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Modified Concentric Rings Based Square Shaped Fractal Antenna for Wi-Fi & WiMAX Application

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Abstract

In this paper, a square shaped fractal antenna is designed. The patch has the dimensions of 20 mm × 20 mm. The two iterations are done using reverse fractal geometry. The antenna resonates at three frequency bands which are 4.3719 GHz, 7.777437 GHz and 10.6734 with gain of 1.1974 dB, 4.2745 dB and 4.7233 dB respectively at resonant frequencies. The measured bandwidths are 185 MHz, 198 MHz and 386 MHz at resonant frequencies. After fabrication the antenna resonates at 4.08 GHz, 7.545 GHz and 10.24 GHz with good matching. The square shaped fractal antenna finds its Wi-Fi and WiMAX communication. The measured results are analysed with theoretical results as well as with mathematical analysis which all are in good agreement with each other.

Keywords: Fractal, Multiband, Iterations, Scaling Factor, Reflection Coefficient.

I. INTRODUCTION

The miniaturization of antenna design based on fractal geometry is of great interest in today's wireless communication systems. Multiband nature of antennas is required in each and every aspect of communication system with larger bandwidth. The size must be small enough so that it can be fixed in communication devices. The researchers have developed many antennas with reduced size and multiband characteristics. One of the antenna is fractal antenna [1]. Fractal antenna is developed by using fractal geometries [2]. Fractal structures are generated by Iterated Functions System (IFS) [3], which is determined by

$$-£ = \frac{n}{n+1} \qquad (1)$$

In this proposed work the fractal antenna gives multiband behaviour which in turn can be employed for various applications such as microwave ovens, microwave devices/communications, radio astronomy, mobile phones, wireless LAN, Bluetooth, ZigBee, GPS, amateur radio and for long-distance radio telecommunications, satellite communications, radar, terrestrial broadband, space communications, amateur radio.

The paper is divided into four parts. Section II describes the antenna configuration whereas section III describes the results of proposed antenna. The final section IV is conclusion.

II. PROPOSED DESIGN

Fig 1 depicts the geometry of proposed fractal structure of microstrip patch antenna having two iterations of operation. In this composition, reverse fractal geometry having outer ring as the base design and then adding the rings with the scaling factor of 2. Two iterations are done on the antenna design to get the final structure. The dimensions of square fractal patch are: Length L_A = 20 mm; and width W_A = 20 mm (outermost ring). With the first iteration dimensions of antenna are: Length L_B = 10 mm; and width W_B = 10 mm. For second iteration the dimensions are: Length L_C = 5 mm; and width W_C = 5 mm. The antenna is excited by coaxial feed at the location x = -4.5 mm and y = -8 mm. The fractal configuration is obtained by the iteration process done on the antenna. As feeding is done on the outer most ring, which is appropriate feeding location as it is in maximum electric field.

This antenna is designed and simulated using FR-4 substrate of thickness h = 1.5676 mm; and dielectric constant, ε_r = 4.4. The gap of the split between the rings is $g_1 = g_2$ = 1 mm.

The geometrical construction of this fractal antenna starts with the outer most ring, which is shown in figure 2 (Base Design). By adding another ring with the scaling factor of 2, the first iteration is done in as shown in figure 2 (first iteration). The process is repeated to get the final (2nd iteration) with the scaling factor of 2 on 1st iteration, which is shown in fig 2 (2nd iteration). Fig 2 depicts the base design and iteration process of proposed fractal geometry.

To investigate the design for two iterations, resonant frequency of the antenna is calculated as;

The resonant frequencies can be calculated as [4]

$$f_1 = \frac{c}{2\sqrt{\varepsilon_{eff}}L} \qquad \text{(i)}$$

Where c = free space velocity of light.

Mathematically, length of antenna is calculated as [5]-[6]-[7]

$$l = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta L \qquad \text{(ii)}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{1+12\frac{d}{W}}\right) \qquad \text{(iii)}$$

The Width (W) is calculated by using equation

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \text{(iv)}$$

The extended length of patch is calculated using the equation [8]-[9] - [10]

$$\Delta L = 0.412d\,\frac{(\varepsilon_r+0.3)(\frac{W}{d}+0.264)}{(\varepsilon_r-0.258)(\frac{W}{d}+0.8)} \qquad \text{(v)}$$

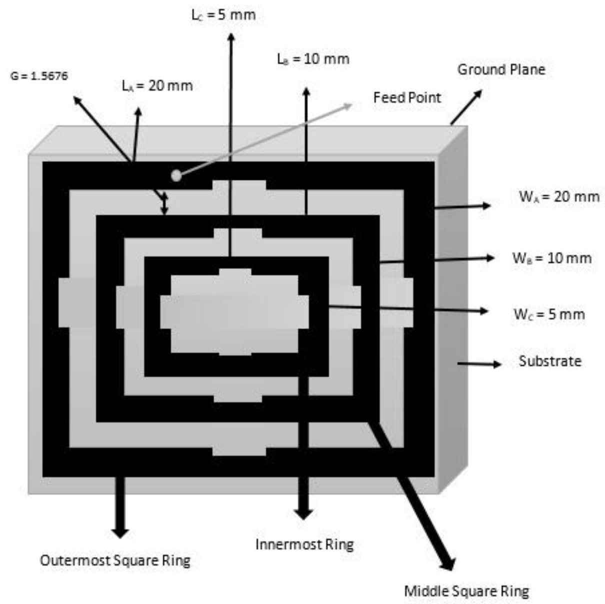

Fig. 1 Square Shaped Fractal Antenna with 2nd Iteration

From the structure, it is seen that addition of rings give rise to self-similarity property and space filling curves of the fractal antenna, which is the most important characteristics of fractal antenna. The inner rings lower the frequency of the antenna and electrical length of the antenna got increased which in turn matches the impedance at lower frequencies as compared with the base design.

Moreover, the second iteration of the proposed antenna does not greatly affect the phenomenon of lowering the frequency of the antenna as higher order iterations do not make significant effect on the antenna properties.

The proposed Square Staircase Fractal Antenna is simulated using HFSS. Figure 3 shows the photograph of top and back view of fabricated proposed antenna. Vector network analyser is used to measure the return loss parameter of the fabricated fractal antenna.

III. SIMULATION & MEASUREMENT RESULTS

The outer square ring of the proposed fractal antenna is excited by coaxial feed. The middle and central square rings have been mutually excited by the outer ring. Fig 4 shows the reflection (S_{11}) coefficient characteristics of the square shaped fractal antenna which resonates at three frequency bands.

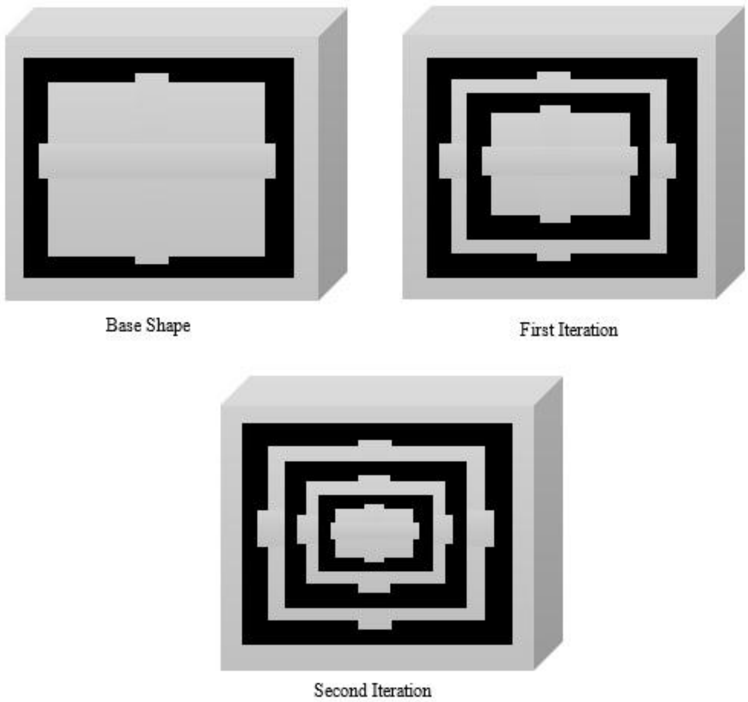

Fig. 2 Iterations of the proposed fractal geometry

Fig. 3 Photograph of fabricated proposed fractal antenna

The proposed antenna resonates at 4.3719 GHz, 7.7437 GHz and 10.6734 GHz with the bandwidth of 185 MHz, 198 MHz and 386 MHZ respectively. The gain of the antenna is 1.1974 dB, 4.2745 dB and 4.7233 dB for resonant frequency bands. The antenna is fabricated and reflection coefficient of measured and simulated antenna is shown in fig 5 at all resonant frequencies.

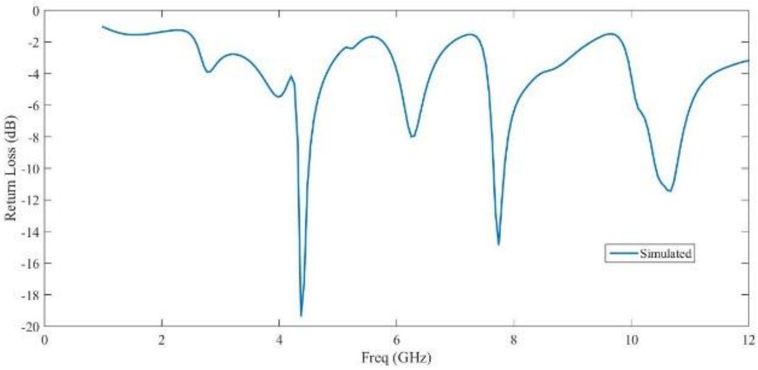

Fig. 4 Simulated return loss for the square shaped fractal antenna with 2nd iteration

Due to mutual coupling between rings, current decreases, in turn exhibit ohmic losses in the conductor which slightly lowers the measured return loss.

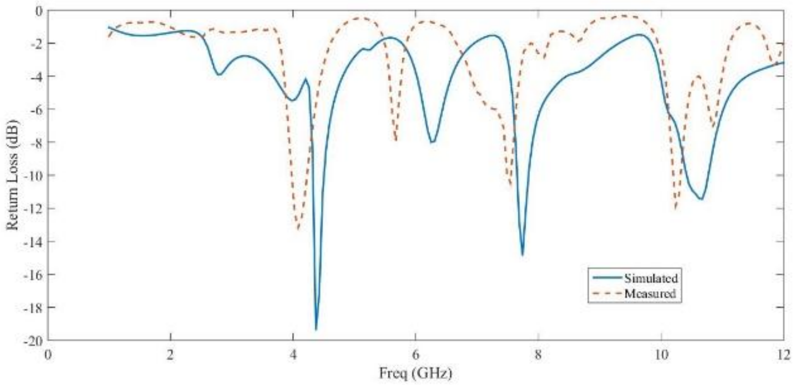

Fig. 5 Comparison of Simulated and Measured return loss of the square shaped fractal antenna for 2nd iteration

Fig 6 & fig 7 depicts the radiation patterns of the square shaped fractal antenna for all the frequencies.

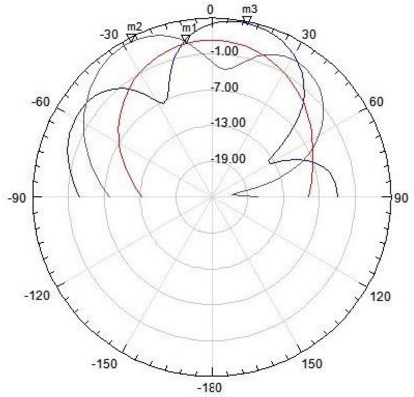

Fig. 6 Radiation pattern (Elevation pattern, Θ) of the proposed fractal antenna at all resonant frequencies.

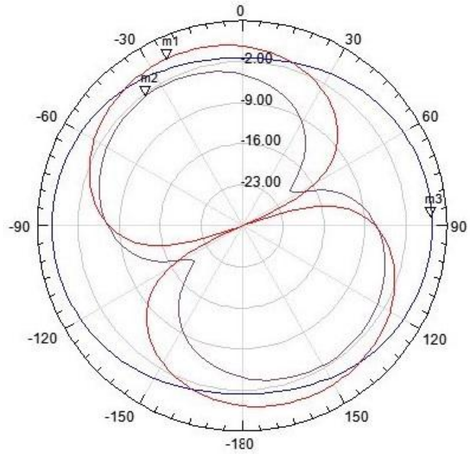

Fig. 7 Radiation Pattern (Azimuth pattern, Φ) of the proposed antenna at all resonant frequencies

Theoretical Discussion: The length of the antenna is calculated using equations as shown in equation (i) to (v). From the mathematical calculations, the effective length of the antenna comes out to be 20.9 mm respectively.

The actual length of the antenna can be calculated by using the below expression

$$L = L_{eff} - 2\Delta L \text{(vi)}$$

Where L = Actual Length of the antenna

L_{eff} = Effective length of the antenna

ΔL = fringing field.

From the calculation effective length is 20.9 mm and fringing field calculated is 1.76. Than actual length comes out to be 19.14 mm respectively. Table 1 shows the simulated and measured results of the proposed antenna.

Table I: Simulated and measured results of the proposed antenna.

S.No	Simulated return Loss GHz	Simulated Matching magnitude dB	Measured Return Loss GHz	Measured Matching dB	Gain dB
1	4.3719	-19.3842	4.08	-13.1692	1.1974
2	7.7437	-14.8702	7.545	-10.4681	4.2745
3	10.6734	-11.4453	10.24	-11.8393	4.7233

Above discussion shows that simulated results, measured results and mathematical analysis of the proposed antenna are in good agreement with each other.

IV. CONCLUSION

The proposed square shaped fractal antenna is multiband antenna as measured results shows the characteristics of fractal antenna. The similarity in the simulated and measured results with that of mathematical analysis of the antenna shows the antenna's predictability for a particular application with consistent gain and bandwidth. The antenna can be used for different applications such as Wi-Fi and WiMAX. The gain and bandwidth can further be enhanced by loading antenna with metamaterials.

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