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Parametric Analysis of Water Lily Shaped Split Ring Resonator Loaded Fractal Monopole Antenna for Multiband Applications

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Abstract**—**A coplanar waveguide (CPW) feed is presented, and comprising a split ring resonator (SRR) loaded fractal with water lily shape is used for multi band applications. The impedance matching of the antenna is determined by the number of Koch curve fractal unit cells. The antenna is designed on a FR4 substrate with a permittivity of $\varepsilon_r = 4.4$ and size of 14 x 16 x 1.6 mm^3 to generate multi resonant mode at 3.8 GHz covering S band, 8.68 GHz at X band, 13.96 GHz at Ku band, and 19.74 GHz at K band with reflection coefficient better than -10 dB. Simulation results show that the antenna exhibits the desired voltage standing wave ratio (VSWR) level and radiation patterns across the wide frequency range. The fundamental parameters of the antenna such as return loss, VSWR, good radiation pattern with reasonable gain across the operating bands are obtained.

Keywords**—**Monopole antenna, fractal, metamaterial, waterlily shape, split ring resonator, multiband.

I. Introduction

RAPID development of telecommunication systems, uses of wideband and multiband applications are more extensive for antennas. A wideband device is a communication device. Recently, due to the miniaturization of the communication devices, the need of compact antenna becomes more attractive nowadays. Moreover, a multiband antenna is designed to operate in several bands of frequencies [1]. These antennas often use a design in which one part of antenna is active for one band, and the other ones are active for different bands [2].

One simple way to cover all frequency bands is using multiband antennas [3]. It has been demonstrated that fractal geometries are based on space filling and self-similarity attributes and they can be useful to improve the performance of antenna. Also, fractal-based antennas can effectively couple energy to the free space [8]. Metamaterials can be classified as electromagnetic and acoustic. In the electromagnetic metamaterials, both electric and magnetic fields are transverse waves, and acoustic metamaterials result in negative refractive index. One of the most fundamental elements for constructing metamaterials is SRR and closed ring resonator (CRR). The size and weight of the antenna are important for the antenna to be used for commercial applications [4], [5]. However, in order to avoid interfering with nearby communication systems, we need to design a single antenna that can operate at the multi frequency bands [6].

In this paper, CPW-fed water lily shaped SRR loaded fractal monopole antenna for multiband applications are proposed [10]. In order to improve the impedance bandwidth with miniaturized size, CPW feed has been found because of their attractive features. The Water lily-shaped patch antenna has modified ground, Koch curve fractal and SRR. Here, SRR is etched on the back side of the substrate. The fractal metamaterial tuning stub is introduced to enhance the coupling between the slot and the feed line which acts as a good candidate for multiband applications. By introducing the Koch curve fractal, the proposed SRR loaded fractal water lily shape antenna achieves the resonance at 3.8 GHz, 8.68 GHz, 13.96 GHz, and 19.74 GHz, respectively [7], [9]. The good performances of the antenna such as return loss, gain, radiation pattern, and impedance matching are required to be consistent along almost the whole operating band.

II. Antenna Structure and Design

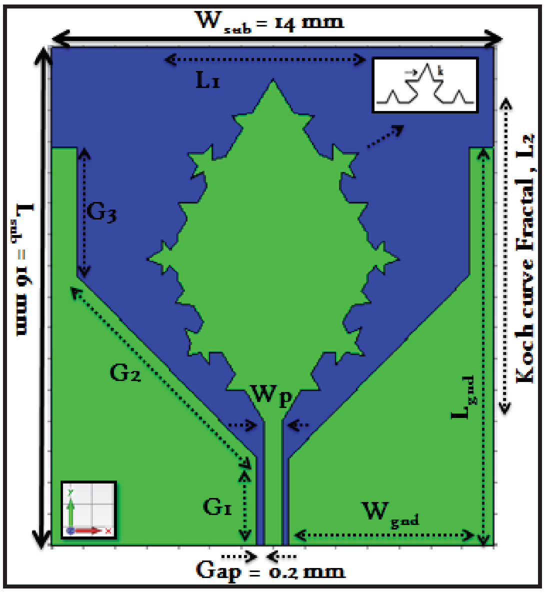

Fig. 1 Geometry of the proposed antenna

Fig. 1 illustrates the geometry of the SRR loaded fractal water lily shaped monopole antenna. The antenna is printed on a FR4 substrate with a permittivity of 4.4.

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The FR4 dimensions are W_{sub} x L_{sub}, and the feed line has a width (W_p) 0.6 mm, which corresponds to a characteristic impedance of 50 Ω. The gap between the ground and the water lily patch is about 0.2 mm. The optimal dimensions of the designed antenna are specified in Table I.

TABLE I
OPTIMAL PARAMETERS OF WATER LILY SHAPED ANTENNA

Parameter	Unit
W_{sub} (Width of the substrate)	14 mm
L_{sub} (Length of the substrate)	16 mm
W_{gnd} (Width of the ground)	6.5 mm
L_{gnd} (Length of the ground)	12.8 mm
W_p (Width of the patch)	0.6 mm
L_p (Length of the patch)	4 mm
L1 (Width of the water lily)	6 mm
L2 (Length of the water lily)	11 mm
G1 (Modified ground)	2.8 mm
G2 (Modified ground)	6.7 mm
G3 (Modified ground)	4.3 mm
K (Koch Curve Fractal)	0.2 mm

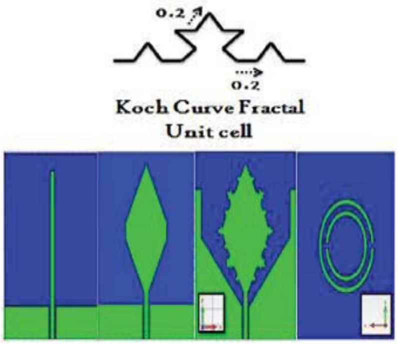


Fig. 2 Koch curve fractal unit cell and Iterations of the proposed antenna

Fig. 2 depicts the Iterations used to develop the antenna is given below:
Iteration 1. Create a CPW feed line monopole patch antenna (Ant. 1).
Iteration 2. Design water lily shaped monopole patch antenna (Ant. 2).
Iteration 3. Embed a Koch curve fractal in monopole patch and ground is modified to extend the antenna's impedance bandwidth for multi band performance (Ant. 3).
Iteration 4. SRR is added to the back side of the dielectric substrate (Ant. 4).

TABLE II
OPTIMAL PARAMETERS OF FRACTAL METAMATERIAL SRR ANTENNA

Parameters	Unit
p (Width of the SRR)	8.0 mm
q (Length of the SRR)	5.0 mm
r (Radius of the outer SRR)	6.0 mm
s (Radius of the inner SRR)	3.0 mm

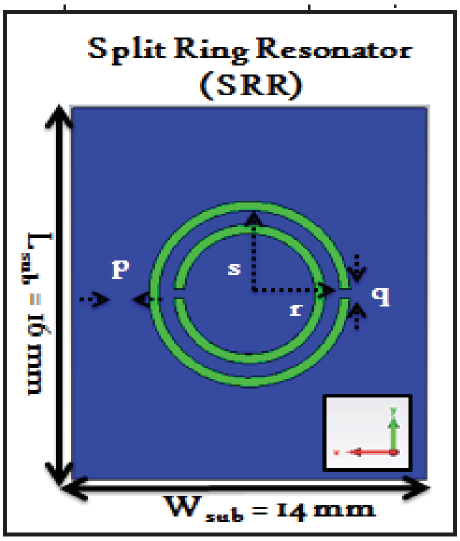


Fig. 3 SRR loaded fractal water lily shaped monopole antenna

Fig. 3 illustrates the geometry of the proposed fractal Split ring metamaterial resonator water lily shaped patch antenna. The two Split ring is placed back side of the FR4 substrate which highly suitable to generate multi band characteristics. Parameter of the SRR loaded fractal antenna is given in Table II.

III. RESONANCE AND RADIATION CHARACTERISTICS

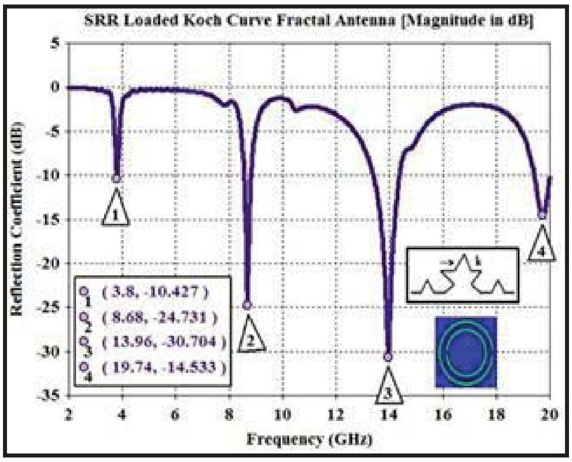


Fig. 4 Return loss versus frequency for SRR Loaded fractal metamaterial patch antenna

A CPW-fed SRR loaded fractal water lily-shaped radiation patch antenna achieves the resonance at frequency of 3.8 GHz, 8.68 GHz, 13.96 GHz and 19.74 GHz as shown in Fig 4. By introducing a Koch curve fractal with modified ground and Split ring metamaterial, patch radiator leads to the extra resonant.

The simulated surface current distribution on the radiating patch for the Koch curve fractal metamaterial antenna frequencies at 6.0 GHz, 10 GHz, and 16 GHz is shown in Fig. 7.

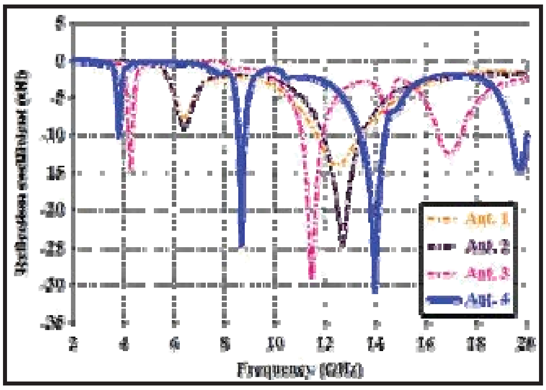


Fig. 5 The comparison of water lily antenna, fractal (Koch curve) water lily antenna and fractal metamaterial (SRR) water lily antenna

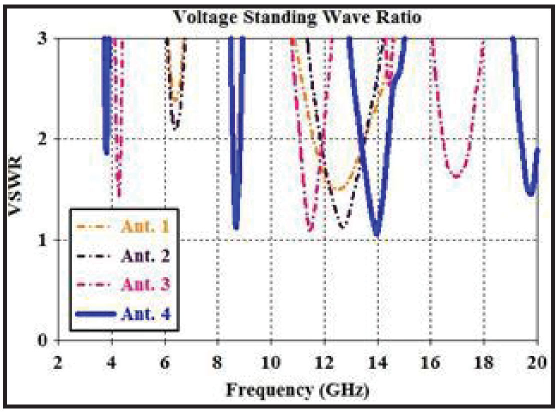
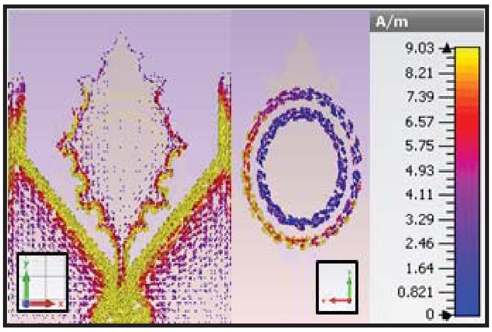
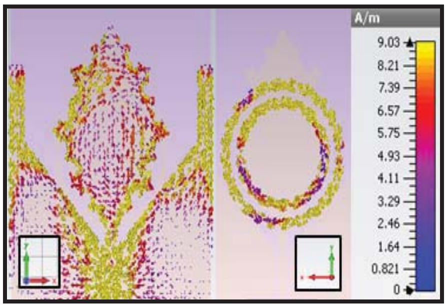


Fig. 6 Simulated VSWR versus frequency for the proposed antenna

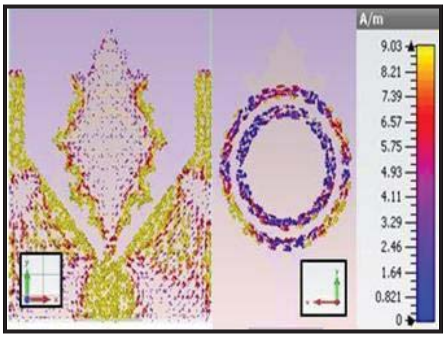
Fig. 5 shows the comparison of reflection coefficient versus frequency, and Fig. 6 shows the VSWR versus frequency for the SRR loaded fractal water lily-shaped patch antenna. The Koch curve fractal and metamaterial SRR achieves the different frequency bands operating at S, X, Ku, and K. Distributions of electric current on the antenna, have been studied to understand the behavior of the planar monopole antenna.



(a) 6.0 GHz

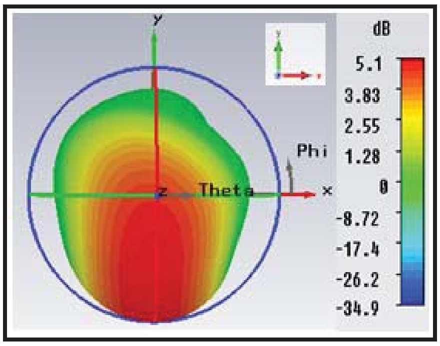


(b) 10.0 GHz

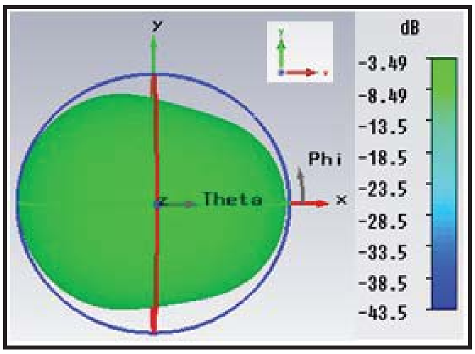


(c) 16.0 GHz

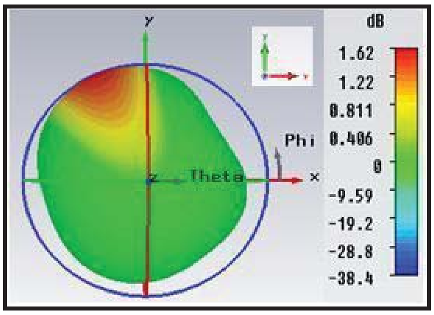
Fig. 7 Electric current distributions for proposed antenna



(a) 6.0 GHz



(b) 10.0 GHz



(c) 16.0 GHz

Fig. 8 Electric current distributions in 3D pattern for proposed antenna

Simulated 3D pattern of the fractal metamaterial water lily shaped patch antenna at 6.0, 10.0, and 16 GHz E-Plane and H-Plane is shown in Fig. 8. Simulated realized gain for the proposed antenna is shown in Fig. 9.

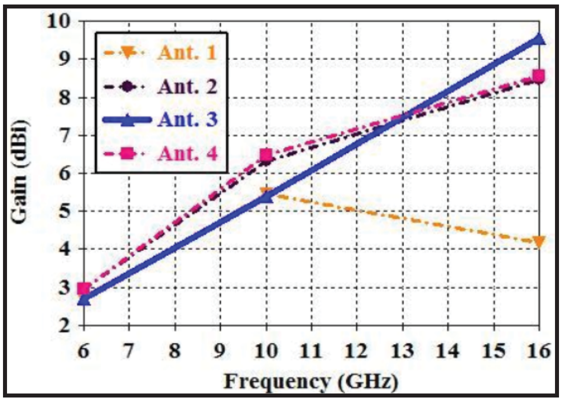


Fig. 9 Peak Gain for fractal metamaterial Water lily shaped antenna

IV. Conclusion

In this paper, coplanar fed SRR loaded Koch curve fractal water lily shaped antenna is presented, which covers 3.8 GHz, 8.68 GHz, 13.96 GHz, and 19.74 GHz band applications. Fractal metamaterial antenna consists of compact size (14 x 16 mm^2) which is for multi operating frequencies. SRR is placed back side of the dielectric substrate which causes multi resonance. The uniqueness of this design is that the Koch curve with size smaller than the resonant wavelength is used for obtaining the wide frequency band, which makes the SRR loaded fractal metamaterial antenna very compact. This antenna shows good radiation characteristics and VSWR (VSWR<2) with moderate gain over the operating bands, which makes antenna suitable for multi band applications.

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