CIRCULARLY POLARIZED KOCH FRACTAL TRIBAND ANTENNA FOR WIRELESS COMMUNICATION APPLICATIONS

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ABSTRACT
A novel monopole asymmetric fractal micro strip antenna is designed and analyzed in this paper. The proposed Koch fractal monopole antenna is resonating at triband with circular polarization operation. Five diff structures - without slot (basic model), single slot (Iteration 1), double slotted (Iteration 2), triple slotted (Iteration 3), and optimized fractal slot (Iteration 4) are studied for circular polarization radiation. Perturbations in the structure for triband CP radiation are introduced by employing optimization in the asymmetrical Koch fractal curves as boundaries of a square patch and embedded triangular slots. The generated 3-dB axial ratios are analyzed with the simulation results demonstrate that the proposed antenna design is suitable for wireless communication applications.

Keywords: axial ratio (AR), circular polarization (CP), koch fractal, triband, wireless communications.

1. INTRODUCTION
With rapid development in advanced wireless communication systems, designing compact, multiband and Omni directional radiation patterns for multi systems are becoming essential as per the future requirements [1-2]. Several antennas have been proposed for dual band, triband and multiband applications. However their designs may increase the complexity, and may have large sizes and may have limited bandwidths [3]. Modern systems are able to support various applications operating at different frequency bands. Hence, there is a need for multiband CP antennas to eliminate the multipath effects and to make the data reception independent of orientation of the device [4-6].

Triband antennas based on circular-arc-shaped strips and asymmetrical strips have been covered in the literature, and resonance frequencies of multiband are controlled by the dimensions of the strips [7-9]. Triband antennas have been demonstrated using H-shape, U-shape, Hexagonal slot with slits, and dual annular shaped slot patch structures. However, most of these triband antennas are linearly polarized, and the fabrication complexity increases with complex structures in the design of the antenna. Single layer single probe fed triband CP antennas with slits on the patch and ground plane are available in the open literature [10-11]. Although these structures give CP at three bands, the generated 3-dB axial ratio Band width at tribands is very narrow [12]. In this paper we designed triband CP operation for wireless communication applications using Koch fractal concept to generate wide 3-dB axial ratio CP bandwidth.

Fractal antennas have already been proved to have some unique characteristics that are linked to the geometrical properties of fractals [13]. The self similarity property of fractals makes them especially suitable to design multi frequency antennas. Some fractal shapes have complex, convoluted shapes that can enhance radiation when used as antennas [14-15]. For instance some fractal loops can be designed to enclose a finite surface with an arbitrary large perimeter. Certain monopoles can be designed to have an arbitrary large length, although they can be constrained to fit a given volume. In this work coplanar waveguide fed monopole Koch fractal boundary patch is implemented for triband CP radiation. This paper will demonstrate the design procedure of triband fractal slot antenna and its performance characteristics in simulation with Finite element method (FEM) based HFSS tool.

2. ANTENNA GEOMETRY AND DESIGN PROCEDURE
The configuration of the proposed Circular polarized antenna in HFSS simulation is shown in Figure-1(A) and the prototyped model on FR4 substrate is shown in Figure-1(B).
The specifications of the proposed model are shown in Table-1. The three sides of the square patch are replaced with Koch fractal curve to design the compact antenna for Circular polarization radiation. To excite two orthogonal modes of 90 degrees phase shift for good CP radiation at triband, proper asymmetry is implemented by rotating the fractal slot by 45 degrees as shown in the design. This slot is a scaled version of the main patch. Perturbation to the structure is inserted through edges, so that the feed point at lower side will not disturb the Koch fractal structure. To facilitate better understanding of the proposed triband CP operation mechanism, the HFSS simulation is carried out and the designed models starting with base model to iteration 4 as shown in Figure-2. The antenna models are designed on FR4 substrate of dielectric constant 4.4. The overall dimension of the proposed antenna is around 25x25x1.6 mm.
3. RESULTS AND DISCUSSIONS

One of the primary results from the antenna simulations are the S-parameters (magnitude and phase) plots vs. frequency. The s-parameter plot shows resonant frequencies and operating bandwidths for the microstrip patch antennas analyzed. Figure-3 shows the reflection coefficient characteristics of the antenna models with respect to the resonant frequencies. The base model is resonating at dual band with low bandwidth at the resonant frequencies. Even though the curve showing without resonating frequency for the base model, the reflection coefficient is negligible in the simulation and in the measurement this third band is not obtained. From iteration 1 to iteration 4, we can observe the improvement in the bandwidth as well as reflection coefficient as shown from the Figure-3. A notable observation from the return loss characteristics are observed that there is a sharp discontinuity in the curves at higher bands indicating the possibility of CP radiation. The first resonant band at 4.6GHz is excited by outer fractal curves and inner slot boundaries, thus a wide impedance bandwidth that covers wireless applications with 10-dB return loss bandwidth 65% (3GHz-6GHz) is obtained. The second resonant frequency band at 7.7GHz covers (FM-UWB transceiver) with 6.5% (7.5GHz-8GHz) bandwidth. The third frequency band at 10.28GHz is mainly due to the inner embedded fractal slot, and bandwidth is 4% (10GHz-10.4GHz).

![Figure-3. Return loss vs. frequency of the antenna models.](image)

Iteration 4 is showing better impedance i.e., at fundamental resonant frequency impedance nearer to 50 ohms. Figure-4 shows the axial ratio curve for the antenna models at the resonant frequencies. It has been observed that axial ratio at the corresponding resonant frequencies for all the models are showing < 3dB. The axial ratio 3dB CP bandwidths are 1200 MHz, 487 MHz and 830 MHz at operating frequencies around 4.6, 7.7 and 10.28 GHz respectively.

![Figure-4. Axial ratio vs. frequency of the Koch fractal circularly polarized antenna.](image)
The proposed antenna radiation patterns in horizontal plane and vertical plane at its resonance frequencies are shown in Figure-5. The difference between these two radiation patterns produces the axial ratio in that direction. Due to smaller electrical length of the antenna at 10.28GHz a broad side Omni directional radiation pattern can be observed from Figure-5 the cross polarization value is less than -36db in the E-plane and in the H-plane an 8 like radiation pattern with nulling at 90degrees, 270 degrees can be observed. The current model is giving larger axial ratio band width when compared with stacked antennas.

Figure-5. Radiation pattern in E and H-Plane for the proposed antenna model at 4.6, 7.7 and 10.28 GHz.

Figure-6 shows the current distribution over the surface of the proposed antenna at different resonant frequencies. A circular polarization can be observed from this figure. Most of the current density is focused at feed
line for all resonant frequencies but a considerable current distribution can be observed for the proposed antenna at 7.7 GHz. Figure-7 shows the directivity of the antenna models at their resonant frequencies. Directivity of more than 3.3db at 10.28 GHz for proposed model can be observed from Figure-7. Figure-8 shows gain of the antenna models with respect to their resonant frequencies. A maximum gain of more than 2.8 dB is obtained at higher resonant frequency for the circular polarized antenna. Figure-9 shows the efficiency of the antenna models with respect to their operating resonant frequencies. Iteration 1 and iteration 4 are giving efficiency more than 96% at 4.6 GHz.

Figure-6. Current distribution of the proposed antenna at resonant frequencies 4.6, 7.7 and 10.28 GHz.

Figure-7. Frequency vs. directivity of the antenna models.

Figure-8. Frequency vs. gain of the antenna models.
CONCLUSIONS

A novel coplanar waveguide fed tri-band circularly polarized Koch asymmetrical fractal monopole antenna has been proposed and analyzed in this paper. Circular polarized rectangular, fractal slotted antenna for tri-band operation is studied and its performance characteristics are presented in this work. By optimizing feed and slot dimensions tri-band circular polarization is achieved. The proposed model showing axial ratio bandwidth of 1200 MHz, 488 MHz and 830 MHz at 4.6, 7.7 and 10.2 GHz, respectively. The circular polarized proposed antenna is highly suitable for the modern wireless communication systems with its excellent AR bandwidth and efficiency.

ACKNOWLEDGEMENTS

Authors like to express their gratitude towards the Department of ECE and Management of K L University for their support and encouragement during this work. Further Madhav likes to express his gratitude to DST through FIST grant SR/FST/ETI-316/2012.

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