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Circular Shaped Quad band Fractal Slot Antenna with Co-axial Feed line for Wireless Communication

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Abstract: A circular shaped fractal slot antenna with co-axial feed line for multiband operation is presented in this paper. The proposed antenna is consisting of a multi slot circular patch at the top layer of a substrate. On the same substrate a wide rectangular slot, two symmetrical rectangular slots and an elliptical notch on the ground layer are designed. The designed antenna was fabricated on FR-4 epoxy (tan (δ) = 0.02, εr= 4.3 and h=1.6mm) substrate. When fabricated antenna is energized by co-axial feed line, it exhibited quad band performance with band-1(0.871-1.88 GHz), band-2 (2.328-3.37 GHz), band-3(4.165-4.30 GHz) and band-(4.66-5.436 GHz) for |S11| ≤ −10 dB. Radiation pattern and surface current distribution at simulated resonating frequencies 0.89, 1.66, 2.796, 4.97 and 5.09 GHz are analyzed in this paper.

Keywords: hybrid fractal, multiband antenna, co-axial feed line etc.

Introduction

The need of present wireless communication system attracted the focus of researcher towards fractal geometry. In the application of global positioning systems (GPS), global systems for mobile (GSM), Wi-Max, Wi-Fi, Blue-tooth, universal telecommunication and mobile services (UTMS) etc., multiband and multi resonant frequency wide band are the necessity of the present wireless communication system. Recent research summarizes that fractal geometry can exhibit multi frequency behavior using a single radiating structure. This avoids the use of different antennas for different frequency of operation [1]. Self-similarity and space filling properties of fractal geometry are two common properties. In which application of self-similarity in design of antenna exhibits multiband characteristics while space filling provides reduction in antenna size [2-7]. Also to obtain better performance from fractal antenna, it is advisable to use hybrid fractal geometry which is combination of at least two different types of fractal. Traditionally hybrid fractal can be designed using various combinations [8-12] as listed below:

- Fractal shape with itself e.g.; Minkowski- Minkowski, Koch-Koch etc.
- Sierpinski- Minkowski
- Sierpinski-Koch
- Sierpinski-Meander etc.

In this paper a hybrid slotted at reduced scale has been simulated and fabricated up to fourth iteration. This designed antenna exhibits multiband behavior. The detailed information regarding antenna geometry and the parameters is discussed in section II, while the simulation and measured results have been discussed in section III. Finally section IV summarized the findings from the work done in this paper.

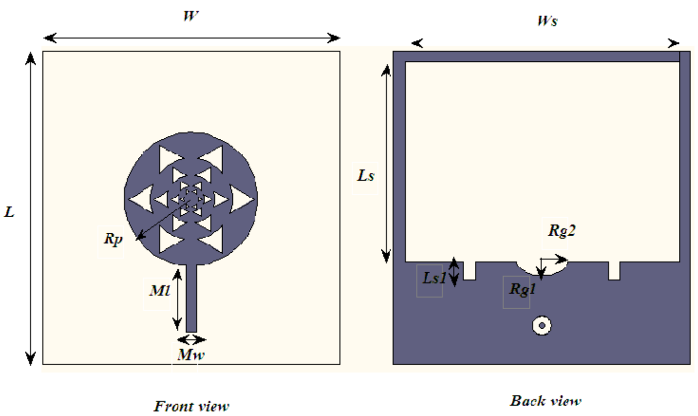

Figure 1 Geometry of Circular shaped fractal slot antenna

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II. **Antenna Geometry and antenna evolution**

Figure 1 displays the geometry and dimensions of the proposed antenna. Figure 2 represents the evolution of the proposed antenna. The proposed structure is placed on two dimensional x-y plane and symmetric about horizontal plane.

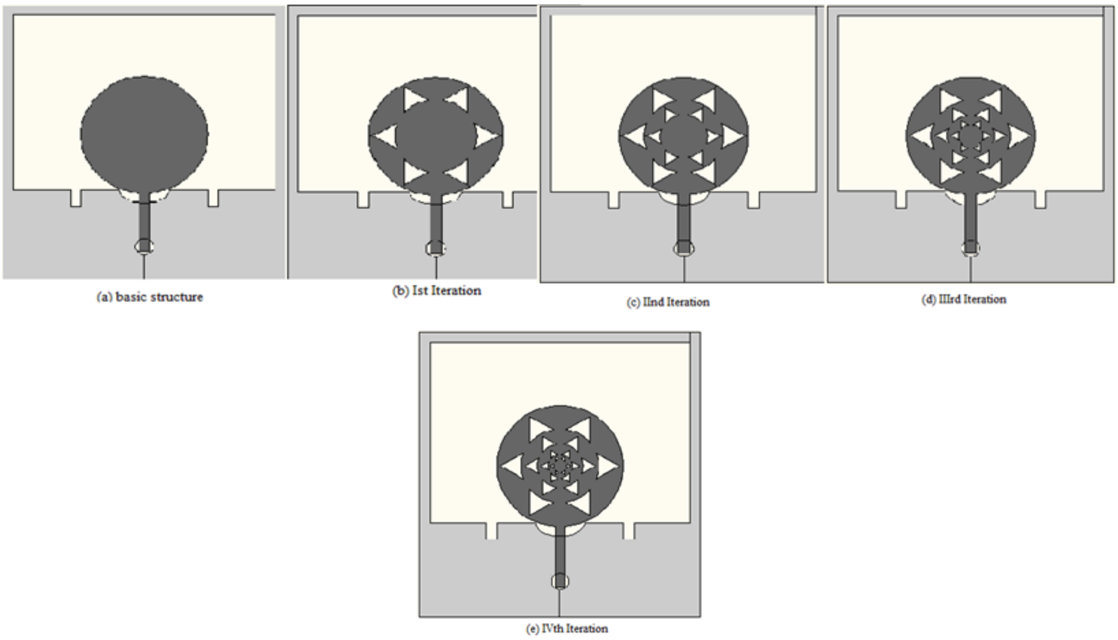

Figure 2 Evolution of the Circular shaped fractal slot antenna

A circular patch of radius R_P with 50 Ω microstrip line of dimensions $(M_l \times M_w)$ is printed on the top layer of FR-4 fiber glass epoxy substrate (tan (δ) = 0.02, εr= 4.3 and h=1.6mm) as the basic structure. One wide slot has been cut on the ground layer of the dimensions $(L_s \times W_s)$. For impedance matching one elliptical notch R_{g1} (semi-minor axis) R_{g2} (semi-major axis radius) and two symmetric rectangular slots $(L_{s1} \times W_{s1})$ are incorporated on the ground plane. The proposed structure is energized by coaxial feed connected with a microstrip through via. In the first iteration six triangular slots with one curved side towards centre have been incorporated. It is achieved by slotting; two mirror imaged equilateral triangles of side 29.44 mm each from the basic structure and Boolean adding one circle of radius 11 mm concentric to R_P. Such Boolean subtraction and addition are repeated up to four iterations at reduced scale in similar way a shown in figure 2 to achieve proposed structure. The overall volume of the antenna is $(85 \times 80 \times 1.6)\text{mm}^3$. Table 1 enlists the optimized dimensions of the proposed antenna.

Table 1 the optimized dimensions of the proposed antenna

Parameter	Dimension	Parameter	Dimension
M_l	19mm	W	80mm
M_w	3mm	R_{g1}	7mm
L_s	54 mm	R_{g2}	4mm
W_s	74mm	L_{s1}	5mm
R_p	18mm	W_{s1}	3mm
L	85mm		

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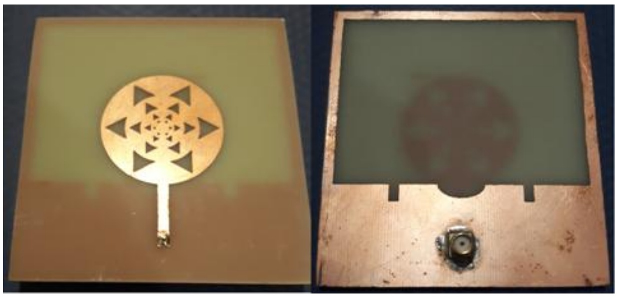

Figure 3 Fabricated Circular shaped fractal slot antenna

III. Result and Discussion

The fabricated Circular shaped fractal slot antenna is presented in figure 3. Figure 4 represents the comparison between measured and simulated results of fabricated antenna. Initially, for numeric simulation of the proposed antenna for scattering parameter is investigated from 0 GHz to 6 GHz than measured through Vector Network Analyzer. The fabricated antenna covers four bands with band-1(0.871-1.88 GHz), band-2 (2.328-3.37 GHz), band-3(4.165-4.30 GHz) and band-4(4.66-5.436 GHz) for $|S11| \leq -10$ dB and exhibits six resonant frequencies 0.995, 1.655, 3.05, 4.24, 4.84 and 5.25 GHz. The difference between measured and simulation results is due to lack of synchronization between top and ground layers in fabrication, mismatch of soldering of connector and difference between ideal and realistic environment at the time of measurement. Figure 5 shows the variation of input impedance of the fabricated antenna.

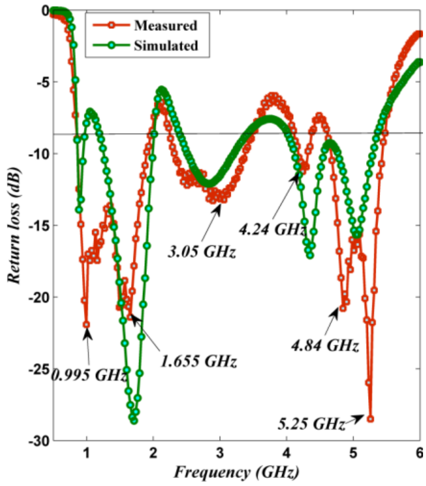

Figure 4 Measured and simulated results of the proposed antenna

Radiation pattern is the graphical representation of radiation characteristics, which is combination of E-plane and H-plane pattern. Figure 6 represents the simulated radiation (E-plane and H-plane) pattern of the proposed antenna at 0.89, 1.66, 2.796, 4.39 and 5.09 GHz respectively.

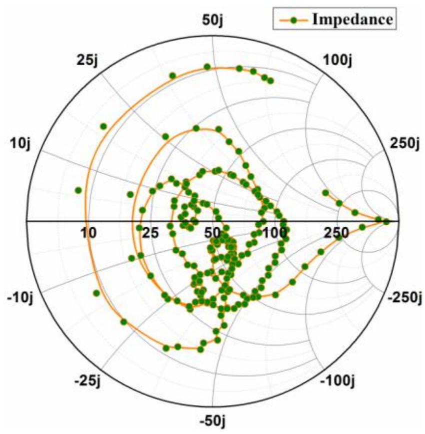

Figure 5 Variation of input impedance of the fabricated antenna

At frequencies 0.89, 1.66 and 2.796 GHz eight shaped pattern has been found in E plane. At higher frequencies (4.39 and 5.09 GHz) pattern has been deformed due to presence of the higher order modes.

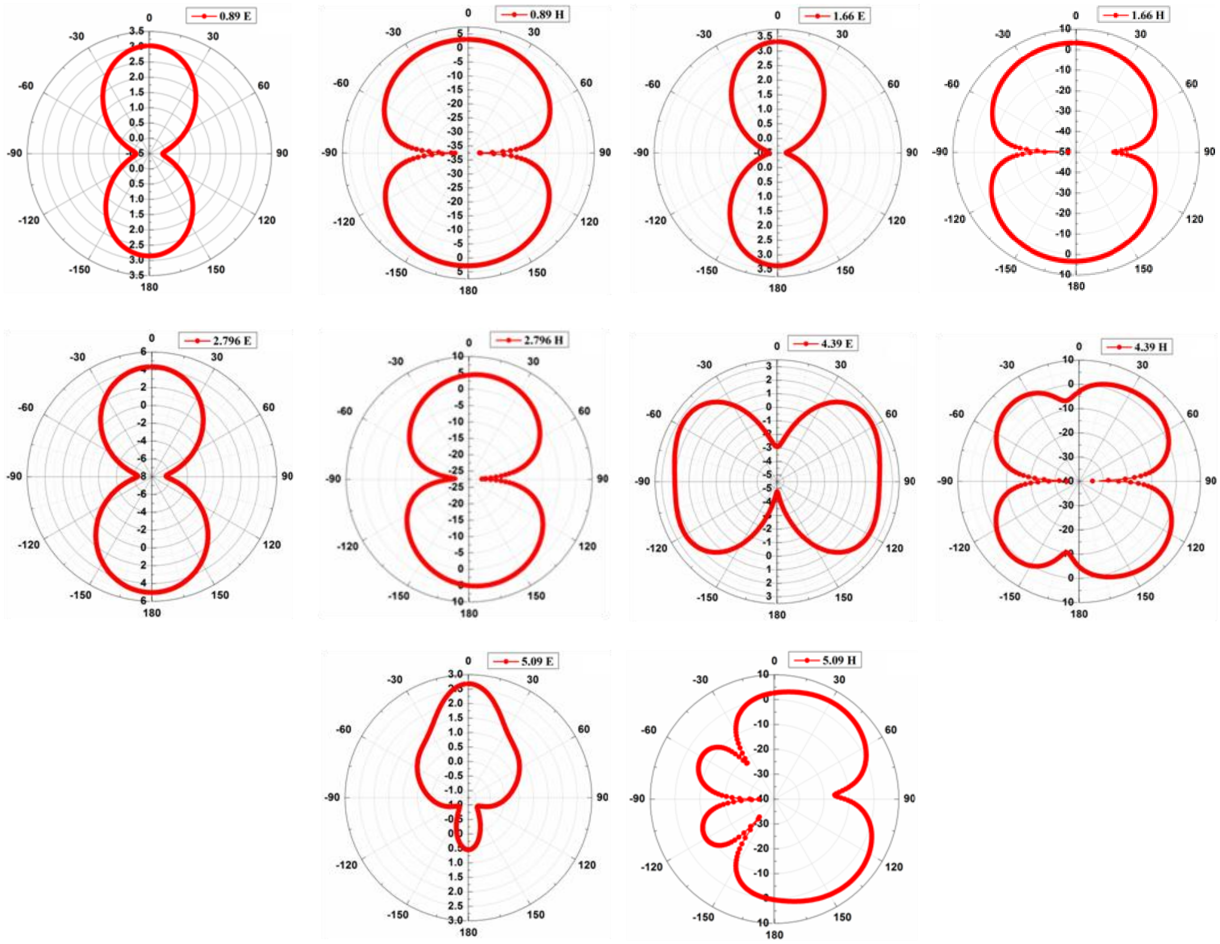

Figure 6 simulated E and H pattern of proposed antenna at resonance frequencies 0.89, 1.66, 2.796 4.39 and 5.09 GHz

At frequencies 0.89, 1.66 and 2.796 GHz, we have noticed the omni-directional pattern. Due to existence of higher order modes the omni directionality has been lost at frequency 4.39 and 5.09 GHz and deformed pattern has been observed.

The surface current distribution of the proposed antenna at resonating frequencies has displayed in figure 7. At frequency 0.89, 1.66 and 2.796 GHz, the current density is maximum at upper side of the Circular shaped fractal slotted radiating element. At frequency 4.39 GHz, the current density is maximum at top and bottom both side of the radiating patch. It has been noticed that as frequency increases the number of modes are also increased. At frequency 4.39 and 5.09 GHz, the complicated surface current distribution has been noticed.

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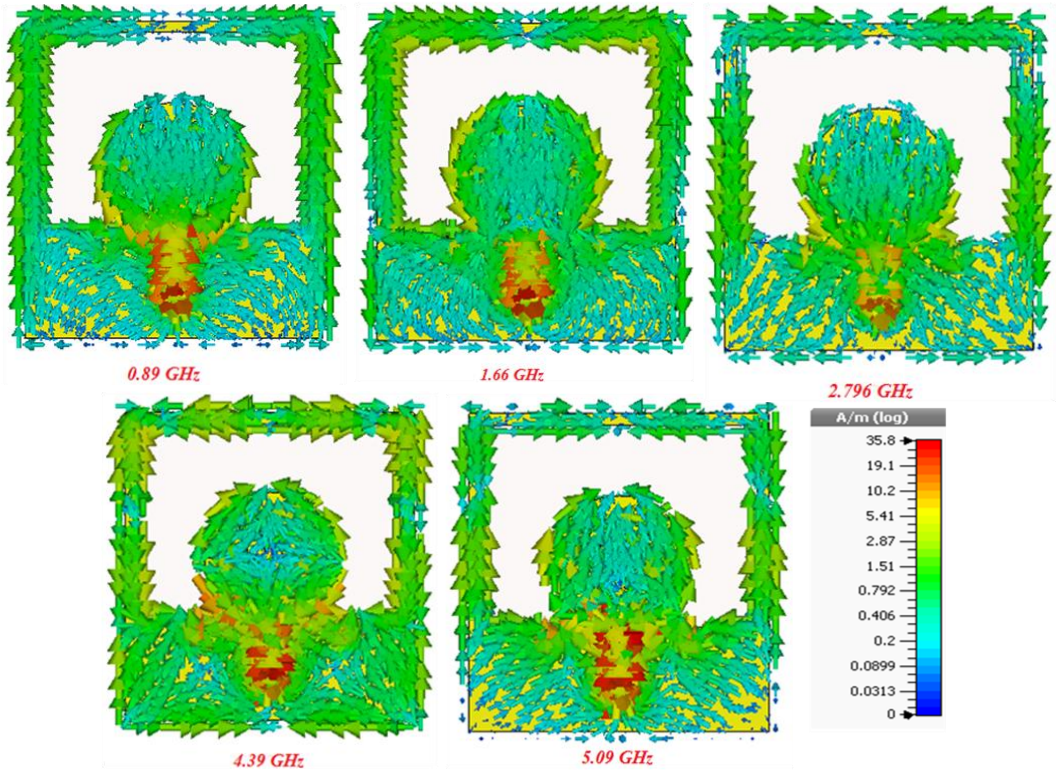

Figure7 simulated Surface Current Distribution of proposed antenna at resonance frequencies 0.89, 1.66, 2.796 4.39 and 5.09 GHz

Table 2 displays the list of covered frequency band, resonating frequencies and bandwidth. Where bandwidth is calculated using the expression given as, $(BW(\%) = (f_h - f_l) * 200/(f_h + f_l)$

A good agreement between simulated and measured S_{11} characteristics has been found. A small error between simulated and measured resonating frequencies has been also investigated. This small error has been inspected due to fabrication error and SMA connector effect.

Table 2 Measured frequency bands and resonating frequencies

Frequency Band (GHz)	Measured Resonance frequency (GHz)	Bandwidth (%)
0.871-1.88	0.995	73.55
	1.655	
2.328-3.37	3.05	36.57
4.165-4.30	4.24	3.21
4.66-5.436	4.84, 5.25	15.37

IV. Conclusion

A co-axial feed quad band fractal slot antenna is designed and fabricated in this paper. The quad band performance with band-1(0.871-1.88 GHz), band-2 (2.328-3.37 GHz), band-3(4.165-4.30 GHz) and band-(4.66-5.436 GHz) for $|S11| \leq -10$ dB has been reported from the fabricated antenna. The impedance bandwidth has been observed 73.55%, 36.57%, 3.21% and 10% simultaneously for the multiband operation reported above. The proposed antenna is simple in design, low cost, easy to fabricate and compatible to use in wireless system.

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