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Poly Fractal Boundary Circularly Polarised Microstrip Antenna for WLAN/Wi-MAX Wireless Applications

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ABSTRACT

The design of circularly polarised multiband poly fractal boundary microstrip antenna is proposed and experimentally studied. Initially the two orthogonal sides of the square patch are replaced with different fractal curves for circular polarisation (CP) radiation. Along the x and y axes, Minkowski and Koch fractal curves are employed. A 45° rotated poly fractal slot is embedded at the center of the fractal patch for triband CP operation. The indentation depths and indentation angles of the Minkowski and Koch fractal curves are optimised for better CP emission. The inserted fractal slot redistributes the current elements on the patch for tri band CP radiation. The measured 3-dB axial ratio bandwidths of the proposed antenna at 2.4 GHz, 3.4 GHz, and 5.8 GHz are 1.53 per cent, 0.81 per cent, and 1.62 per cent respectively, making it an able candidate for WLAN and Wi-MAX wireless applications.

Keywords: Circular polarisation, Koch, Minkowski, microstrip antenna, wireless application, multiband antenna

1. INTRODUCTION

Recent advancements in the field of wireless communications have increased the requirement for multiband antennas. Necessities of present day communication systems have also prompted an increased demand for minimal and more conservative antennas. The advantage of the multi-band antennas is their ability to integrate several frequency bands on one single antenna, making it useful for various applications. There are several multiband linearly polarised antennas as evident from literature. However, modern handheld device designers prefer to have circular polarisation (CP) in gadgets to enable the user to orient the device in any direction which can still maintain the link. This is very much desirable for many users as they would like to operate these devices when they are in various postures. In view of these perspectives, compact circularly polarised antennas with multi-band operations will be more useful in wireless systems for use in future.

Nayeri[1], *et al*. have proposed a stacked microstrip antenna with asymmetrical U-slot patches for dual band CP radiation. Two orthogonal modes for CP at dual band are obtained by introducing properly optimised U-slots with unequal slot lengths on the square patches. Nasimuddin[2], *et al.* have suggested a dual-band single-feed circularly polarised aperture coupled microstrip antenna. For dual band operation, an S-shaped slot is cut at the center of the square patch. By adjusting the S-shaped slot arm lengths, two resonating frequency bands can be obtained with good CP. A novel design employing the multi stacked patches are fed with a single coaxial probe has been studied by Falade[3], *et al.* for GPS receivers. By introducing two pentagonal slots on the patch structure, dual band circularly polarised antenna is studied[4]. The two asymmetrical pentagonal slots are responsible for generation of two CP radiation bands. Three asymmetrical patches are introduced on the three stacked layers for the triple band CP emission. Triple band antennas have been demonstrated using H-shape[5], dual annular-shaped slot[6], and hexagonal slot with slits[7] patch structures. Several multilayered stacked[8,9] and coplanar waveguide[10,11] patch structures are proposed for tri band CP operation. However, most of these antennas[1-11] are based on stacked patch technique to generate multiband CP emission, so the fabrication process becomes complex with an increase of number of stacked layers. Single probe feed, single layer triple band antennas with slits on the patch[12] and ground plane are available in the literature[13]. Although these structures generate CP at three bands, the generated 3-dB CP bandwidths of all these approaches are very narrow (<1 %). So, the design of single layer, single probe feed, triple band CP antennas using fractal boundary structures is investigated in the present study.

Fractal concept has been successfully applied so far to design compact and multiband antennas. Several Koch fractal boundary slot antennas with CPW feed are proposed for broadband operation covering WLAN and WiMAX applications[11-16]. However, these antennas generate only linear polarisation radiation. So far, in the literature available**,** boundary fractals are applied to patch structures for designing only compact antennas[17] and CPW fed slot antennas. In the present work, two different fractal boundary curves Minkowski and Koch[18] are applied along the x and y axes of a square patch for CP radiation. Later, a 45° rotated poly fractal slot is embedded in the center of patch for multiband CP operation.

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To generate good CP performance at tri-band, the dimensions of the fractal curves and probe feed locations are optimized using HFSS software optimetric analysis tool.

2. ANTENNA GEOMETRY

The proposed fractal boundary circularly polarised antenna can be obtained by replacing two orthogonal directions x and y axes of a square patch with first iterated Minkowski and Koch fractal curves. Here, the end to end length of the patch is considered as L = 36 mm to resonate the antenna on first frequency band at 2.4 GHz. Afterwards, a 45° rotated poly fractal slot is inserted in the middle of the patch with dimensions W_1 = 0.15 *L and L_1 = 0.35*L and with a feed point at (7 mm, 7 mm), triple band CP operation is achieved. The inserted poly fractal slot is a scaled version of main fractal patch. The dimensions of the fractal slot are chosen in such a way that the fractal slot resonates at 5.8 GHz frequency. The proposed antennas side and top views are depicted in Fig. 1.

To study the triband CP radiation physically, the simulated surface current distributions on the fractal patch structure is as shown in Fig. 2. The first band at 2.4 GHz is excited due to strong current distribution along outer fractal boundary curves and inner fractal slot. The second band at 3.4 GHz is mainly generated because of the current distribution along the only outer fractal boundary curves. The scaled fractal slot at the center is mainly responsible for 5.8 GHz frequency band. Different fractal curves are used as boundaries of the patch and slot along the two orthogonal directions to generate the two modes with equal amplitude and 90° out phase for circular polarisation at all the generated frequency bands. From the simulation study it is observed that, with the increase of phase angle by 90° there is a movement of surface current distribution elements on the patch surface in anticlockwise direction at all the three resonating frequencies, which indicates that the antenna generates right-hand CP (RHCP) at triband. The studied patch structures for various indentation depths (D_x) and indentation angles (θ_y) of the Minkowski and Koch fractal curves are pictured in Fig. 3.

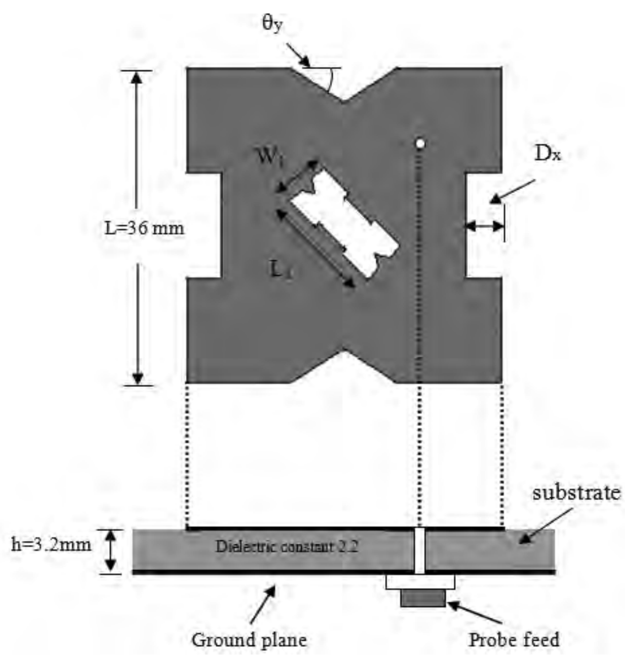
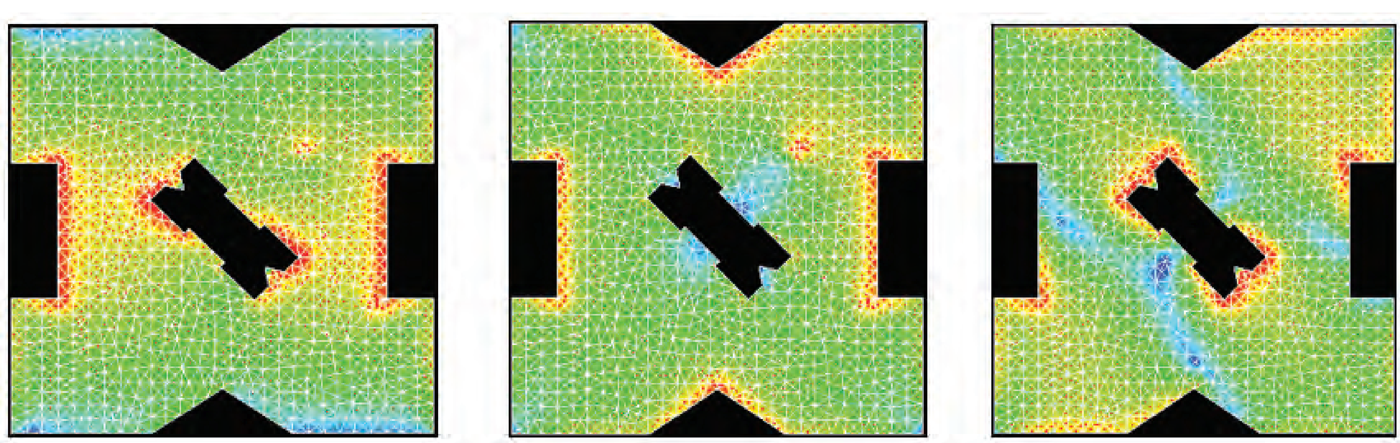


Figure 1. The top side views of proposed triband CP antenna.

3. RESULTS AND DISCUSSIONS

The indentation parameters of the Minkowski and Koch fractal curves along x- and y- axes (D_x, θ_y) control the radiation characteristics. If it is the same symmetrical fractal, either Minkowski or Koch curves are used as the boundaries on all four sides of a square patch. In this case the antenna generates linear polarisation. The CP radiation from symmetric patch can be obtained by using different fractal curves along the x- and y-axes. The two dissimilar fractal curves make the electrical length different in two orthogonal directions and this generates the required perturbation in the structure for CP radiation. The proposed antennas are simulated and corresponding return loss and axial ratio plots are shown in Figs. 4 and 5, respectively. It is observed that with increase of indentation parameters of the fractal curves, the return loss and axial ratio curves are shifted towards left. It is due to increase of the electrical length of the patch with the increase of indentation parameter. The summarised simulation results are given in Table 1.

To validate the proposed design and simulation results, the CP Ant 2 patch under investigation is fabricated on RT/duroid 5880 substrate of volume 50×50×3.2 mm^3 and measurements



(a) (b) (c)

Figure 2. The simulated current distributions on the tri-band fractal patch: (a) at 2.4 GHz, (b) at 3.4 GHz, and (c) at 5.8 GHz.

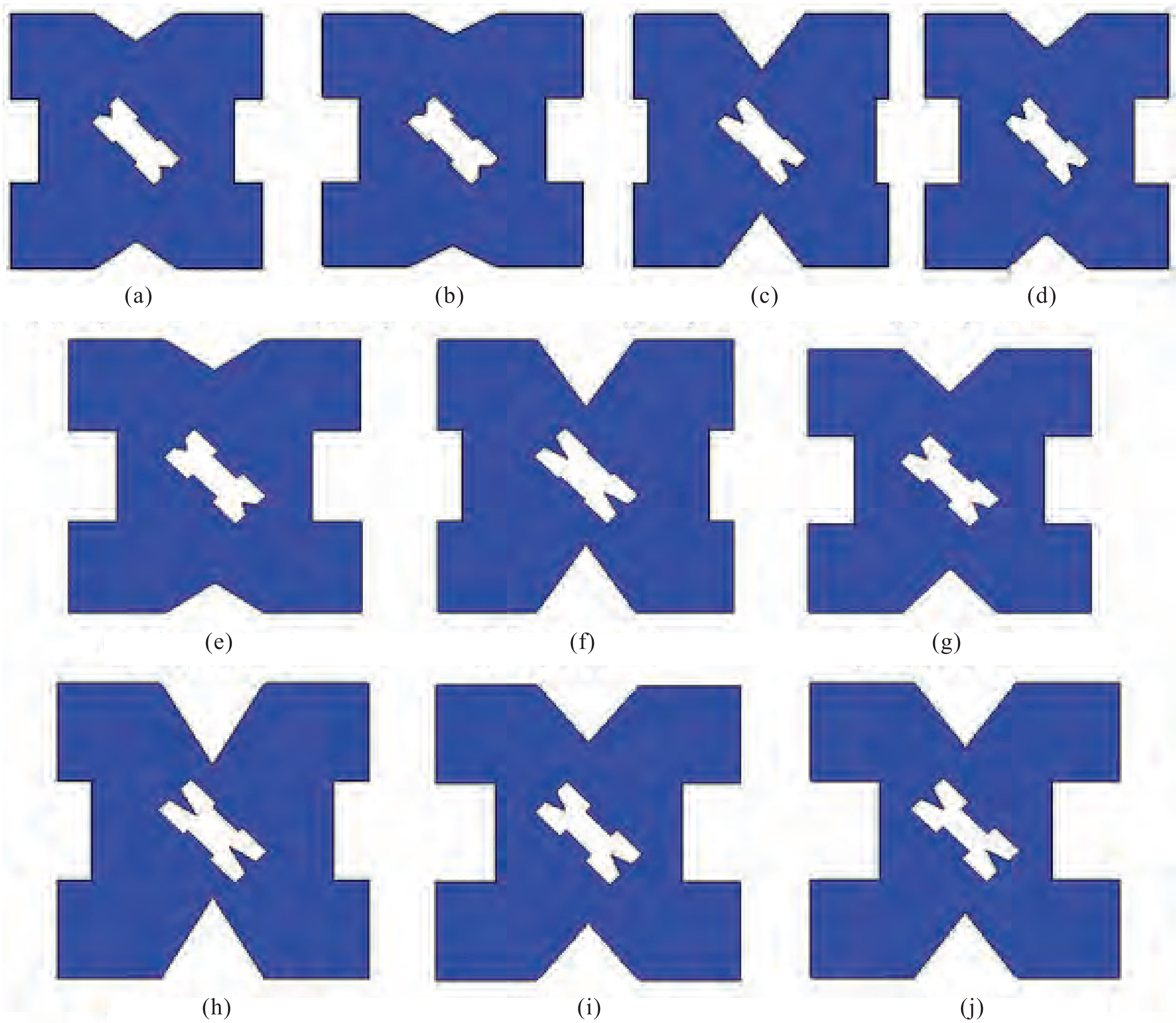


Figure 3. The proposed patch structures: (a) Poly CP Ant 1, (b) Poly CP Ant 2 , (c) Poly CP Ant 3, (d) Poly CP Ant 4, (e) Poly CP Ant 5, (f) Poly CP Ant 6, (g) Poly CP Ant 7, (h) Poly CP Ant 8, (i) Poly CP Ant 9, and (j) Poly CP Ant 10.

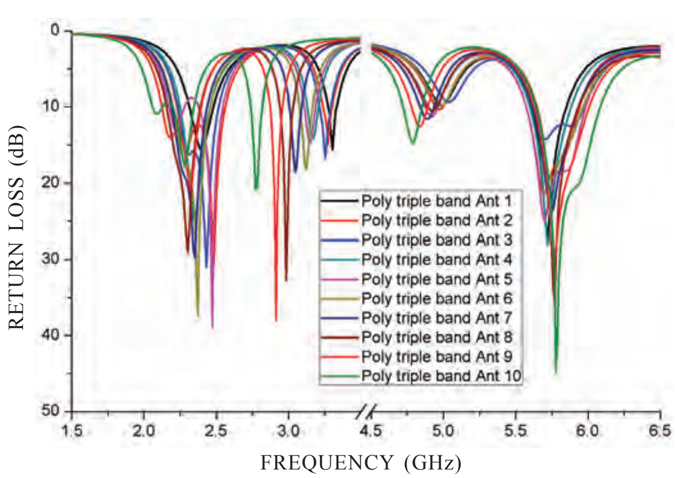


Figure 4. The simulated return loss curves.

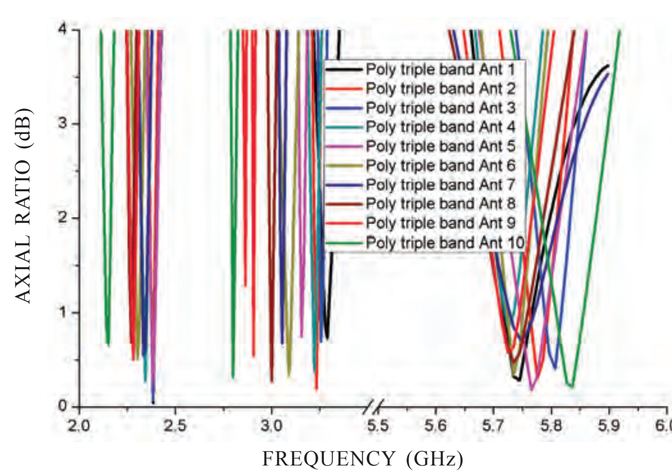


Figure 5. The simulated axial ratio plots.

Table 1. The summarised simulation results

Antenna	Indentation factors		10-dB return loss bandwidth (%)			3-dB Axial ratio bandwidth (%)		
	D_x	θ_y	2.4 GHz	3.4 GHz	5.8 GHz	2.4 GHz	3.4 GHz	5.8 GHz
CP Ant 1	0.22	34°	6.8	1.6	4.2	2.09	0.6	1.42
CP Ant 2	0.27	27°	13.7	1.83	6.6	1.68	0.9	1.73
CP Ant 3	0.11	54°	11.7	2.15	6.22	2.52	0.96	1.55
CP Ant 4	0.27	40°	8.51	2.53	5.06	2.13	1.2	1.57
CP Ant 5	0.33	34°	10.02	2.85	7.28	2.5	1.17	2.4
CP Ant 6	0.16	58°	11.15	2.56	5.87	2.6	1.23	2.1
CP Ant 7	0.33	45°	10.38	2.62	5.54	2.56	0.98	2.2
CP Ant 8	0.22	62°	9.69	3	5.1	1.76	1.33	2.34
CP Ant 9	0.38	50°	11.5	3.2	6.54	2.18	0.68	1.92
CP Ant 10	0.44	54°	12.7	2.52	7.5	2.33	1.18	2.4

are carried out. The fabricated antenna is pictured in Fig. 6. The corresponding comparisons of simulated and measured results are presented in Figs. 7 and 8. The achieved 3-dB axial ratio bandwidhts at tri-bands 2.4 GHz, 3.4 GHz, and 5.8 GHz are 1.53% (2382–2418 MHz), 0.81% (3386–3414 MHz), and 1.62% (5745–5855 MHz) respectively. The comparison of simulated and measured radiation patterns in horizontal plane and vertical plane are depicted in Fig. 9. As can be seen, the proposed antenna is implemented over a single layer and simple probe is used for the feeding purpose. By using different fractal curves and increasing the iteration order, more compact antennas can be designed.

From the measured axial ratio plots, it is observed that the best axial ratio values close to 0-dB are obtained at the three resonant frequencies. It is an indication of pure circular polarisation radiation at the center frequencies. The proposed antennas generate more than 2–dBi gain at all the operating frequency bands. A close agreement between the simulated and measured results is observed. The proposed antennas generate better triband CP radiation with single layer when compared with stacked layered CP antennas.

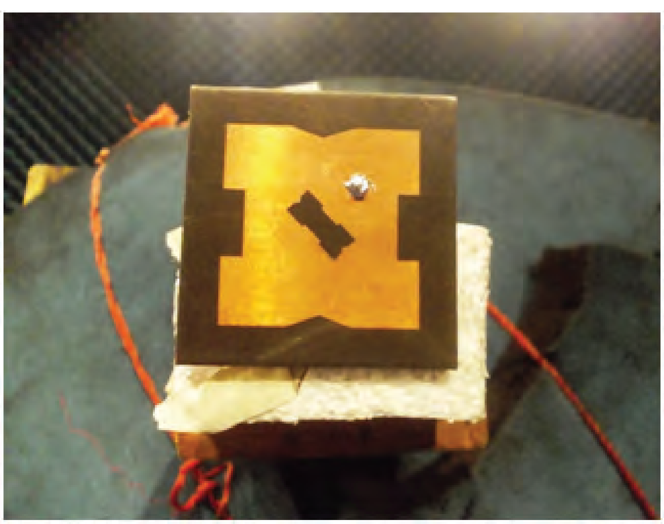


Figure 6. The fabricated poly fractal triband antenna.

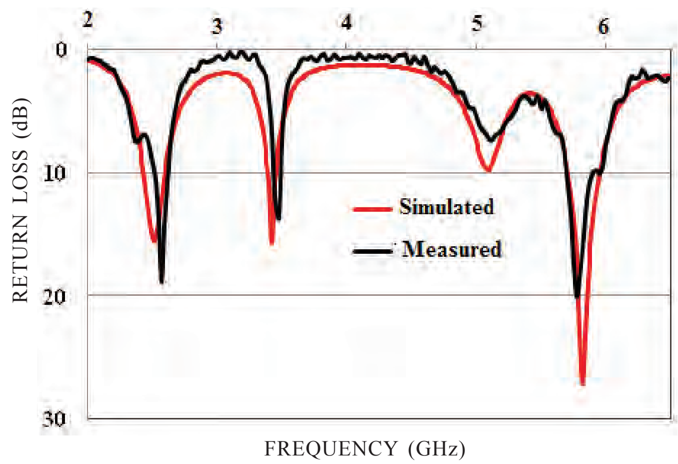


Figure 7. Comparison of simulated and measured return loss results.

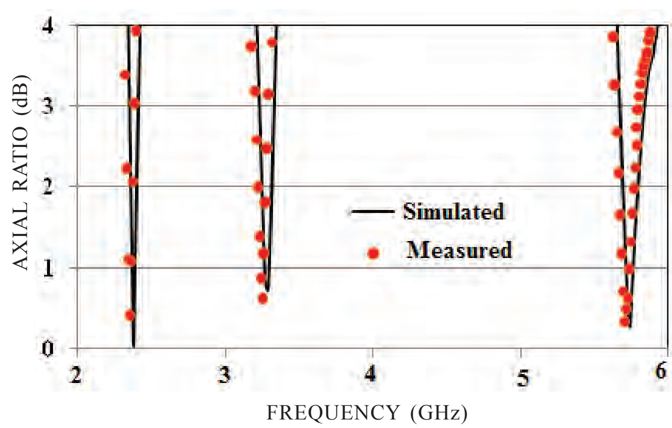
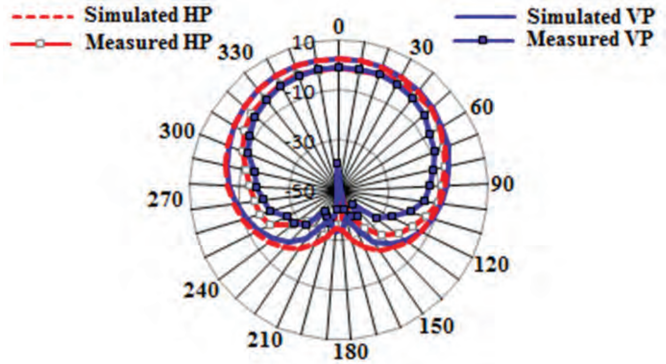
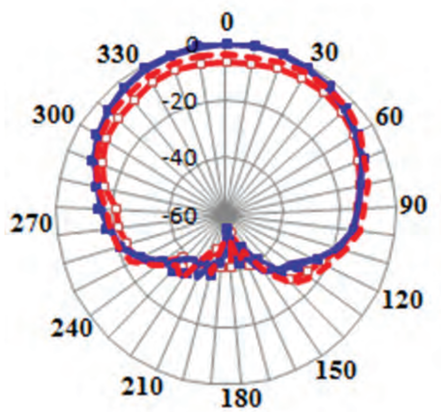


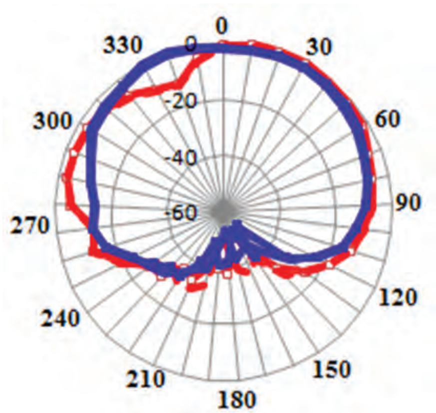
Figure 8. Comparison of simulated and measured axial ratio results.



(a)



(b)



(c)

Figure 9. The horizontal and vertical plane radiation patterns of fabricated CP Ant 2: (a) at 2.4 GHz, (b) at 3.4 GHz, and (c) at 5.8 GHz.

4. CONCLUSION

The design of poly fractal boundary microstip antenna for triband circular polarisation radiation is presented. A poly fractal slot is inserted in the middle of the fractal patch for triband CP operation. By varying the indentation factors of the Minkowski and Koch fractal curves, several triband antennas are proposed. The simulated antenna is fabricated and experimentally studied. A good agreement between the simulation and measured results is obtained. The suggested single layer, single probe feed multiband CP slot antenna is easy to fabricate and cost effective when compared with the multi layered antennas that find mention in literature on antennas.

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CONTRIBUTOR

Mr V.V. Reddy has carried out simulation planning, practical measurements, comparison of simulation and measured results, while also preparing the manuscript.

Mr N.V.S.N. Sarma has supervised the whole process of preparing manuscript, taking measured results and given valuable inputs to improve the academic merit of this paper.