A Novel Flower Shaped Multiband Hybrid Fractal like Antenna for Wireless Communication

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Abstract: In this paper, a novel flower shaped multi-band hybrid fractal-like antenna for wireless communication (GSM, Wi-Max, ISM and WLAN etc.) is presented. The proposed antenna is fabricated on an FR-4 substrate ($\tan(\delta)$ = 0.02, εr= 4.3) with the thickness of 1.6 mm. A good impedance matching is achieved by two symmetrical small rectangular slots and one elliptical slot. On energizing with 50 Ω microstrip feed line, the fabricated antenna covers four bands of frequency, band-1 (0.651-1.696 GHz), band-2 (2.76-2.98 GHz), band-3 (3.53-3.97 GHz) and band-4 (4.55-5.92 GHz), for $|S_{11}| \leq -10$ dB. Surface current distribution and far-field pattern of the simulated antenna is also discussed in this paper.

***Key Words*- flower shaped, hybrid fractal, multiband antenna etc.**

I. INTRODUCTION

The tremendous growth in wireless communication field is accelerating development of more compact antennas to use operating bands efficiently. Several bands of frequency are occupied for different services such as global systems for mobile (GSM 890-960 MHz), Personnel communication systems (PCS 1880-1990 MHz), Digital communication systems (DCS 1710-1880), universal mobile telecommunication systems (UTMS 1920-2170 MHz), Bluetooth (2400-2484), Wi-Max (3400-3600 MHz), WLAN (5150-5350 & 5725-5875) etc.

Presently various simple and compact structures of broadband [1-5] and multi-band antenna [22-24] have been designed for fixed and mobile wireless devices. Those suits for various services in operation mentioned above. To achieve dual-band, triple band or multi-band of frequency the solution is presented for wireless devices [6-10]. Self- similar fractal antenna has attracted a lot of attention of antenna designers in recent years as it is small in size, light in weight, and low profile with wideband and multi-band features. In the recent year publications, several configurations of fractal or fractal-like antenna and hybrid fractal antenna have been discussed. In the year 1983 B.B. Mandelbrot suggested a word 'fractal', a structure which can be subdivided into parts, each part is similar in shape to itself. So the fractals are generally self-similar but independent of scale with regular or irregular shape [12-21]. Practically fractal means similar geometry fragmented at the different scale.

Instantly, ferns, tree leaves, snowflakes, coastline mountain ranges can be model as irregular fractals while Sierpinski gasket or carpet, Koch Iceland, Minkowski fractal and Meander fractal can be considered as a regular fractal. In [13] Werner explored his research as fractal antenna engineering. He reveals the different type of designing methods of fractal antenna: Sierpinski gasket and carpet, fractal trees, Hilbert curve, Koch curve, cantor linear array and Minkowski curves etc. These structures provide conformal, low profile, compact size, wideband and multi-band attributes to an antenna element. In this paper, a hybrid fractal-like structure has been designed to obtain a simple multi-band antenna.

The proposed antenna has been fabricated, measured and investigated. The simulated and measured S_{11} parameter is analysis graphically. Surface current distribution and far-field pattern are discussed briefly.

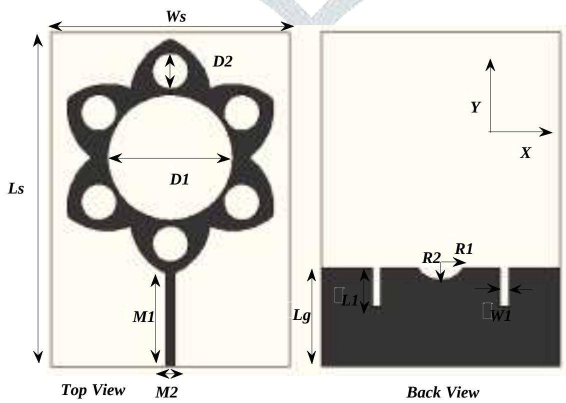


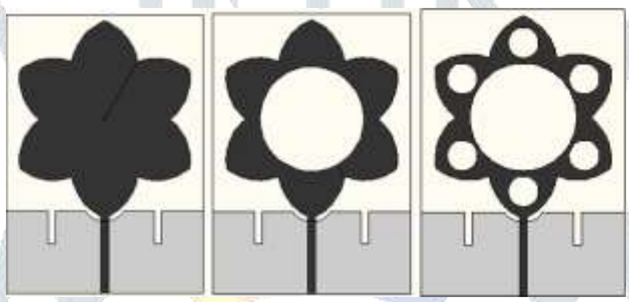
Figure 1 Geometry of the flower shaped hybrid fractal antenna.

II. ANTENNA GEOMETRY

Two-dimensional planner flower shaped hybrid fractal structure is illustrated in figure 1, which is fabricated on the FR-4_epoxy substrate ($\tan(\delta) = 0.02, \varepsilon_{sub} = 4.3$ and $h = 1.6$ mm. A microstrip feed line of impedance 50Ω ($M_1 \times M_2$) has been designed on the top layer of a substrate, which is terminated on the leaf of the fractal shape structure. A wide circular slot of diameter D_1 has been truncated in the center of the designed structure while six small circular slots of diameter D_2 have been slotted from the six leaves of the flower incorporated with the multiband operation. A ground plane (Z=0), on the bottom side of the substrate has been printed with the dimensions of L_g and W_g. A semi-elliptical slot of radius R_1 (major axis) and R_2 (minor axis) has been etched from this ground plane. Also two small rectangular open slots symmetrical about Y-axis of dimensions ($L_1 \times W_1$) have been made on this ground layer for proper impedance matching. The optimized parameters of the proposed antenna have been shown in Table 1.

Table 1 Optimized dimension of proposed antenna

Parameter	Dimension	Parameter	Dimension
M_1	33.5mm	D_2	12mm
M_2	3mm	L_g	33mm
L_s	112mm	R_1	8mm
W_s	80mm	R_2	6mm
D_1	42mm	L_1	13mm
W_1	3mm		



Antenna1 Antenna2 Antenna3

Figure 2 Evolution of the flower shaped hybrid fractal antenna 1, 2 and 3

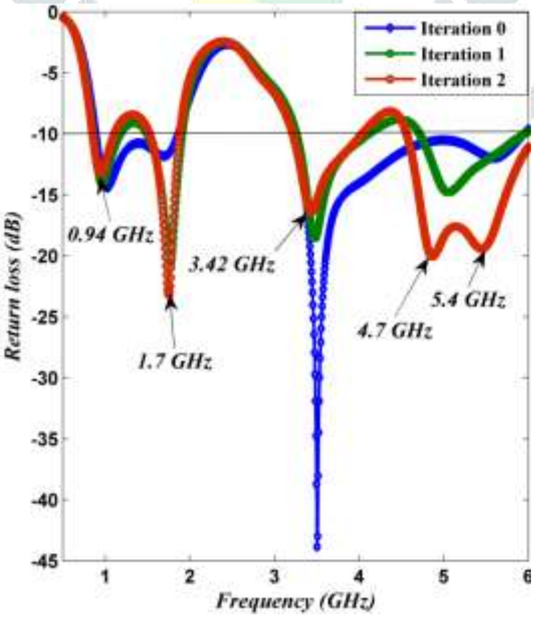


Figure 3 Simulated frequency response of flower shaped hybrid fractal antenna 1, 2 and 3

III. EVOLUTION OF ANTENNA

The evolution of the flower shaped hybrid fractal antenna is depicted in figure 2. A comparative frequency response of antenna 1, 2 and 3 is shown in figure 3. On simulation with CST microwave studio antenna 1, exhibits two frequencies of resonance at 0.95 GHz and 3.5 GHz. In the first iteration (antenna 2), a circular slot has etched concentric to the flower-shaped structure on the top layer of the substrate which introduces another band of frequency at 1.75 GHz and 5 GHz. Basically, slot modifies the value of inductance (L) and capacitance (C) and reduces the phase velocity ($v_p = 1/\sqrt{LC}$) of modes which is responsible for overlapping of modes. Antenna 2 exhibits four bands of frequencies at five resonant frequencies 0.94 GHz, 1.75 GHz, 3.42 GHz, 3.5 GHz and 5 GHz. In second iteration antenna 3, six circular slots etched on the leaves of flower-shaped structure which improves the impedance matching between radiating structure designed on the top layer and modified ground plane on the bottom layer. It exhibits four bands of frequencies at five resonant frequencies 0.94 GHz, 1.7 GHz, 3.42 GHz, 4.7 GHz and 5.4 GHz with improved return loss versus frequency response. It exhibits the impedance bandwidth of 23%, 18%, 16% and 29% for band 1, band 2, band 3 and band 4 for $S_{11} \leq -10\ dB$.

IV. EXPERIMENTAL RESULTS

The fabricated flower shaped hybrid fractal antenna is presented in figure 4. After fabrication, this antenna has tested using Vector Network Analyzer N9923A in the range 0.5 to 6 GHz. Figure 5 illustrates a comparison between simulated and measured results.

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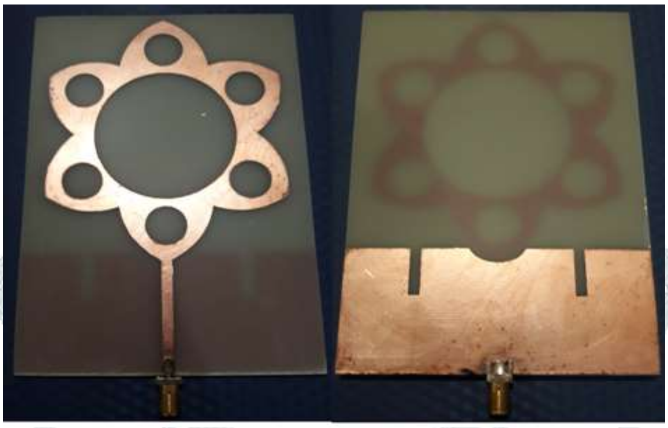

Figure 4 Fabricated flower shaped hybrid fractal antenna

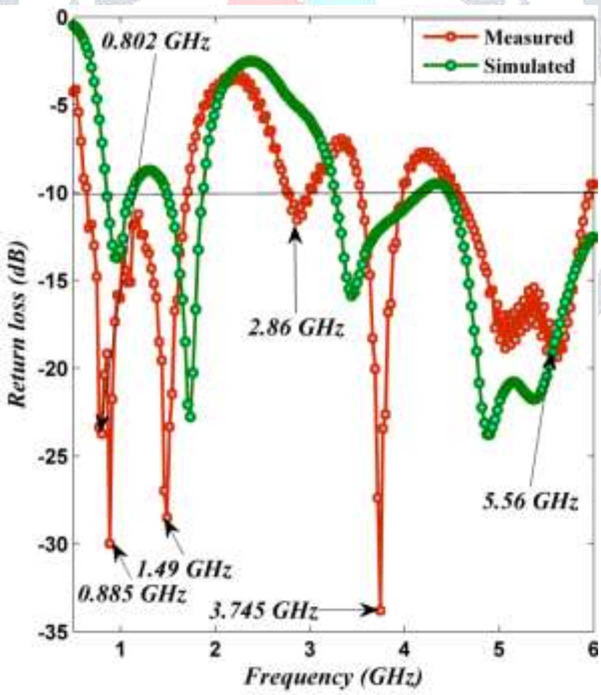

Figure 5 Measured and simulated frequency response of the proposed antenna

The variation at lower frequencies is clearly shown from figure 5 is due to a lack of synchronization between top structure and ground plane. Also lossy characteristic of FR-4 glass epoxy substrate, the difference between realistic and ideal environment for measurement and improper soldering of microstrip connector any one or all may because of such variation. To avoid such type of variations extra care is needed to solder the connector to microstrip feed. The fabricated antenna covers four bands of frequency band-1 (0.651-1.696 GHz), band-2 (2.76-2.98 GHz), band-3 (3.53-3.97 GHz) and band-4 (4.55-5.92 GHz), for $|S_{11}| \leq -10$ dB. The resonant frequencies exhibited by this fabricated antenna are 0.802, 0.885, 1.49, 2.86, 3.745 and 5.56 GHz. Table 2 represents a list of the covered frequency band of the proposed antenna and their fractional bandwidth ($BW(\%) = (f_h - f_l) * 200/(f_h + f_l)$).

Table 2 Frequency response characteristic of fabricated antenna

Frequency Band (GHz)	Measured Resonance frequency (GHz)	Bandwidth (%)
0.651-1.696	0.802	89
	0.885	
	1.49	
2.76-2.98	2.86	7.66
3.53-3.97	3.745	11.73
4.55-5.92	5.56	26

Figure 7 graphically represents the variation of an input impedance of the proposed antenna with respect to the frequency. The graphical representation of an antenna is the combination of E-plane and H-plane pattern. Figure 7 represents the E-plane and H-plane pattern of the simulated structure at five resonant frequencies 0.94, 1.7, 3.42and 5.4 GHz. At frequencies 0.94, 1.7 GHz eight shaped Omnidirectional E and H shaped pattern have been observed. At higher frequencies 3.42 and 5.4 GHz distorted radiation pattern has been observed due to the presence of higher order modes.

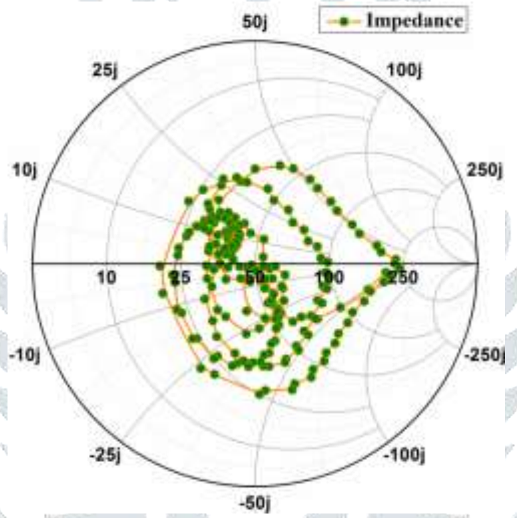

Figure 6 Normalized input impedance of the proposed antenna

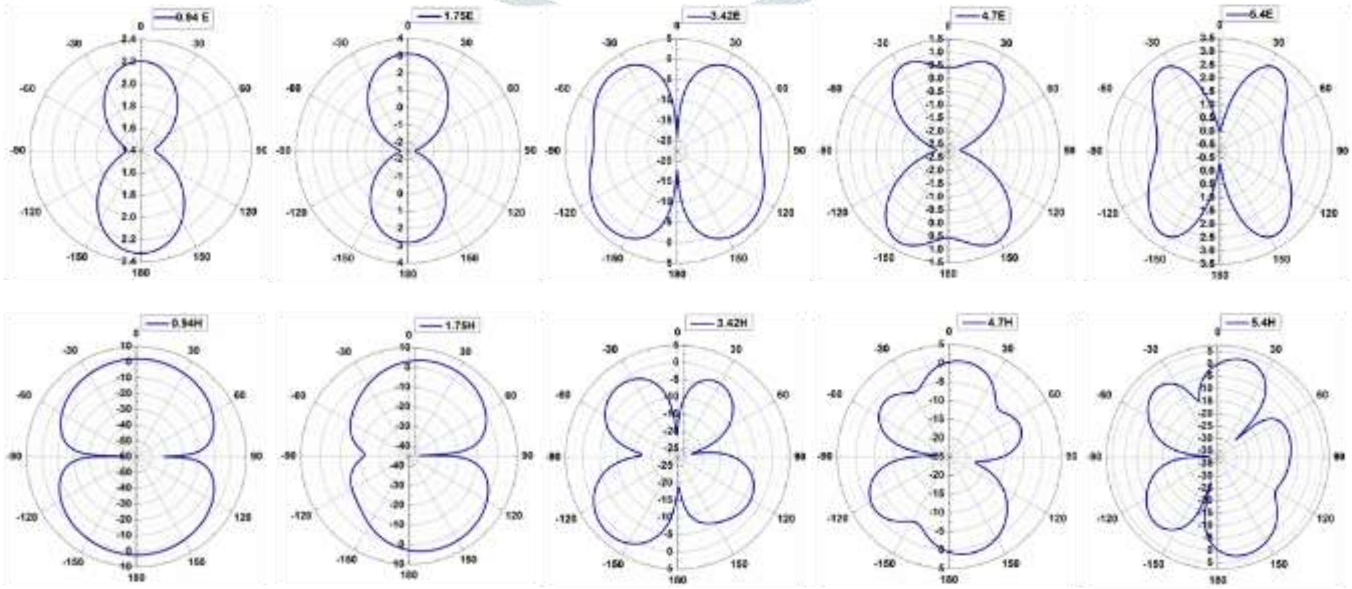

Figure 7 E and H plane radiation pattern of the proposed antenna 0.94, 1.75, 3.42, 4.7 and 5.4 GHz

At frequencies 0.94 GHz and 1.75 GHz, the current density at the top side of the flower shaped radiating structure is largest. Additionally, at these frequencies one half wave variations of current vectors has been observed on the perimeter of the radiating element. At frequencies 3.42 and 5.4 GHz, the complicated surface current variation has been observed. The current vectors are least at bottom of the radiating element at higher frequencies.

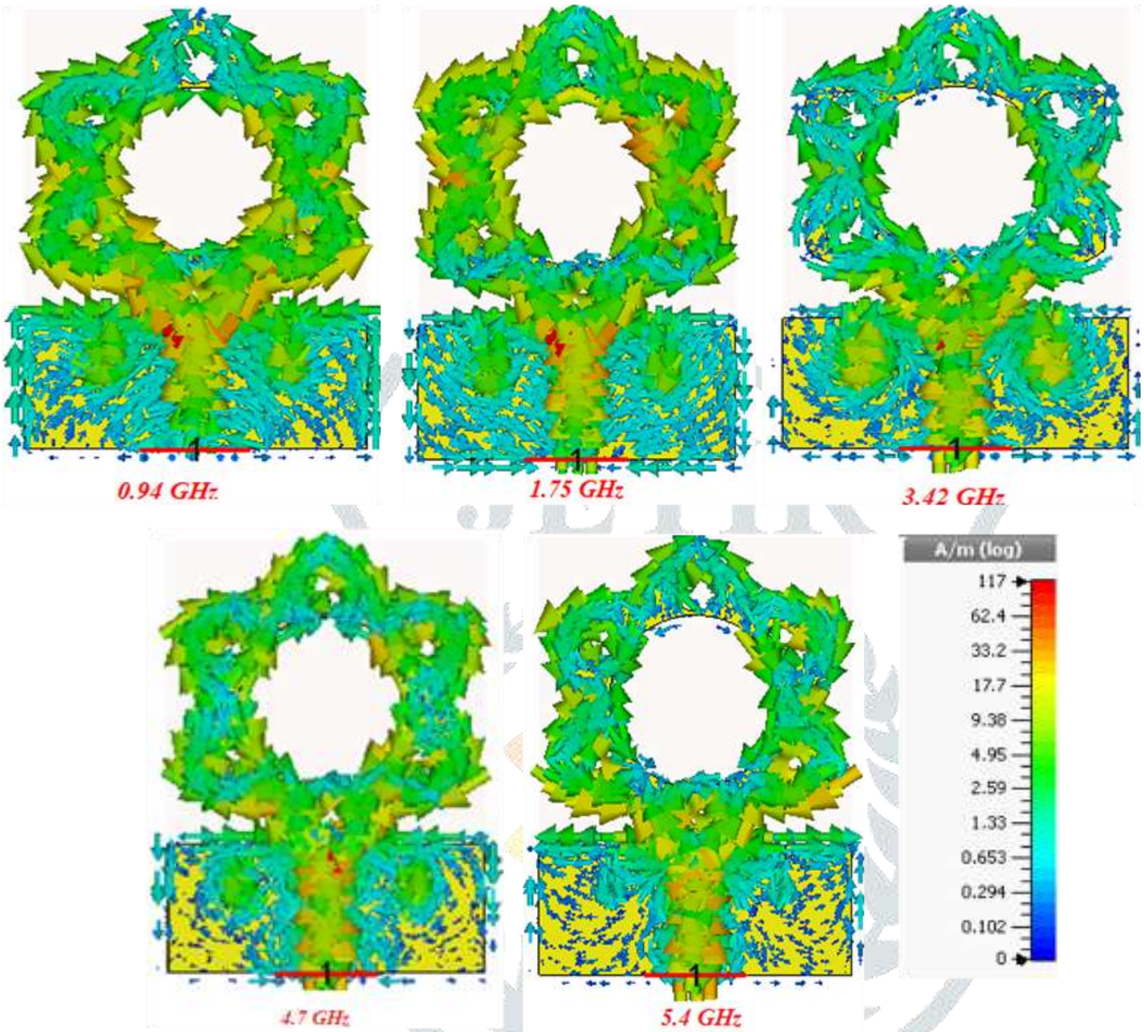

Figure 8 represents surface current distribution of the proposed antenna at frequency simulation 0.94, 1.75, 3.42 and 5.4 GHz.

V. CONCLUSION

A novel flower shaped multiband fractal antenna has been simulated and fabricated in this communication. Multi-frequency operation is achieved using self-similar circular slotting at different scale inside the flower-shaped structure. The fabricated antenna has covered four bands of frequency band-1 (0.651-1.696 GHz), band-2 (2.76-2.98 GHz), band-3 (3.53-3.97 GHz) and band-4 (4.55-5.92 GHz), for $|S_{11}| \le -10$ dB, which are suitable for GSM, Wi-Max, ISM and WLAN services of wireless communication. The fabricated antenna exhibits six resonant frequencies of 0.802, 0.885, 1.49, 2.86, 3.745 and 5.56 GHz.

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