison between recently reported wideband antennas is presented in Table II. It clearly indicates that the proposed design is compact with wider bandwidth and higher gain value.

Table II. Comparison Between Recently Reported Wideband Antennas

| Parameter | [8] | [9] | [10] | Proposed |
|---|---|---|---|---|
| **Size (mm)** | 40 × 30 × 1.6 | 18 × 18 × 0.8 | 42.5 × 48 × 1.6 | 36 × 22 × 1.6 |
| $\varepsilon_r$ | 2.2 | 4.3 | 4.6 | 4.4 |
| **Bandwidth (GHz)** | 1.17 | 1.1 | 2.33 | 4.59 |
| **Operating frequency range (GHz)** | 1.75 – 2.92 | 4.9 - 6 | 4.05 – 6.38 | 2.74 – 7.33 |
| **Peak Gain (dBi)** | 1.26 | 2.4 | 3.9 | 6.7 |
| **Application** | WiFi, WiMAX | WiFi, WiMAX | WLAN, WiFi, WiMAX | ISM, WLAN, C-band, S-band |

## IV. Conclusion

The proposed antenna is designed and fabricated with a slotted circular fractal geometry at the radiator on FR4 substrate. It exhibits a wideband characteristic covering the frequencies from 2.74 GHz to 7.33 GHz, obtaining a fractional bandwidth of 91.16 % and achieving the realized gain more than 2.5 dBi. The wide operational bandwidth with omnidirectional radiation pattern makes the compact antenna suitable for 5.8 GHz ISM band, WLAN, C-band and S-band applications.

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