On the Design of Square-Cut Circular Multiband Antenna for Wireless Communication

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ABSTRACT

This paper presents the four iterative circular shaped fractal antenna and its backscattering RCS with respect to iteration. First, the solid circular patch antenna has been designed on substrate $\varepsilon_r = 2.2$, h=0.787 mm with a = 40.766 mm and aspect ratio b/a = 0.98. The antenna has been simulated using FDTD method. The resonant frequency of this antenna has been observed at 1.42 GHz. The four iterative circular fractal antennas have also been designed with same substrate and dimension. This multi-band fractal antenna has been simulated, fabricated and tested. It has been observed experimentally that antenna is working on multiple frequencies. The size reduction of antenna is evident because first resonant frequency is shifted to 1.09 GHz in comparison to solid simple patch at 1.42 GHz. The experimental resonant frequencies of fractal antenna are 1.09 GHz, 1.65 GHz, 2.92 GHz and 4.485 GHz. The experimental and simulated resonant frequencies of antenna are in good agreement. The backscattering power with respect to iteration has been analyzed. It is observed that four iterative structure offers less backscattering power.

Keywords

Multiband Antenna, Fractal Antenna, Coaxial Feed, Microstrip Antenna

1. INTRODUCTION

Advances in antenna technology requires antenna of small size, low profile, easily fabricable and low cost. Microstrip antenna is one of them. Rectangular and circular microstrip patch antenna have been studied in open literature by several researchers [1-2]. These patches have been excited in a single dominant mode provided for linearly polarized radiation as well as circular polarization. Circularly polarized antenna can be classified as single feed type and dually feed type. The attractive feature is the ability to produce the CP waves easily with single feed [4-5]. This is achieved by applying some perturbation or modification to the patch. For a nearly square patch and a nearly circular, the feed position of antenna is taken at ± 45^o with respect to the symmetrical axis.

The limitations of conventional microstrip antennas are narrow bandwidth, poor radiation and size of the antenna. The size of conventional microstrip antenna for efficient radiation is around $\lambda/2$. As the size of antenna reduces less than $\lambda/2$, it results into poor radiation efficiency as well as degradation of other antenna parameters. By the applications of Fractal geometry the size of the antenna can be reduced [5-7]. The incorporation of fractal geometry in conventional microstrip antenna provides the size reduction of antenna as well as multi-band properties depending upon the number of iteration of fractal geometries.

The backscattering reduction of printed microstrip antennas is useful for electronics warfare. As microstrip antennas are conformable, are well suited for use on aircraft and aerospace vehicles. Therefore, scattering by antennas mounted on the structure may be most significant. Incorporation of fractal geometry in microstrip antennas helps to reduce the backscattering power of antenna [9] in comparison of conventional microstrip antenna. The backscattering of the antenna depends on the number of iteration of fractal geometries. This paper presents the new antenna geometry called coaxially feed circular shaped fractal microstrip patch antenna and study of its backscattering power. The antenna provides the size reduction, multi-band properties and fractal gives the backscattering reduction useful for EW system. This antenna has been simulated using FDTD [8]. Such type of antenna is useful for commercial and military wireless communication system.

2. DESIGN OF CIRCULAR MICROSTRIP ANTENNA

The design expression of simple circular Microstrip patch antenna for calculating the resonant frequency is given below

$$f_r = 1.841 v_o / 2\pi r_{eff} \sqrt{\epsilon_{eff}}$$

where v_o is the velocity of light. The effective radius r_{eff} can be calculated by following expression

$$r_{eff} = r_o[1+2h/\pi r_0 \epsilon_r\{\ln(r_0/2h)+(1.41\,\epsilon_r+1.77)+h/r_0(0.268\,\epsilon_r+1.65)]^{1/2}$$

The dimension of the solid circular patch is taken as a radius 40.766 mm as shown in Figure 1. This patch has been designed on FR4 substrate dielectric constant $\epsilon_r = 2.2$ and thickness h = 0.787 mm. This simple patch has been simulated using FDTD method based software. The simulated result has been shown in Figure 3. The simulated resonant frequency of this patch has been observed at 1.42 GHz.

3. DESIGN

The geometry of solid circular patch and four iterative circular shaped fractal antennas with geometrical design steps are shown in Fig. 1 and 2. First, the solid circular patch antenna has been designed on RT - Duroid substrate with $\varepsilon_r = 2.2$, h=0.787 mm, a = 40.766mm and aspect ratio b/a = 0.98. This antenna has been fed at position -25.346 x 25.68 mm radially. The four iterative circular shaped fractal antenna has also been designed on the same substrate dielectric constant and thickness with b/a aspect ratio 0.98, a=40.766mm. The fractal geometry has been introduced in this solid patch with four iterations. Solid patch shown in Fig. 1 is called zeroth iteration. In the first iteration, a square patch of dimension 56.08 x 56.08 mm has been subtracted from nearly circular patch shown in Fig. 2a. Then a nearly circular patch 28.32 x 27.73 mm with same aspect ratio 0.98 has been made which should touch all four arms of subtracted square. Then the square has been subtracted as shown in Fig. 2b. Then this process repeats in the same way upto fourth iteration. The infinite process has not been taken because practical constraints. The four iterative antenna structure is shown in Fig. 2d. This fractal geometry of antenna is having self - similarity in antenna structure and this antenna has been fed diagonally. The fabrication of this antenna has been implemented by taking the care of connectivity of the current over the patch. This is achieved by small overlapping of metallization each fractal iteration as shown in Fig. 2d.

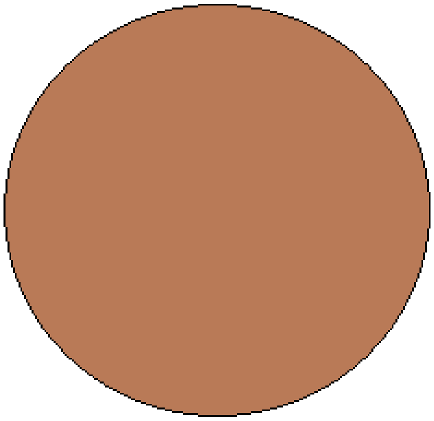


Fig 1: Solid patch with Zeroth iteration

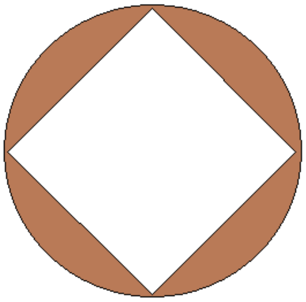


Fig 2a: First iteration

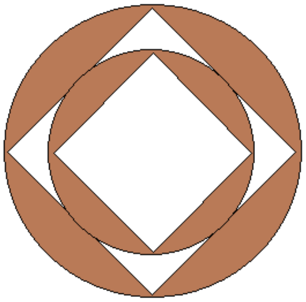


Fig 2b: Second iteration

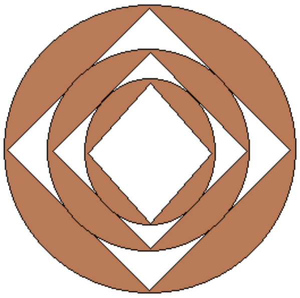


Fig 2c: Third iteration of of Circular Fractal Patch

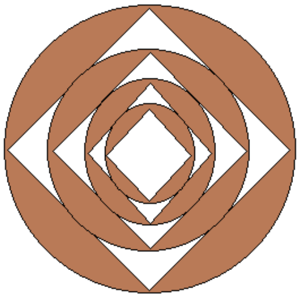


Fig 2d: Fourth iteration Circular Fractal Patch

4. SIMULATED & EXPERIMENTAL RESULTS

The conventional circular microstrip patch antenna and four iterative circular shaped fractal microstrip antennas have been simulated by using FDTD method [8]. The resonant frequency of conventional solid circular patch is found 1.42 GHz. It has been shown in Figure 3, return loss vs frequency. The fractal geometry has been incorporated in the solid simple circular patch with four iterations. The four iterative circular shaped fractal patch antenna has been simulated, fabricated and tested on vector network analyzer ZVA40. It has been observed that the first resonant frequency of the fractal antenna is shifted at 1.08 GHz in comparison to conventional simple circular microstrip patch at 1.42 GHz. It indicates the size reduction of antenna by the application of fractal geometry. The resonant frequency shifts around 340 MHz towards lower frequency side. The simulated result of this fractal antenna has been shown in Figure 4.

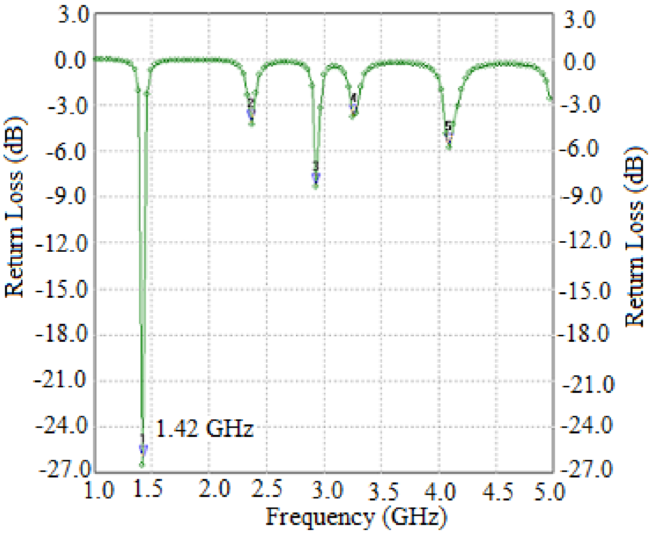


Fig 3: Return Loss of Circular Microstrip Patch Fractal Microstrip Antenna

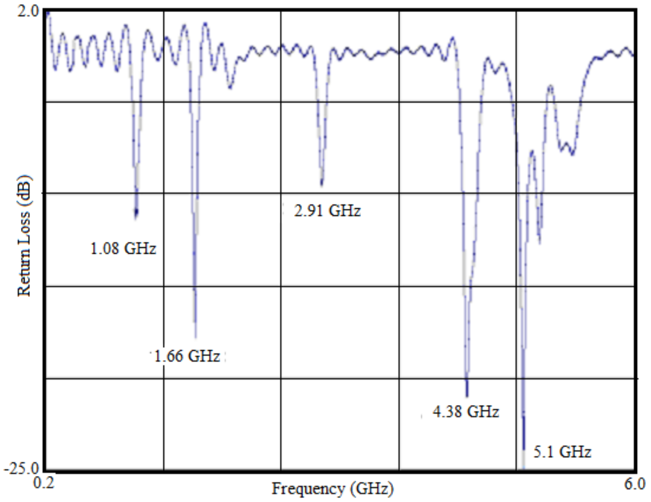
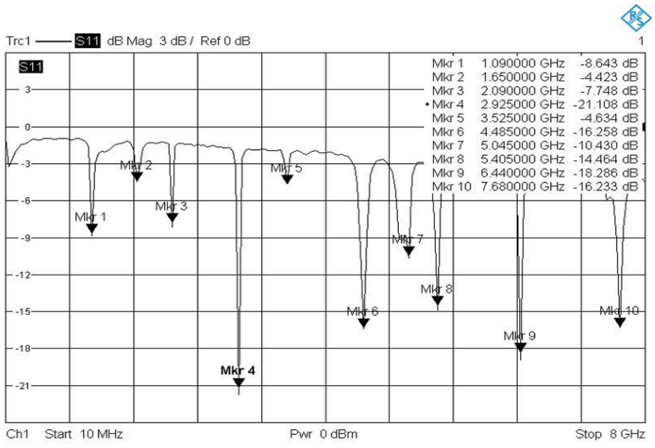


Fig 4: Four Iterative Circular Shaped Fractal Microstrip Antenna

The result shows the multiple resonant frequencies because of self similar properties of fractal in circular fractal antenna. The multiple resonant frequencies are observed on 1.08GHz, 1.66GHz, 2.91GHz, and 4.36 GHz as shown in Fig. 4. The fourth iterative fractal antenna has also been fabricated and tested. Figure 5 shows the experimental results i.e. return loss versus frequency of designed four iterative circular shaped fractal antenna. This experimental result shows multiple resonances at 1.09 GHz, 1.65 GHz, 2.92 GHz, and 4.485 GHz respectively. This reveals that the simulated and experimental resonant frequencies are in good agreement. The first experimental resonant frequency is shifted to 1.09 GHz in comparison to the first resonant frequency of simple circular microstrip patch. This indicates the size reduction of antenna by the incorporation of fractal geometry. The gain of the simple patch is shown in Figure 6.



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 Mkr 1   1.090000 GHz   -8.643 dB
 Mkr 2   1.650000 GHz   -4.423 dB
 Mkr 3   2.090000 GHz   -7.748 dB
•Mkr 4   2.925000 GHz  -21.108 dB
 Mkr 5   3.525000 GHz   -4.634 dB
 Mkr 6   4.485000 GHz  -16.258 dB
 Mkr 7   5.045000 GHz  -10.430 dB
 Mkr 8   5.405000 GHz  -14.464 dB
 Mkr 9   6.440000 GHz  -18.286 dB
 Mkr 10  7.680000 GHz  -16.233 dB
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Fig 5: Experimental Return loss of Four Iterative Circular Shaped Fractal Microstrip Antenna

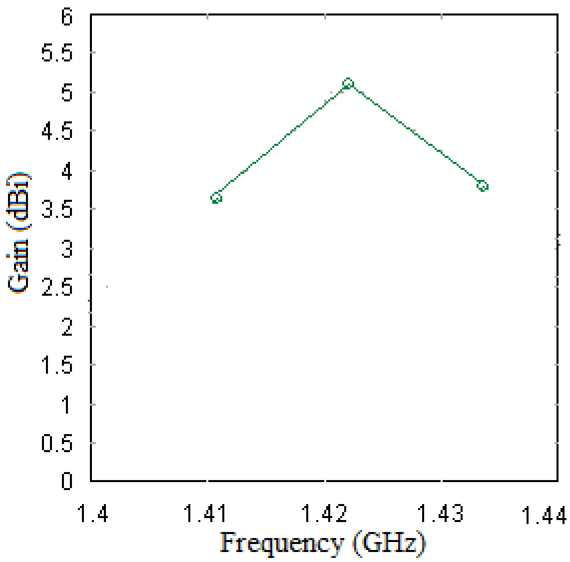

Fig 6: Simulated gain of Simple circular patch

5. RADIATION PATTERN

The simulated radiation patterns of simple patch in H- and E-plane are shown in shown in Figure 7 and Figure 8. The radiation pattern has also been measured in the in-house anechoic chamber by using antenna measurement system. The radiation patterns have been measured at selective frequencies 3.25GHz and 5.34GHz. The H-plane radiation pattern are shown in Figure 9 and Figure 10. The gain of this antenna is less than 5 dBi as shown in Figure 11. The cross polarization of antenna has also been measured. As the frequency increases the cross polarization of the antenna reduces. But at the lower frequency cross polarization is -14 dB. The cross polarization of antenna at frequencies 0.995 GHz and 5.78 GHz are shown in Figure 12 and Figure 13 respectively.

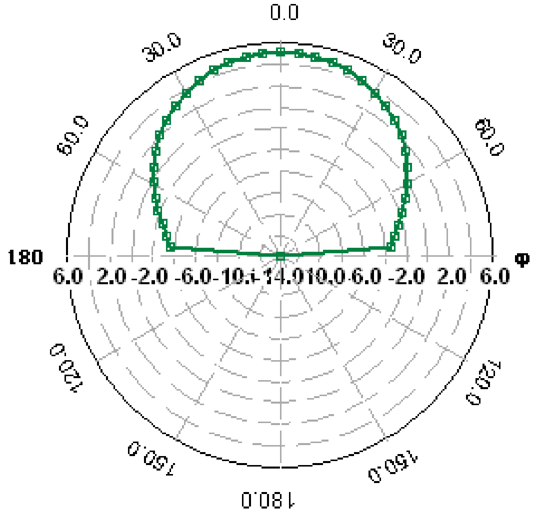

Fig 7: Radiation pattern of simple patch at 1.42 GHz in elevation Plane

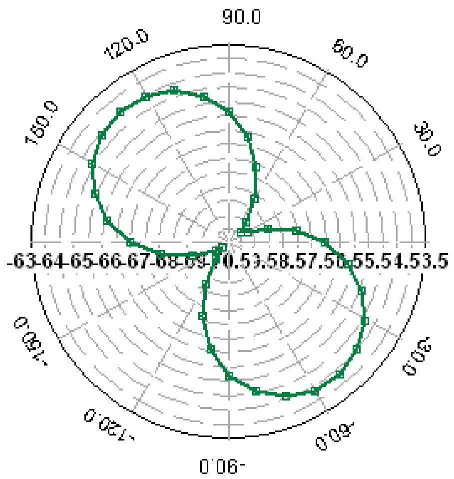

Fig 8: Radiation pattern of simple patch at 1.42 GHz in elevation Plane

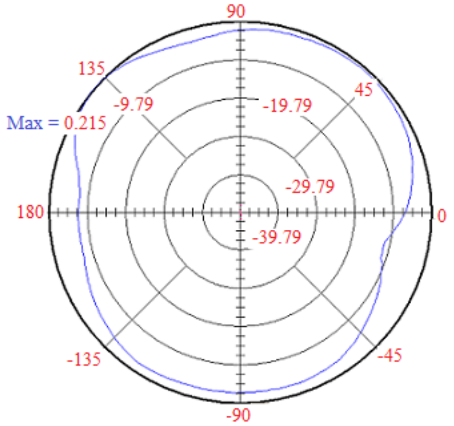

Fig 9: Experimental Radiation Pattern of Fractal Antenna at frequency 3.25GHz in azimuth plane

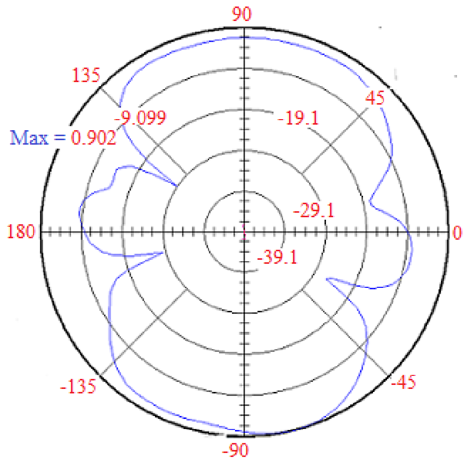

Fig 10: Experimental Radiation Pattern of Fractal Antenna at frequency 5.34GHz in azimuth plane

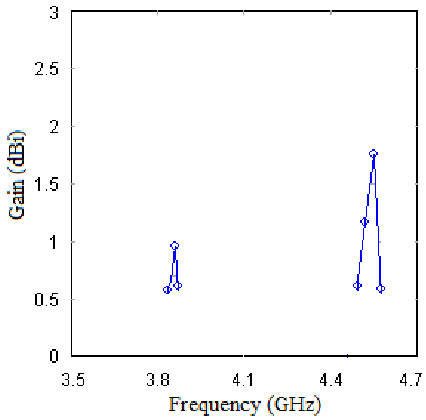

Fig 11: Simulated gain of multiband antenna at two frequencies

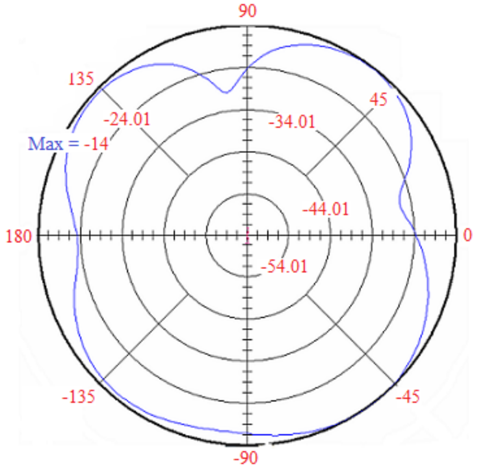

Fig 12: Cross Polarization of Fractal Antenna at frequency 0.995 GHz

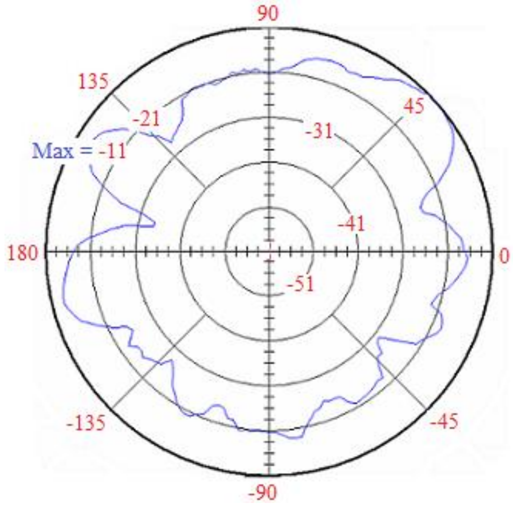

Fig 13: Cross Polarization of Fractal Antenna at frequency at 5.78 GHz

6. BACKSCATTERING RCS OF FRACTAL ANTENNA

The backscattering RCS of an antenna is very important for defence environment. This new fourth iterative antenna has been studied for low RCS. The backscattering RCS of the fractal antenna has been calculated using [11] for vertical-vertical (VV ; incident and scattered wave both are vertically polarized) as well as horizontal – horizontal (HH; incident and scattered wave both are horizontally polarized) polarization from -90^0 to $+90^0$ aspect angle at 1 GHz frequency with respect to iterations as shown in Figure 14 and Figure 15 respectively. It clearly evidence from the Figure 14 that as the iteration increases the backscattering RCS decreases. The four iterative fractal antenna exhibits the maximum backscattering RCS reduction.

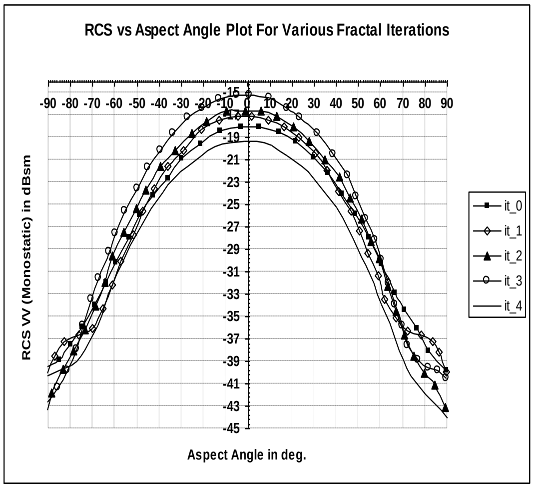

Fig 14: Backscattering RCS of fourth iterative Fractal Antenna

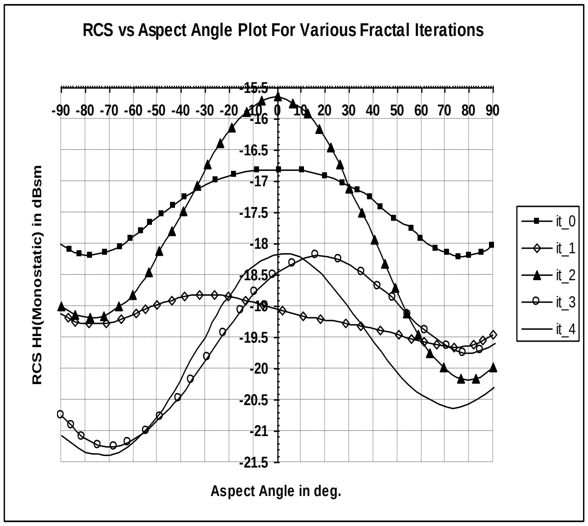

Fig 15: Backscattering RCS of four iterative Fractal Antenna

The monostatic backscattering RCS for fourth iterative inscribed square circular fractal antenna versus aspect angle has been calculated with respect to substrate thickness at 1 GHz for substrate dielectric constant $\epsilon_r = 2.2$ as shown in Figure 16. The monostatic backscattering RCS varies as the thickness of substrate varies. The monostatic backscattering RCS has been calculated for the thickness of substrate 1mm, 3mm, 5mm, 7mm and 9mm. It is clear from the Figure 16 that backscattering reduction is more around thickness 1 mm of the substrate. Figure 17, the backscattering reduction for substrate thickness 1mm, 3mm, 5mm, 7mm and 9mm for horizontal polarization. Figure 18 shows bistatic backscattering reduction for various thicknesses of substrate for veridical polarization. This backscattering reduction of antenna is useful for Electronic Warfare applications.

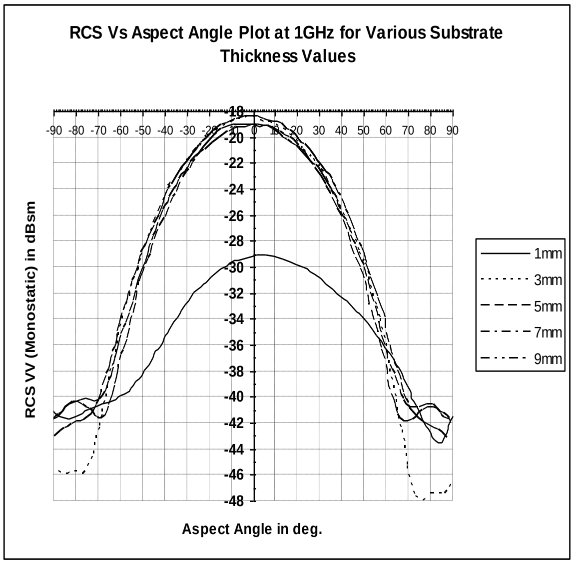

Fig 16: Backscattering RCS of fourth iterative Fractal iterative Fractal dielectric constant ϵr = 2.2

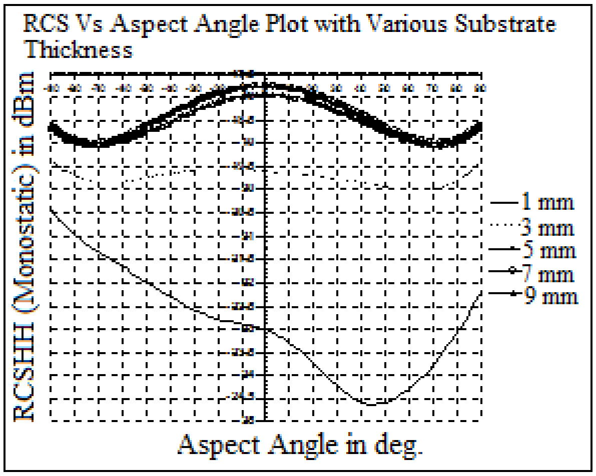

Fig 17: Backscattering RCS of fourth iterative Fractal iterative Fractal dielectric constant $\epsilon_r = 2.2$

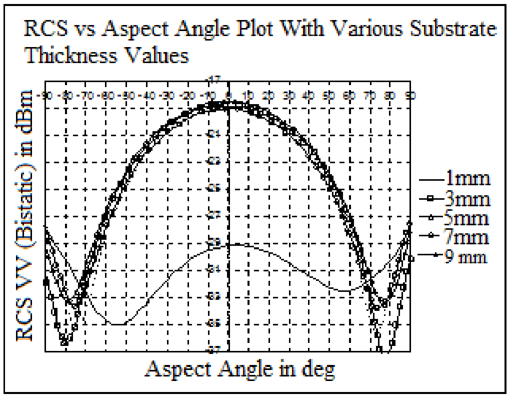

Fig 18: Backscattering RCS of fourth iterative Fractal iterative Fractal dielectric constant $\epsilon_r = 2.2$

Figure 19 shows the backscattering RCS of the fractal antenna for monostatic as well as bistatic with respect to frequency. Figure 20 shows the bistatic backscattering reduction versus frequency for various thickness of the substrate. The backscattering reduction is better for the substrate approaching 1mm. The backscattering RCS has been calculated using simulator based on MOM method [8]. This backscattering reduction of antenna is useful for Electronic Warfare applications

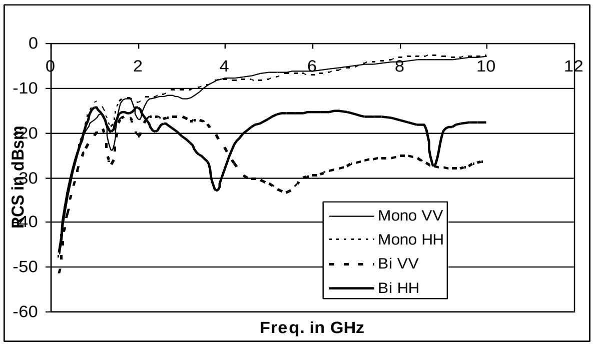

Fig 19: Backscattering Monostatic and Bistatic RCS (dBm) of proposed antenna

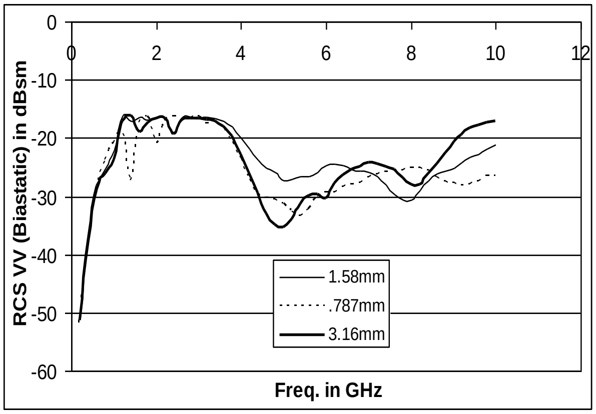

Fig 20: Backscattering RCS of fourth iterative Fractal Antenna at various thickness of substrate

7. CONCLUSIONS

The new coaxially feed circular fractal microstrip antenna has been studied. This antenna provides size reduction in comparison to the conventional microstrip antenna of same size. The circular microstrip fractal antenna has been simulated using 3D electromagnetic software Concerto based on FDTD and MoM method. This fractal antenna resonants at multi-band frequencies. This fractal structure provides the four resonances, are equal to the number of iterations. The simulated and experimental resonant frequencies of antenna are observed in good agreement. The four iterative fractal antenna is found suitable for low RCS in comparison to other iterative fractal antenna and conventional microstrip antenna. This antenna has been designed for less backscattering power which has a great potential in military applications. This circular shaped fractal antenna has the privilege of size reduction, multi band, circular polarization, and useful for military applications where RCS of antenna is an important parameter. This antenna is useful for wireless communication and easily integrable with MIC/MMIC

8. ACKNOWLEDGEMENTS

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