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# Design of inscribed circle Apollo UWB fractal antenna with modified groundplane

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**Abstract**

In this paper, we have achieved two ultra wideband antennas by applying fractal geometry with co-planar waveguide (CPW) feeding technique. These antennasare designed on dielectric substrate εr= 4.3 and thickness h = 1.53 mm. The return loss of first antenna design is achieved a good input impedance matching throughout the pass band from 2.5 GHz to 11GHz. The second antenna offers the impedance matching from frequency range 2.1GHz to 12GHz. The proposed antennas can provide an impedance bandwidth more than100% at VSWR<2. Second antenna helps to increase impedance bandwidth by reducing the ground plane. The simulated radiation pattern of antenna is nearly omni-directional. Such type of antenna can be useful for mobile and wireless communication.

**Keywords:** Microstrip antenna, monopole antenna, CPW-feed and UWB antenna.

## Introduction

Ultra-Wideband (UWB) commonly refers to signal or system that either has a large relative bandwidth (BW) or a large absolute bandwidth (Aiello &Rogerson, 2003; Schantz, 2005; Allen, 2007). Existing single band, dual band and multi-band antennas are simple than some UWB antennas (Liang*et al.,* 2004). Antenna structures are classified into three types planar, non planar and co-planar, most of the UWB monopole antennas are non-planar as in (Hammoud*et al.,* 1993; Ray, 2008). Because of their protruded structure, it is difficult to integrate them with integrated circuits like MMIC/MICs.

The antenna is an important element of UWB system. The antenna should have properties like the small size, conformal, low cost, and ease of fabrication. Microstrip antenna fulfills all these requirements. The microstrip antenna is an efficient radiator around half wavelength long. As the size of the antennabecomes less than λ/2, the radiation resistance,gain and bandwidth of the antennas deteriorate. But the limitations of the conventional microstrip antenna are its narrow bandwidth and efficiency (Bahl & Bhartia, 1981; Garg, 2001). Fractal geometry is a very goodsolution for this problem (Liang *et al.,* 2004). The term fractal, which means broken or irregular fragments, was originally coined by Mandelbrot (Mandelbrot, 1983) to describe a family of complex shapes that possess an inherent self-similarity or self affinity in their geometrical structure. In the recent years, geometrical properties of self-similarity and space filling nature has motivated antenna research to meet the target of multi-band , wideband and miniaturization.

This paper presents UWB fractal antenna. The new printed-circuit antenna in coplanar technology (Min Ding *et al.,* 2007) offers excellent ultra wide bandwidth with compact size. The radiation pattern of antenna is nearly omni-directional. This antenna can be useful for UWB applications, microwave imaging and radar applications.

## Basic antenna geometry

To make the structure of Apollo fractal antenna, first three circles of diameter 75mm are arranged in such a way that all the three circles are touch each other as shown in Fig. 1.

Fractal with iteration wise has been constructed from the initial geometry. This initial geometry is fed with CPW-feed as shown in Fig. 2a. In first iteration, one circle of diameter 9.5mm has been subtracted from Apollo shaped initial geometry as shown in Fig. 2b.(Fig. 2)

In 2nd iteration, three circles of 2.4 mm are subtracted from three ends of the monopole. Six circles of diameter 1.6mm have been group of two circles are just place

*Fig. 1. Geometrical base of Apollo monopole antenna-1 and antenna-2*

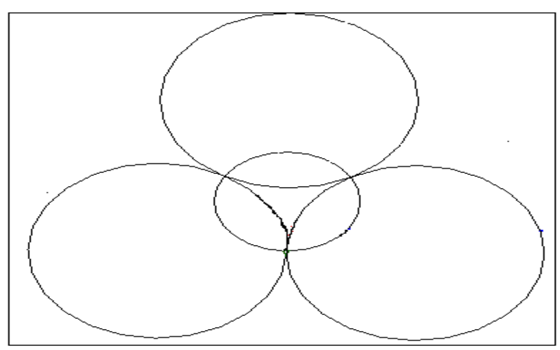
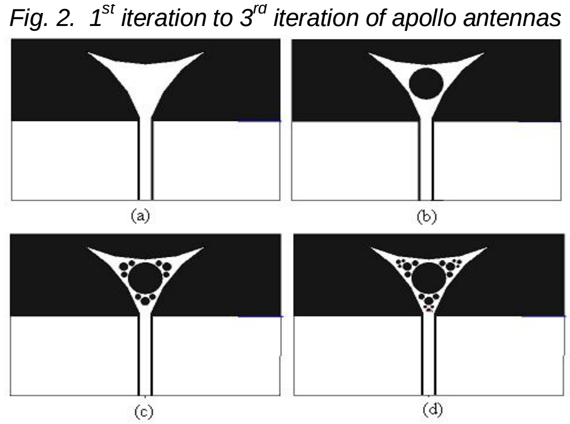


*Fig. 2. 1st iteration to 3rd iteration of apollo antennas*

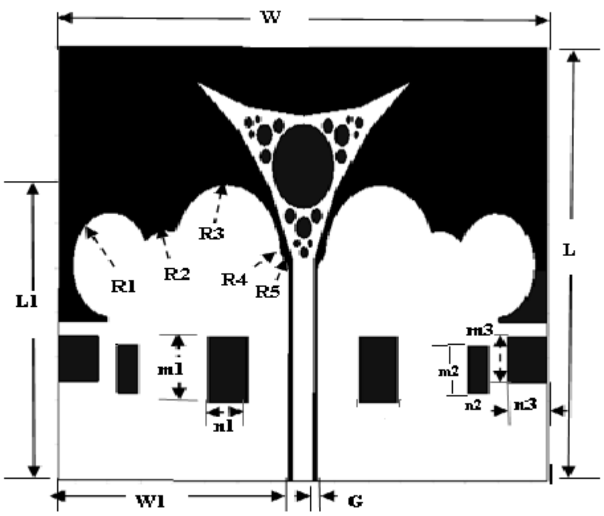


below the circle of 2.4 mm at each end of monopole antenna and subtracted as shown in Fig. 2c. Then in 3rd iteration three circles of diameter 1.2mm has been taken and each circle is placed just above the circle of diameter of 2.4mm at each end of monopole antenna. Then eight circles of diameter 0.8mm are placed just below the circle of diameter 1.2 mm at each end of monopole antenna. 3rd iteration is shown in Fig. 2d.

**Geometry of antenna -1**

Coplanar (CPW) feeding technique is used in this antenna which is parallel to ground planes. By adjusting the gap between ground plane and stripline, 50 ohm impedance can be achieved. The proposed fractal antenna have been designed on the substrate $\varepsilon_r$ =4.3 and thickness = 1.53 mm. The substrate size of the antenna has been taken as 49 mm x 75 mm. The antenna has been designed.Fig.3

*Fig. 3. Proposed antenna-1 with optimized dimensions*




The current distribution calculated at 2.4 GHz, 3.5 GHz, 5.0 GHz, 8.0 GHz and 11.1 GHzfrequencies are shown in Fig. 4. The current distribution is along the edges of radiating patch at lower frequency. This decides the first resonant frequency of antenna. At 3.5 GHz, the current distribution showed one minima on feed line which corresponds to the resonance mode in the return loss results. Similarly, at 11.1 GHz, three minima at feed line correspond to three resonance mode in return loss graph. It is observed that current distribution is along the width of ground plane. This indicates width of ground plane and any modification along the width of ground plane will effectively affect the impedance matching throughout the band. The current is also more on feed line and ground near the feed line, it indicates that gap between feed and ground is also important for impedance matching to achieve the wider bandwidth.

**Simulated and discussion of antenna - 1**

*Fig. 4. Current distribution at 3.5GHz, 5.0 GHz, 8.0 GHz and 11.1 GHz frequencies*

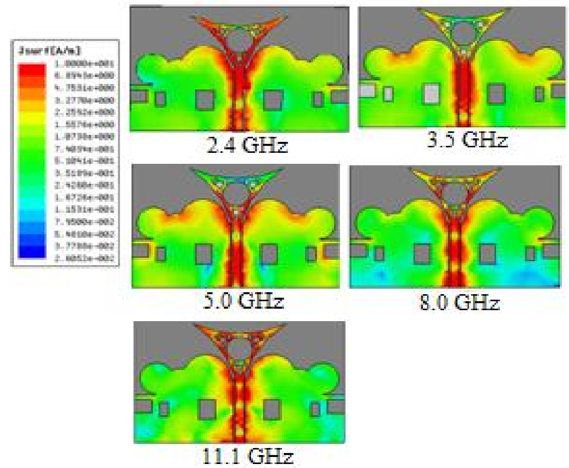
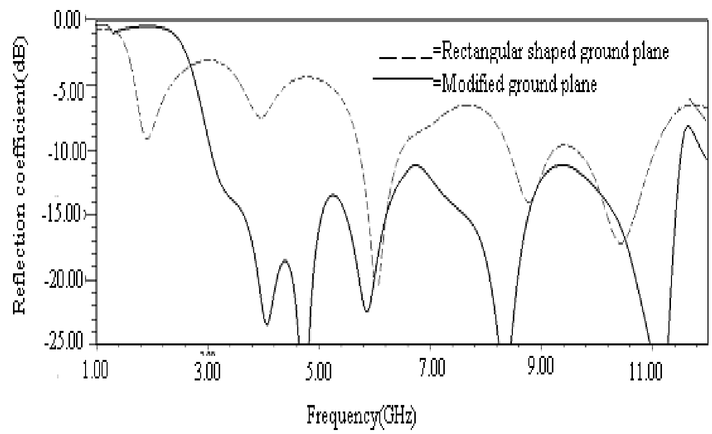



*Fig. 5.Simulated result of antenna -1 with and without modified ground*




*Modified ground plane with curves*

Initially, the monopole fractal antenna is simulated with the simple rectangular ground plane. The ground plane length and width are taken to be 35.39 mm x 24.0 mm. But with this rectangular ground plane required UWB impedance bandwidth has not achieved. Return loss is not less than -10dB throughout the band with rectangular shaped ground plane as shown in Fig. 5.A parametric study and some modification of ground is required to achieve the impedance bandwidth throughout the band.

Reflection coefficient below -10 dB helps to improve antenna performance. By adding curves in ground plane, it is observed that return loss at higher frequency increases. And different slots in ground plane increase the impedance bandwidth. The simulated result of fractal antenna exhibits ultra wideband characteristics in the frequency range from 2.5 to 11.0 GHz as shown in Fig. 5. The VSWR is shown in Fig.6.

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*Fig. 6. Simulated VSWR of proposed antenna-1*

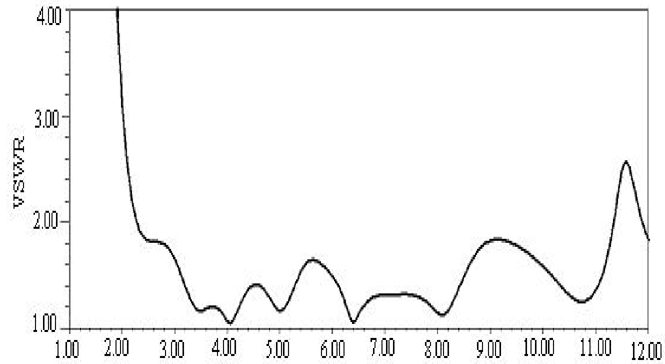



*Fig. 7. Optimization of gap between ground plane and feed of Apollo antenna-1*

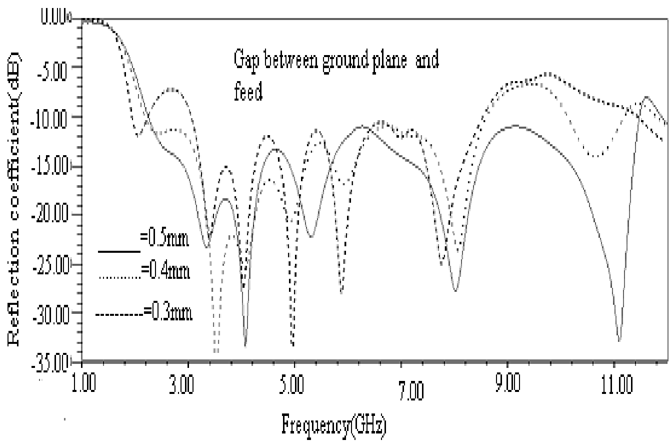



*Fig. 8. Optimization of ground plane width of apollo monopole antenna - 1*

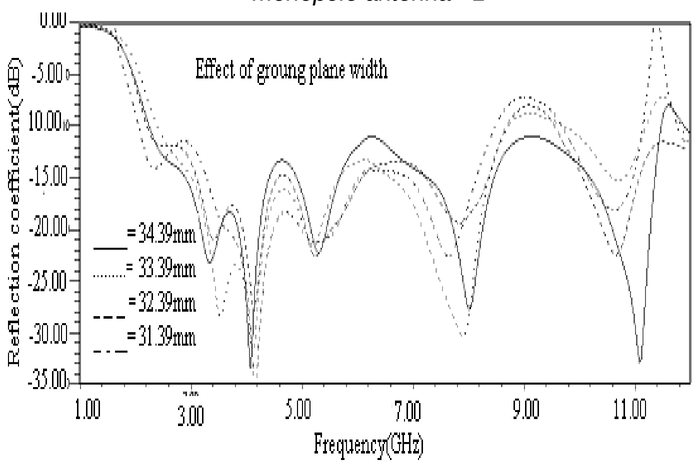
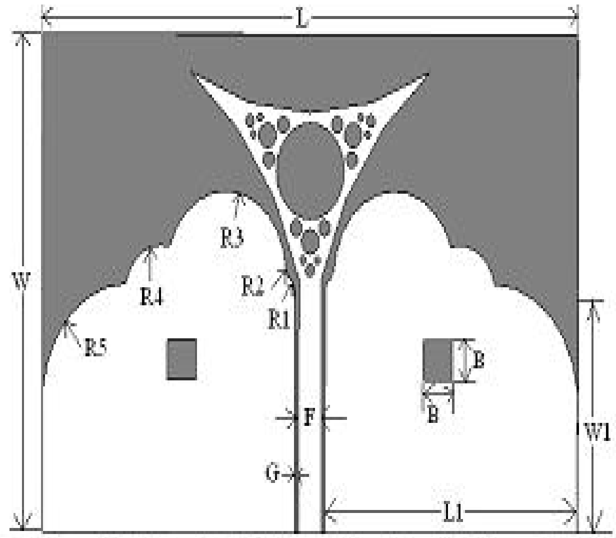



*Fig. 9. Proposed antenna-2 with optimized dimensions*




L=75mm, W=49mm, L1=35.39mm, W1=24mm,F=3.2mm, G=0.5mm, B=4mm, R1=1.0592mm, R2=0.6mm, R3=8.5mm,R4=5mm, R5=12mm

*Fig. 10. Simulated return loss of the antenna-2*

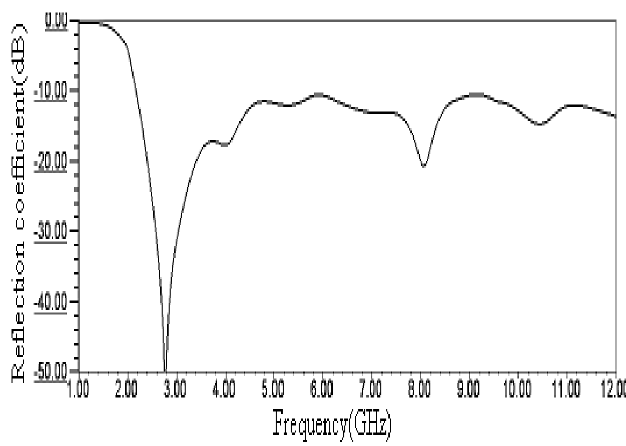
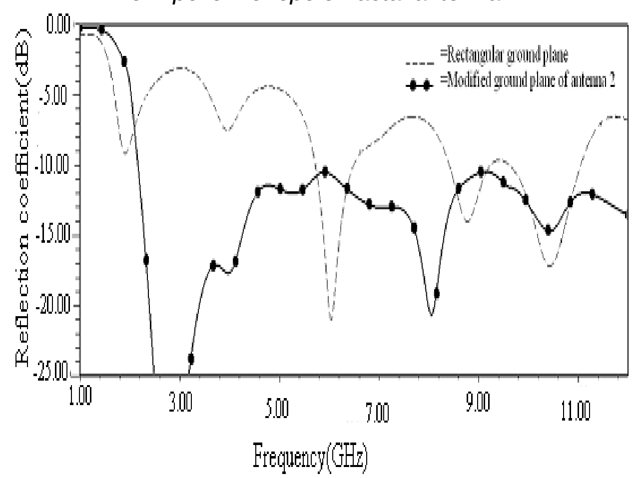



*Fig. 11. Simulated result of modified ground plane of Apollo monopole fractal antenna -2*




*Effect of ground plane length*

The ground plane length is varied in steps of 1 mm from 21 mm to 24 mm. As the length of the ground plane increases, the return loss curve is shifted to the lower frequency side. From the Fig. 7, it is observed that better performance is achieved at 24mm throughout the band.

*Effect of gap between feed and ground plane*

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*Fig.12. Simulated return loss of antenna-1 and antenna-2*

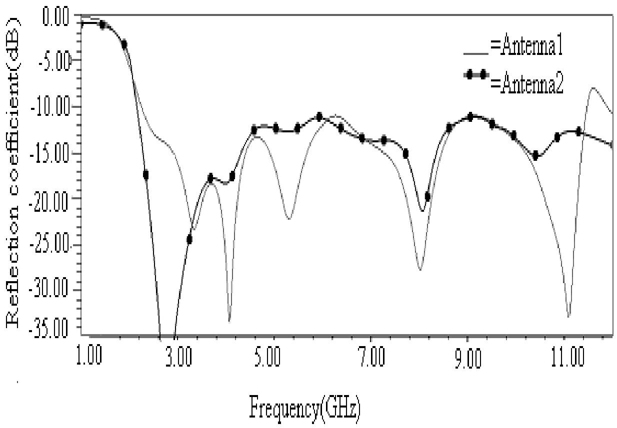
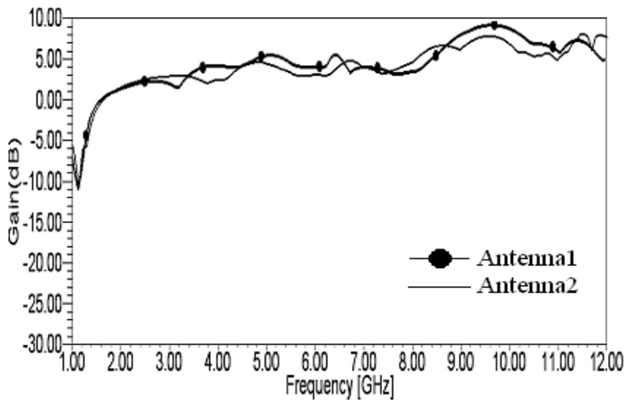



*Fig. 13.Simulated peak gain of antenna -1 and antenna -2*




The gap between feed and ground and the width of the feed are the deciding parameters of impedance matching, the gap between feed and ground is selected so as to support best matching for the 50 ohm line. Separation of feed and ground is optimized from 0.3mm to 0.5mm to achieve better impedance matching. It is observe from Fig.8, 0.5mm gap between feed and ground

*Fig. 14. Simulated radiation efficiency of antenna -1 and antenna -2*

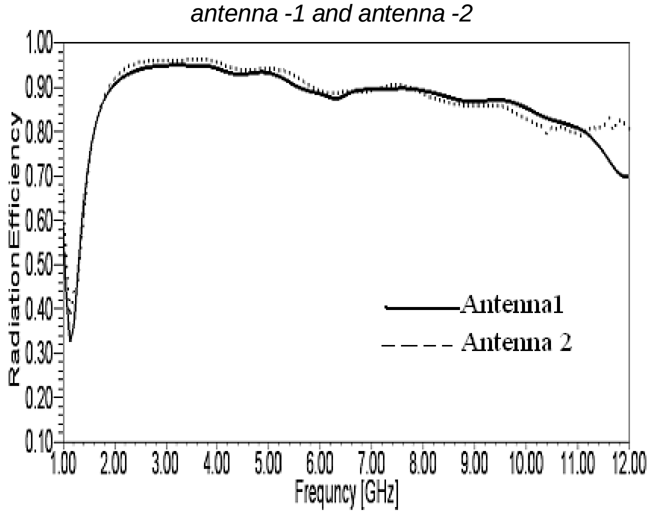
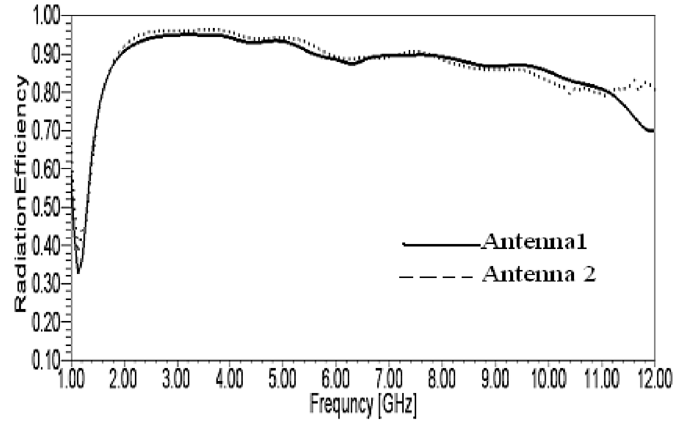



*Fig. 14. Simulated radiation efficiency of antenna -1 and antenna -2*




plane provides good impedance matching and helps to cover UWB bandwidth.

*Effect of ground plane width*

The ground plane width is varied from 34.39 mm to 31.39 mm by the step of 1 mm. As the width of the ground plane increases, the return loss curve is shifted to lower frequency side. It is because current distribution is along width of ground plane. As width increase and decrease, the current distribution increases and decreases which in term effect the shifting the resonance mode. From the Fig.9, it is observed that better performance is achieved at 34.39 mm width of ground plane throughout the band.

**Geometry of antenna -2**

Fig. 10.Shows the schematic representation of the same antenna but with a further partially modified ground plane. Antenna - 2 have been designed on the substrate $\varepsilon_r$=4.3 and thickness of antenna h=1.53mm. Antenna - 2 is designed on substrate of 49mm x 75mm.This antenna helps to achieve maximum bandwidth 138% by adding curvatures in the ground plane. Return loss of the antenna - 2 is less than -10dB which shows good impedance matching throughout the band from 2.1 to 12GHz as show in Fig. 11.

*Modified ground plane structure for antenna - 2*

Fig. 12 shows the return loss of antenna -2. The return loss has been improved at higher frequencies by adding curves in partial ground plane structure of an antenna-2 in comparison to antenna -1. Modified partial ground plane helps to improve the performance of the antenna -1 as shown in Fig. 11 throughout the band.

Antenna -1 and antenna -22 has same the fractal patch shape but the difference is in their partial ground structure. In Antenna -2 ground plane shape is reduced by side curve. These side curves affects at higher frequencies of antenna-2 as shown in Fig. 13.

*Simulated peak gain and radiation efficiency*

The antenna -1 and antenna -2 have been simulated for peak gain and radiation efficiency of antenna. The peak gain of antenna -1 and antenna -2 is shown in Fig. 14 The peak gain of antenna -2 is more flatter than antenna-1 particularly at higher frequency. It is also

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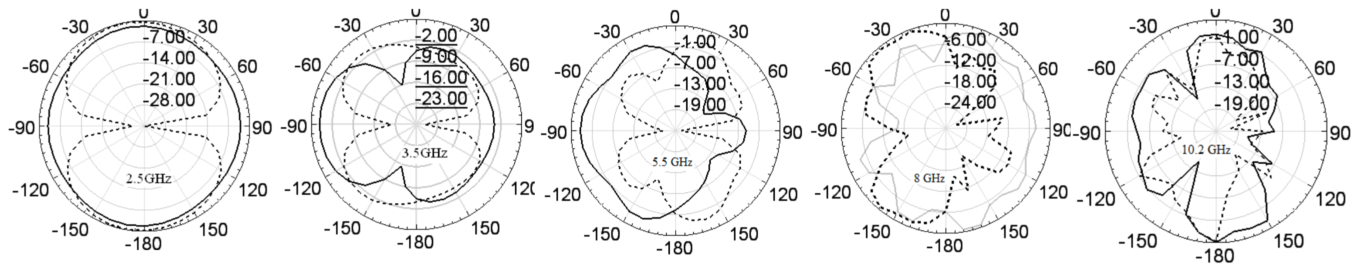
*Fig.15. Simulated radiation pattern at frequencies 2.5 GHz, 3.5 GHz,5.5 GHz, 8.0 GHz and10.2 GHz of antenna-1*




observed as frequency increases the peak gain increases. This is because at high frequency the effective receiving area of antenna increases and wavelength becomes shorter. The radiation efficiency of antenna -1 and antenna -2 is also shown in Fig. 15. The radiation efficiency of both the antenna-1 and antenna -2 decreases as frequency increases. This because of lossy dielectric material used with higher loss tangent. The radiation efficiency at 3 GHz of antenna -1 and antenna -2 is 94% and 96% respectively. Similarly, radiation efficiency at 12 GHz of antenna -1 and antenna -2 is 70% and 82% respectively. It means radiation efficiency of antenna-2 is better than antenna -1.

**Radiation pattern of antenna-1**

The radiation pattern of antenna -1 has been simulated at various frequencies in E and H plane. The radiation patterns in E -and H-plane are shown in Fig. 15 at frequencies 2.5 GHz, 3.5 GHz, 5.5 GHz, 8.0 GHz and 10.2 GHz. The radiation pattern is obtained at different frequencies under ideal feed conditions. At lower frequencies omni-directional nature of the structure is evident. The simulated radiation pattern clearly indicates that the proposed antenna-1 exhibits omni-directional behavior in H-plane and bidirectional in E-plane. The simulated H-plane and E-plane radiation patterns at higher frequency are slightly distorted that may be due to the variations in dielectric constant, substrate thickness, loss tangent and fractal nature.

**Conclusions**

Apollo fractal antennas with CPW-fed antenna that offers larger bandwidth has been investigated. The simulated bandwidth of the proposed antenna-1 is from 2.5 to 11GHz (113%) for VSWR <2, and bandwidth of antenna-12 is from 2.2 to 12GHz, which covers the commercial UWB band approved by the FCC. Radiation patterns of these antennas are omni-directional in the H-plane and bidirectional in E-plane. These properties of the antennas make it a suitable candidate for modern UWB applications. These antennas are compact, light weight, low cost, simple to fabrication and easy to integrate with MIC/MMIC devices. This antenna may be useful in applications like precision positioning systems, ground penetrating radar and vehicular radar and medical imaging.

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