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Broad and Dualband Sierpiniski Gasket Double Sided Printed Dipole Antennas

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ABSTRACT

A Double Sided Printed Dipole Antenna (DSPDA) consists of two radiating arms printed on opposite sides of a dielectric. However, in place of rectangular shaped arms, triangular shape is used in to increase Return Loss (RL)/impedance bandwidth. Flaring of arms helps in gradual transition of impedance and results in increased RL bandwidth. But maximum RL bandwidth reported so far is not sufficient for high speed data application like streaming video, real time navigation, medical imaging, broadband EMI measurement etc. Maximum 10dB RL bandwidth reported with flared arms is 51% [1] and a fat PDA with higher cross polar component 10dB RL bandwidth reported is 58% [2]. Several techniques such as complicated feed structure, use of BALUN, parasitic element etc. are used to increase the RL bandwidth. But their design and fabrication are more complicated. A novel but simple designs of PDA with fractal shaped arms (Sierpiniski Gasket) are reported with 10dB RL bandwidth as high as 76% with the centre frequency of 4.2GHz. Multiband behavior of PDA has been reported by many workers [3-17]. But the impedance bandwidth obtained in each band is very small. Here we propose a novel dual band DSPDA with significantly higher bandwidth of 20% and 39% around the centre frequencies of 1.5GHz and 3.9 GHz.

Keywords: Broadband, Dual band, Printed Dipole Antenna, Sierpiniski Gasket

1. Introduction

Two radiating arms known as active and ground radial of DSPDA are printed on opposite sides of a substrate. DSPDA with rectangular shaped arms yield lower RL bandwidth compared to triangular shaped arms. DSPDA having rectangular shaped arms was reported by Y.D. Lin et al with 20% of RL bandwidth [18]. R.P.Ghosh et al. reported a DSPDA with rectangular shaped radials and using shaped ground plane, a RL bandwidth as high as 41% [1]. A fat PDA of RL bandwidth 58% is reported by Theodore .G. et. al [19]. But the arm width was significantly wider which resulted in transverse component. As a result, discrimination between co and cross polar component in the radiation pattern must was lessen. Though the reporter has not reported of such discrimination. To increase the RL bandwidth many attempts were made such as flaring of arms, use of parasitic patches, use of DSPDA in array environment, designing complicated feed structures with integrated balun [20-26]. A T-shaped printed dipole with an adjustable integrated balun in feed structure is reported to show 10dB RL bandwidth of 41% [20].With a double-layered printed dipole, maximum -10dB Return Loss (RL) band width reported is ~50% in S-band [27]. Technique of flaring angle of radials was used to increase the bandwidth up to 51% with the centre frequency at 1GHz [1].

By introducing parasitic elements close proximity to the radiating arms, increased RL bandwidth from 39%to 56% is reported by Evtioushkine et al [28]. In a proposed ‘Quasi –Yagi’ configuration, coplanar parasitic element has been used and RL bandwidth of 48% is reported [29]. Stacked parasitic elements are also used to increase bandwidth but its fabrication is relatively complicated and expensive.

Multiband DSPDA is reported by many workers [3-17] and frequency of operation is restricted to either two or three. But the RL bandwidth obtained in both bands are small.

Novel but simple design of DSPDA presented here. Arms are made Sierpiniski Gasket shaped fractal. Two antennas have been designed. Antenna-1 is first iterated Sierpiniski Gasket DSPDA with arms flared at 30^0. In Antenna-2, smallest triangular elements of Antenna-1 are judicially shorted. This results in a dual band antenna with significantly higher bandwidth in both the bands. In each antenna common area between active and ground radial is adjusted to optimize bandwidth. In the ground radial a triangular shaped ground plane which is connected near the common is also adjusted to optimize bandwidth. Antenna -1 yields RL bandwidth of 76% around the central frequency of 4.2GHz. The dual band antenna (Antenna-2) provides impedance bandwidth of 20% and 39% around the centre frequency of 1.5GHz and 3.9 GHz.

2. Design procedure

Sierpiniski Gasket geometrical shape named after Polish mathematician Sierpiniski who described the properties of this fractal shape [30]. First iterated fractal shape is obtained by removing a central inverted triangle from the main triangle. After removal, three equally shaped triangle remains in the structure. The same procedure is followed for the subsequent iterations. Scale factor (ζ) of such antenna is given by

$$\zeta = h_n/h_{n+1} \qquad (1)$$

Where n is the iteration number and h is the height of the iterated gasket.

Antenna-1

Antenna-1 is first iterated Sierpiniski Gasket DSPDA. Both arms are made fractal. Flared angle is 30^0. In the ground radial a triangular shaped ground plane which is connected near the common is also adjusted to optimize bandwidth (Fig.- 1). Common area between active and ground radial is also adjusted to optimize the bandwidth. Antenna has been designed in four different lengths i.e. 40, 50 and 60mm and maximum bandwidth is obtained at 40mm.

Antenna-2

Antenna-2 is designed as the Antenna-1 but their smallest triangles are judicially shorted (Fig.-9). Dual band behavior with significantly higher bandwidth is obtained.

After the preliminary design using the approach described above all parameter have been optimized for broad banding performance using extensive computer simulation using Method of Moment based simulator IE3D [32] . Antennas with maximum RL bandwidth have been fabricated. The Antenna-1 has been fabricated and the experimental simulated results are in good agreement with simulated results.

3. Results

Antenna-1

Optimized dimensions used for simulation and fabrication of the broadband Antenna-1 are shown in Fig.-1(a) (Front view), Fig.-1(b) (Back view) and their photographs are presented inFig.-2(a) (Front View), Fig.-2(b) (Back View) respectively.

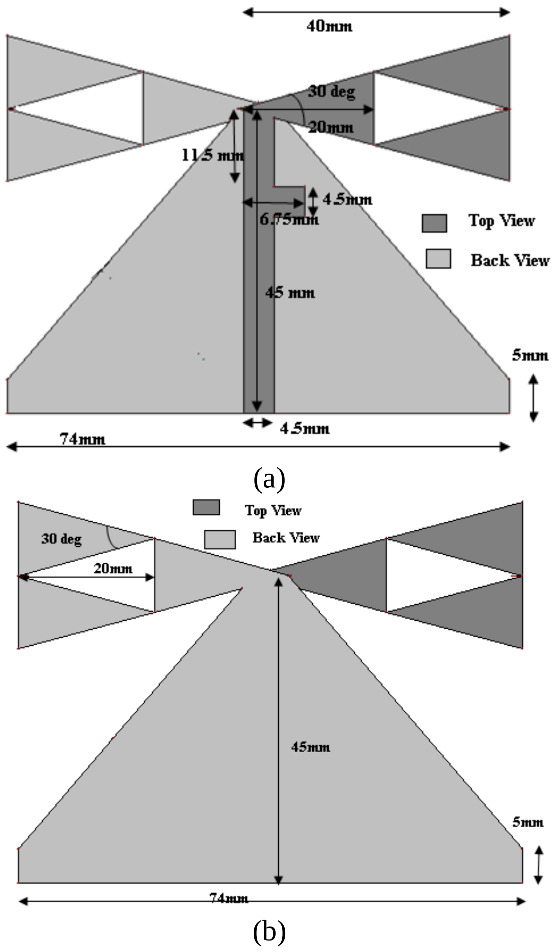
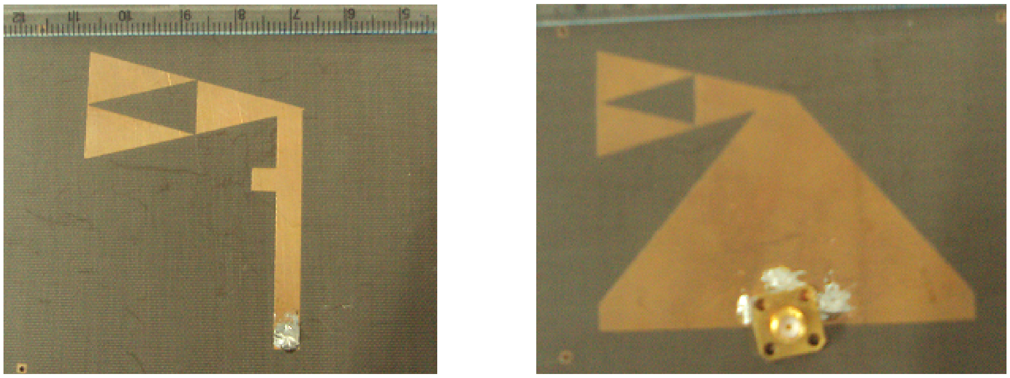


Figure 1: Structure and Optimized dimensions of Antenna-1.
(a) Front View (b) Back View



(a) (b)

Figure 2: Photographs of the fabricated Antenna-1.
(a)Front View (b) Back View

Simulated return loss plots for various lengths are shown in Fig.-3. Simulated and measured return loss plots of the fabricated Antenna-1 are shown in Fig.-4. The antenna provides impedance bandwidth of 76% with centre frequency at 4.2 GHz.

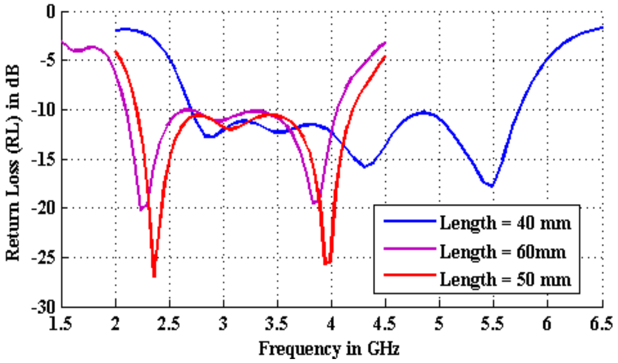


Figure 3: Simulated Return Loss plots for different lengths of Antenna-1

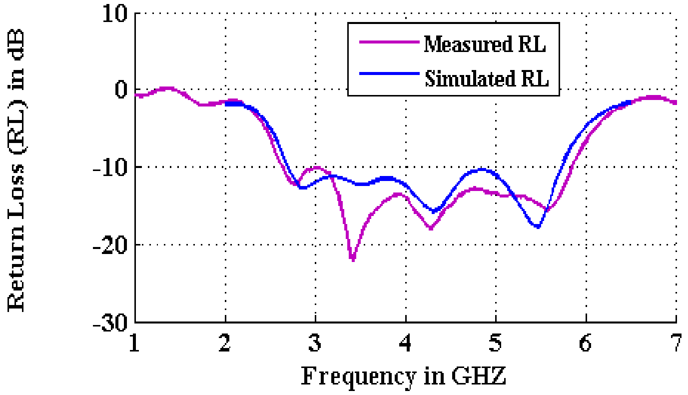
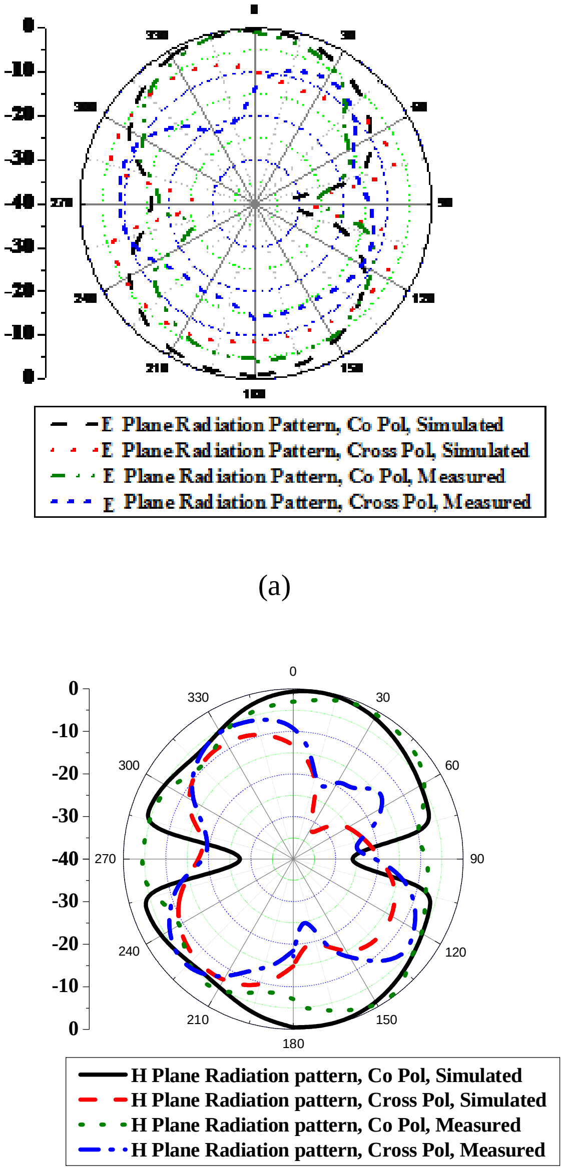


Figure 4: Simulated and measured Return Loss plots of Antenna-1.

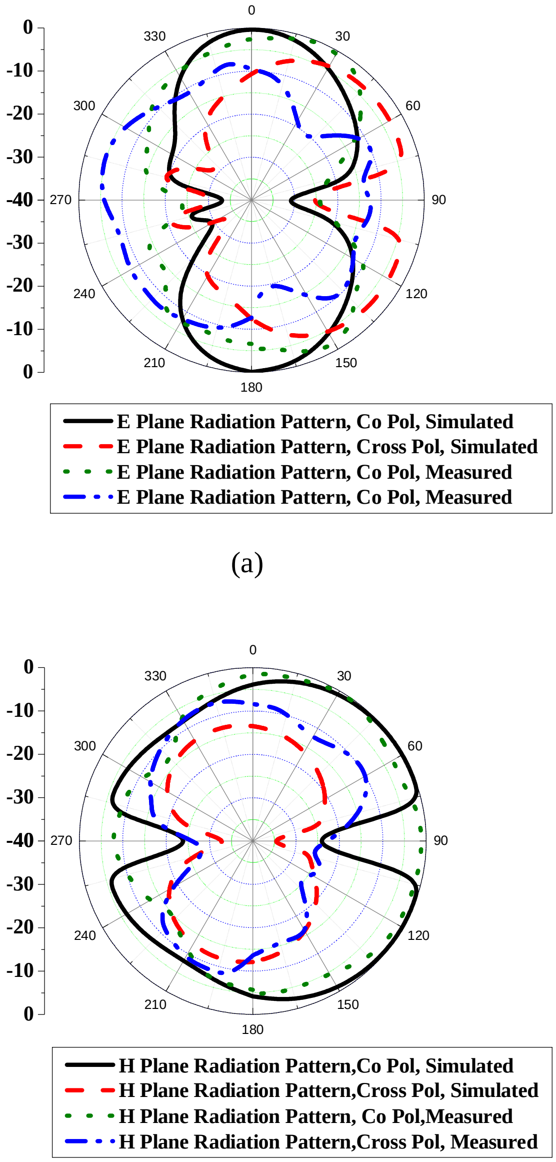
E and H plane normalized radiation patterns of the antenna at three different frequencies are shown in Figs. -5. 6 and 7.



(a)

(b)

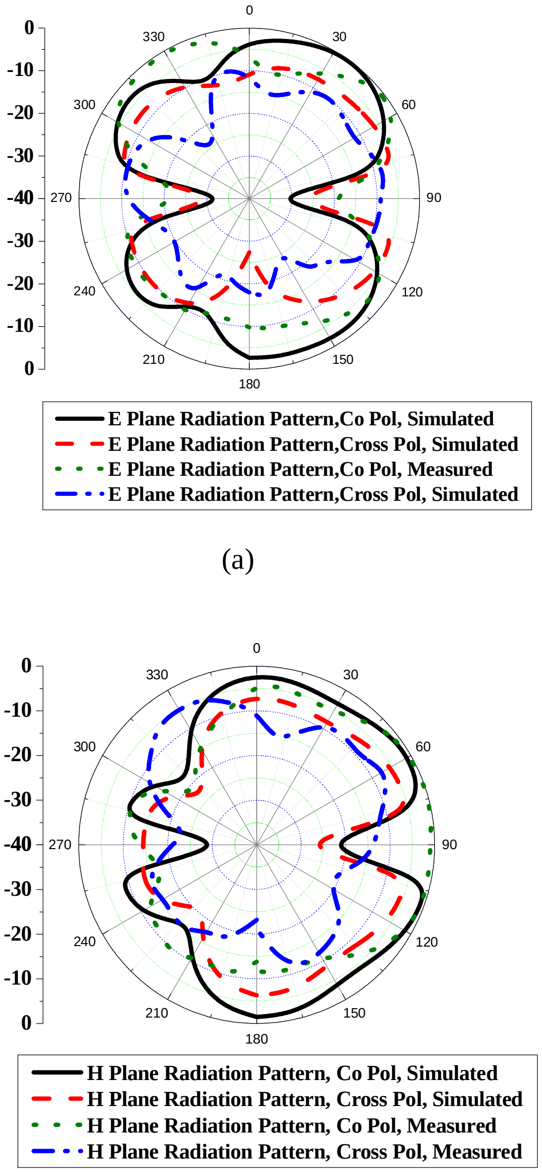
Figure 5: Radiation patterns at 2.70 GHz of Antenna-1
(a) E plane (b) H plane



(a)

(b)

Figure 6: Radiation patterns at 4.2 GHz of Antenna-1
(a) E plane (b) H plane



(a)

(b)

Figure 7: Radiation patterns at 5.73 GHz of Antenna-1.
(a) E plane (b) H plane

From the radiation patterns of Antenna-1 it is found that acceptable amount of 10dB cross polar discrimination is obtained. The gain versus frequency of the antenna is shown in Fig.-8.

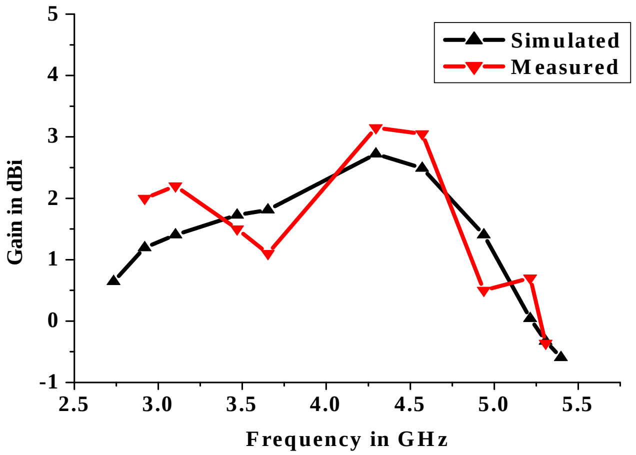
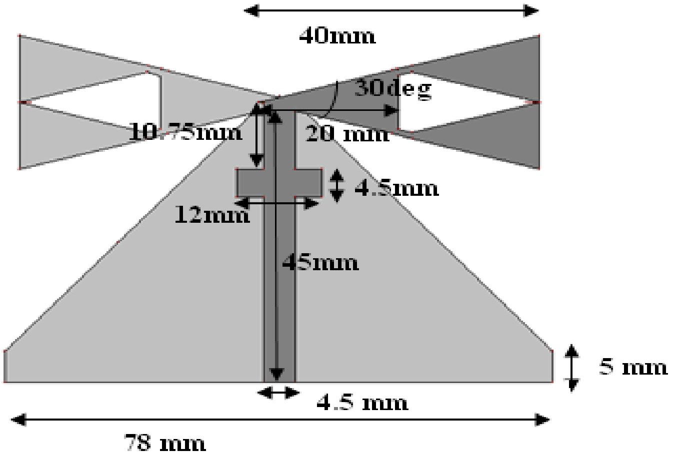


Figure 8: Gain versus frequency plots of Antenna-1.

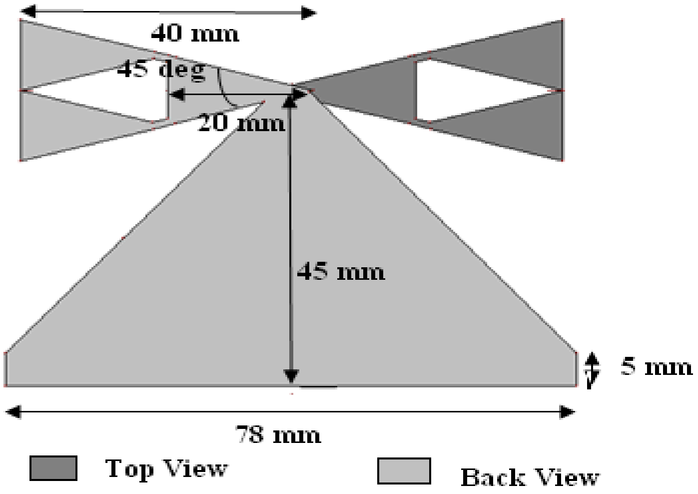
4. Antenna-2

A dual band DSPDA with significantly higher bandwidth at both the bands may be obtained by judicially shorting the smallest triangles. An extra band at lower frequency is excited by this shorting. Thus the antenna acts as a dual band one. The design technique is applied to Antenna-1 of which two smallest triangles are shorted as shown in Fig.-10. The common area between radials and the triangular shaped ground radial are adjusted to optimize the impedance bandwidth. Impedance bandwidth of 20% and 39% is obtained around centre frequencies of 1.5GHz and 4.8 GHz respectively. The impedance bandwidth in a single band is smaller compared to previously designed Antenna-1, but Antenna-2 is operating in dual band with the novelty of significantly large impedance bandwidth in both the bands.

Optimized dimensions used for simulation of the Antenna-2 are shown in Fig.-9.



(a)



(b)

Figure 9: Structure and dimensions of Antenna-2.
Top View (b) Back View

The simulated Return Loss plot of the Antenna-2 is shown in Fig.-10.

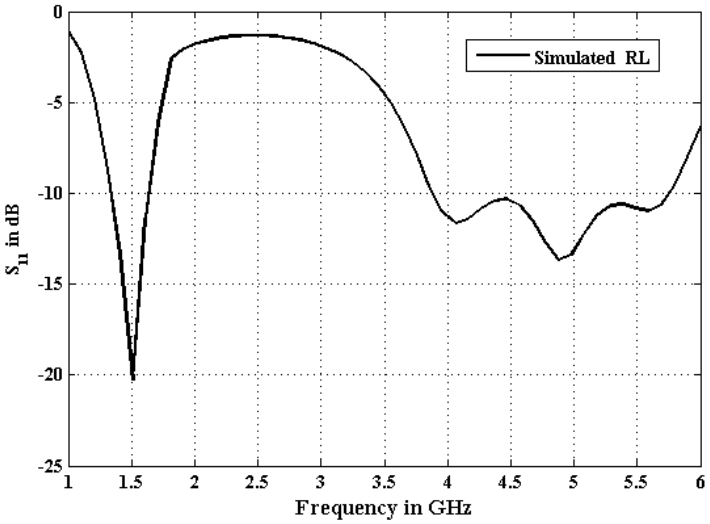
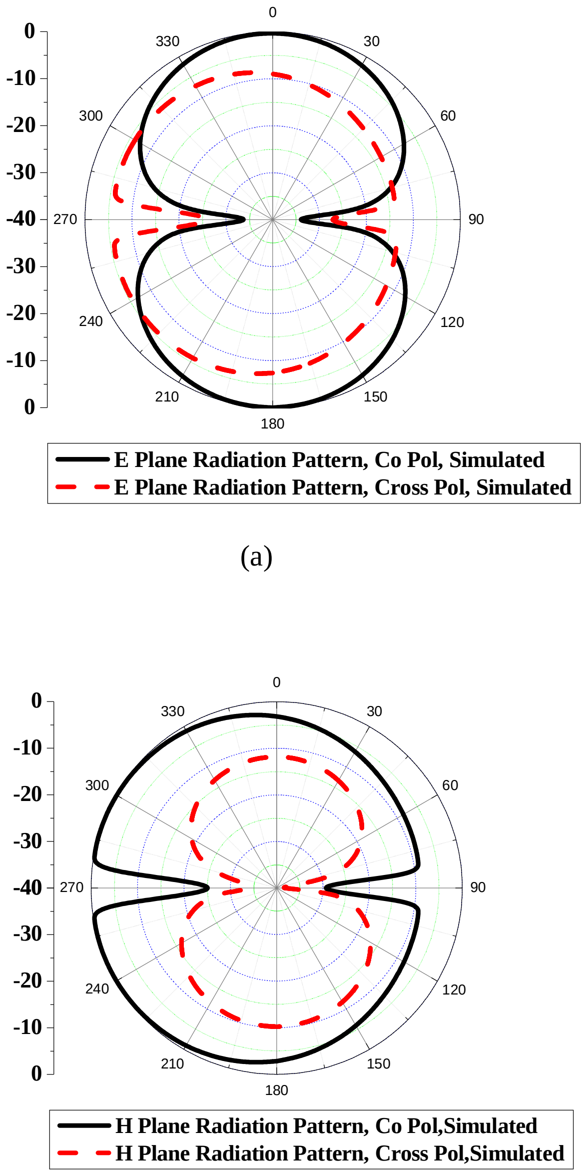


Figure 10: Simulated return loss plot of Antenna-1

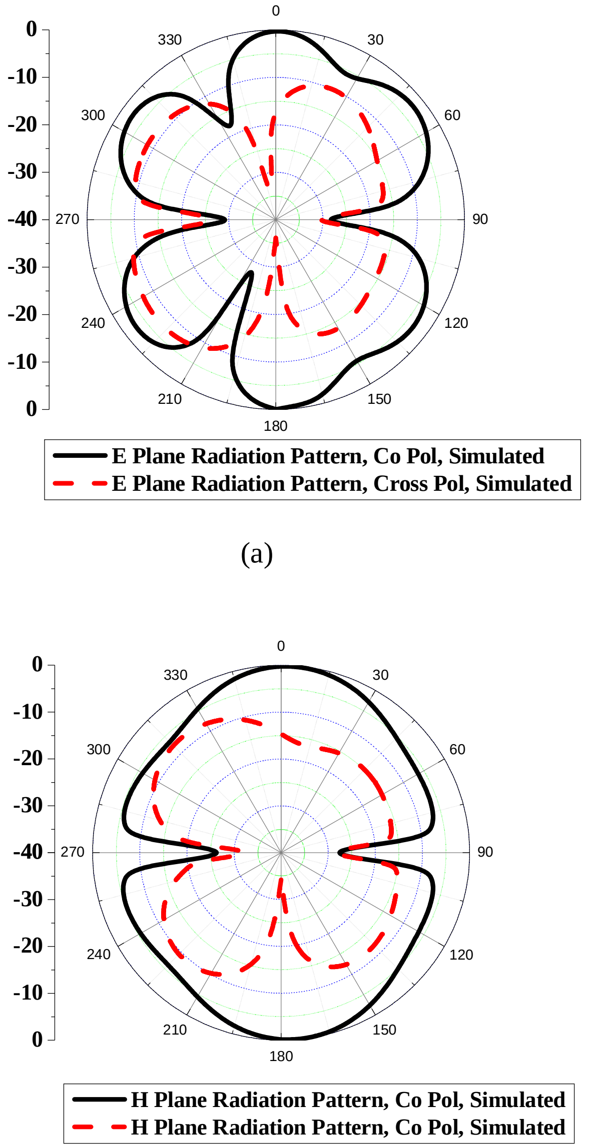
Simulated E and H plane normalised radiation patterns of the antenna at lower band and upper band (at centre frequencies of 1.5GHz and 4.8GHz)) are shown in Fig.-11. and Fig.- 12 and respectively.



(a)

(b)

Figure 11: Radiation patterns for 1.5 GHz of Antenna-2.
E plane (b) H plane



(a)

(b)

Figure 12: Radiation patterns for 4.81 GHz of Antenna-2
(a) E plane (b) H plane.

The simulated gain versus frequency of the Antenna-2 is shown in Fig.-13.

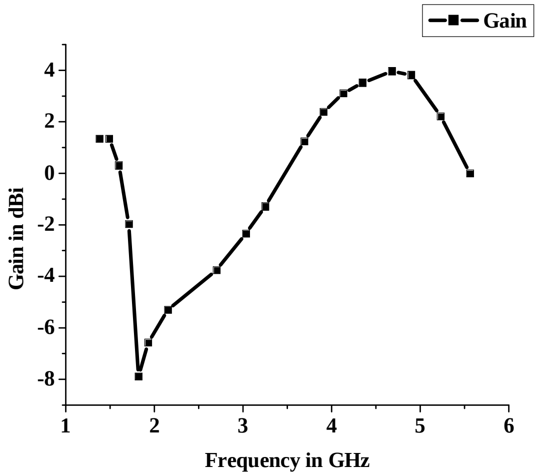


Figure 13: Simulated Gain versus Frequency plot of Antenna-2

5. Conclusion

Double Sided Printed Dipole Antennas with fractal shaped arms are designed for broad band and dual band operation. Arms are designed according to Sierpiniski gasket shape after first and second iterations. A very large impedance bandwidth above 76 %(centre frequency-4.2GHz) is obtained (Antenna-1). But flaring of arms should not be large enough so that its width becomes comparable to the arm length. Otherwise, this will produce high cross polar component. In a novel design, dual band of operation may be achieved by judicially shorting the smallest triangles. The shorting of triangles excites an additional band at lower frequency. Significantly large impedance band width of 20% (centre frequency1.5GHz) and 39% (centre frequency 3.8GHz) are obtained in the lower and upper bands respectively.

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