International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:8, No:11, 2014

# Single Feed Circularly Polarized Poly Fractal Antenna for Wireless Applications

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***Abstract*—**A circularly polarized fractal boundary microstrip antenna is presented. The sides of a square patch along x- axis, y-axis are replaced with Minkowski and Koch curves correspondingly. By using the fractal curves as edges, asymmetry in the structure is created to excite two orthogonal modes for circular polarization (CP) operation. The indentation factors of the fractal curves are optimized for pure CP. The simulated results of the novel polyfractal antenna are demonstrated.

***Keywords*—**Circular polarization, Fractal, Koch, Minkowski.

## I. Introduction

RECENT trends in the development of wireless communications require an antenna that can be integrated on printed circuit board along with other microwave components. One such device is the microstrip antenna, which full fills the requirements like low profile, low weight and low cost. Therefore, much research is focused on this over last two decades. In order to avoid the misalignment between the transmitter and receiver, in all the applications like Wi-Fi, Wi-MAX, WLAN and GPS, generally circularly polarized (CP) antennas are preferred. The conventional method to get CP is by feeding two orthogonal signals to the radiating edge and non-radiating edge of a square patch antenna. Flexibility offered by printing technology helps in designing various CP antennas with single probe feeding. Researchers have introduced different structures of patch antenna with a variety feeding methods to get CP.

A novel compact CP operation of the square microstrip antenna with four slits and a pair of truncated corners is investigated by Kin-Lu Wong et al [1]. The 3 dB axial ratio bandwidth obtained is 0.8% and the minimum axial ratio is around 0.5 dB. Further, the gain obtained for various cases is about 1.4 to 2.8 dBi. A stacked patch configuration is used for the antenna and circular polarization is achieved by designing asymmetrical U-slots on the patches by Fong Lee et al [2]. One of the drawbacks of this design is that optimization of the U-slots dimensions is required. The CP radiation characteristics are achieved by loading with proper asymmetry, which is placed at the opposite angle of the feed line by sung [3]. Y-shaped monopole [4], U slot [5] antennas are proposed for circular polarization. Compact design of single feed circular polarized antenna is achieved by cutting a crossed slot on the circular patch backed by square-shaped ground plane with crossed slot, but the peak gain is very low by J. S. Row [6]. A different method by incorporating slots and adding tails to the square patch to get circular polarization mainly aiming for compact size is presented by Wong et al [7]. The antenna is designed to operate at 2492 MHz. The reported impedance and axial ratio bandwidths are 1.16% and 0.381% respectively. However, the reported 3-dB axial ratio (AR) bandwidth of all these approaches is very narrow (less than 1%) while the best axial ratio at desired frequency is more than 0.5 dB. Wide axial ratio bandwidth is also possible by using the complex feeding mechanisms like aperture [8] and proximity coupled [9] techniques. However, designing a single feed CP antenna with wideband axial ratio bandwidth is still a challenging task. However, designing compact single feed CP antennas by applying fractal concept has not been adequately reported in literature.

Fractal concept has significantly affected microstrip antenna field. Fractals are categorized into mass and boundary fractals. Mass fractal antennas have been proposed for multiband or wideband applications [10], [11]. Boundary fractals are used for microstrip antennas to design compact antennas. However, in this article, a unique patch structure is introduced and usage of fractal as boundary to the square patch to generate circular polarization is clearly explored. The method proposed is to replace the straight sides of square patch by different fractal curves. Because of this slight difference in electrical length in two perpendicular directions of the patch, two orthogonal modes are excited. By effective adjustment of the fractal curves, compact CP microstrip antennas can be realized. In addition to the CP, it is always possible to reduce the size.

## II. Design of Proposed Antenna

The original antenna is chosen to be a square in order to excite two modes with nearby resonant frequencies required for circular polarization. To excite the antenna for operating frequencies at around 2.3 GHz, the dimensions of the square can be roughly determined by (1)

$$\mathbf{f} = \frac{c}{2\,W\,\sqrt{\varepsilon_r}} \tag{1}$$

where c is the speed of light in the air, $\boldsymbol{\varepsilon_r}$ is the effective relative permittivity and W is the length of the patch.

Construction laws of fractal curves are primarily characterized by two parameters: Iteration Order (IO), Indentation Factor (IF). IF is subdivided into Indentation Angle (IA), Indentation Depth (ID) based on the shape of the fractal curve. Fig. 1 shows the utilized generators. Minkowski and Koch fractal curves are applied along the x and y axes of a

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square patch to introduce asymmetry in the structure to excite two orthogonal modes of equal amplitude and 90$^0$ out phase, which is pre-requisite for CP operation. Fig. 2 shows the geometry of proposed antenna. The specifications of simulated antennas are: the length of the patch (L), thickness (h) of the substrate as 3.2 mm, relative permittivity (${}_r$) which is 2.2, loss tangent is 0.0019.

(a) Koch generator (b) Minkowski

Fig. 1 Fractal curves used for the proposed antenna: (a) Koch curve along y- axis, and (b) Minkowski curve along x-axis

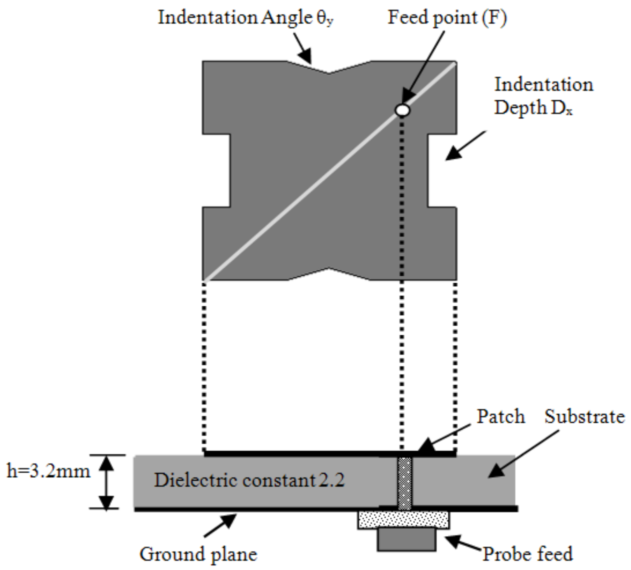



Fig. 2 Generation of proposed compact CP fractal boundary antenna

## III. Asymmetrical Fractal Boundary Structures and Simulation Results

Asymmetry to the structure is introduced through edges, so that the coaxial line feed (F) point is along the diagonal of the patch. Both LHCP and RHCP can be obtained by shifting the feed point to accurate positions on the diagonal axis. Fig. 3 shows the proposed fractal boundary antennas. The return loss characteristics of the antennas are pictured in Fig. 4.

It is observed from the return loss characteristics that with increase of ID-$D_x$ along the x-axis, and IA-$\theta_y$ along the y-axis electrical length of the antenna increase due to which resonating frequency decrease. The IF of the fractal curves is optimized to generate good CP radiation. The axial ratio plots of the proposed antennas are depicted in Fig. 5. The summarized simulation results of the CP antennas are given in Table I. Compared to the other antennas the proposed Ant 4 generates more 3-dB axial ratio CP bandwidth which is due to the highly optimized asymmetry along the two particular directions.

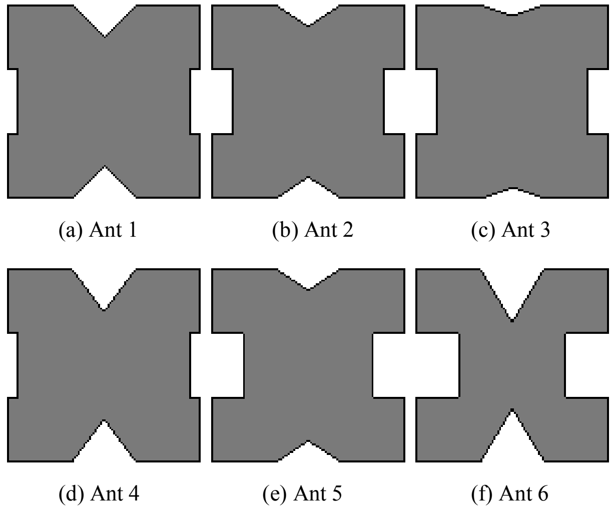



Fig. 3 The proposed antenna structures

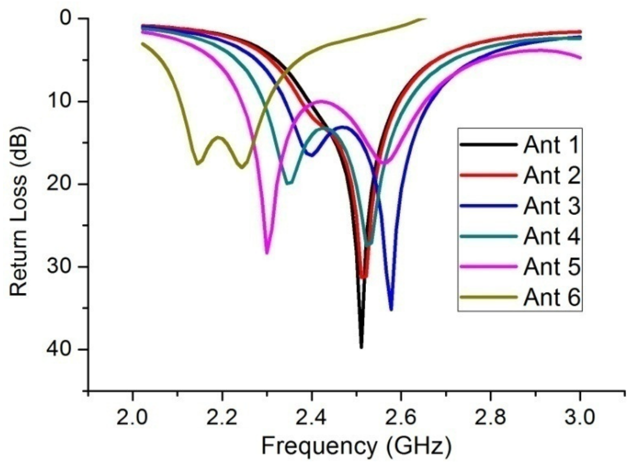



Fig. 4 The simulated return loss characteristics of the proposed antennas

The simulated vector surface current distribution on the patch Ant 4 at 2.388 GHz for four phase angles is pictured in Fig. 6. The clockwise rotation of vector current elements on the patch with increment of phase angle by 90$^0$ indicates the generation of CP emission from the Ant 4 at 2.388 GHz. The polar radiation plot of the Ant 4 is shown in Fig. 7. The simulated gain of the Ant 4 is pictured in Fig. 8. The more compact antennas can be designed by increasing the IO of the proposed fractal antennas.

TABLE I
Summarized Simulation Results of the Proposed Antennas

| Antenna | ID-$D_x$ | IA- $\theta_y$ | Minimum AR frequency (MHz) | 10-dB return loss bandwidth (%) | 3-dB axial ratio bandwidth (%) |
|---|---|---|---|---|---|
| Ant 1 | 0.11 | 45$^0$ | 2.455 | 13.2 | 2.3 |
| Ant 2 | 0.22 | 35$^0$ | 2.433 | 8.6 | 2 |
| Ant 3 | 0.22 | 20$^0$ | 2.422 | 16.3 | 1.2 |
| Ant 4 | 0.11 | 55$^0$ | 2.388 | 7.5 | 2.7 |
| Ant 5 | 0.33 | 35$^0$ | 2.322 | 12.6 | 2.5 |
| Ant 6 | 0.11 | 60$^0$ | 2.166 | 9 | 1.6 |

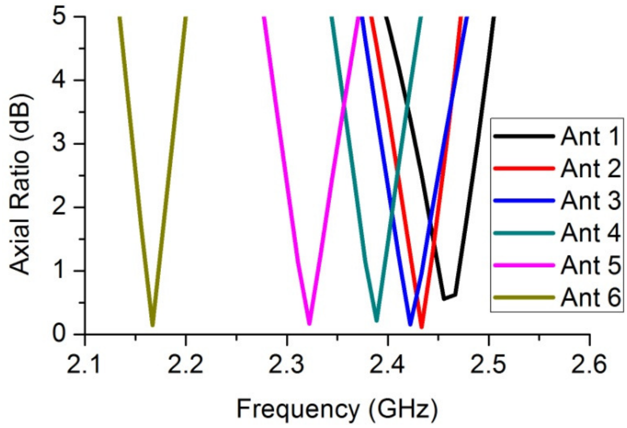
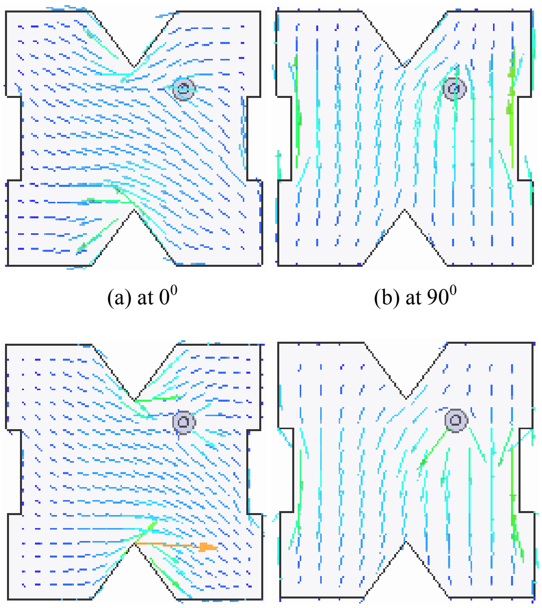



Fig. 5 The simulated axial ratio plots of the proposed antennas



(a) at $0^0$ (b) at $90^0$

(c) at $180^0$ (d) at $270^0$

Fig. 6 Vector surface current distribution on the patch Ant 4 at 2.388 GHz

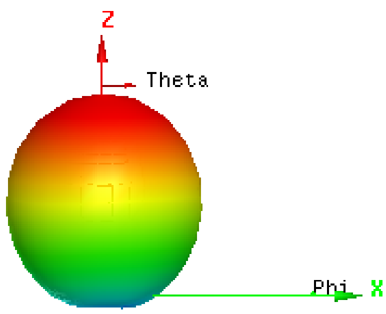



Fig. 7 The polar radiation plot of the Ant 4 at 2.388 GHz

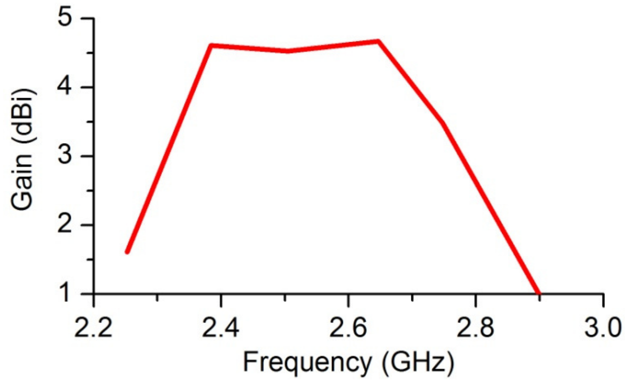



Fig. 8 The simulated gain plot of the proposed Ant 4

## IV. Conclusion

A novel single feed fractal boundary microstrip antenna is proposed for circularly polarized operation. The perturbation in the patch is introduced by replacing the sides of a square patch two different fractal curves. Indentation factors of the utilized fractal curves are optimized to generate good CP. The simulation results show that Ant 4 generates more 3-dB CP bandwidth because of the high optimized asymmetry between the used two fractal curves. By applying fractal curves to the sides of a square patch size of the antennas are also minimized.

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