Design of Modified Circular Inset-Fed Hexa-Band Antenna for Wireless Communication

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ABSTRACT

In this paper, an inset-fed circular microstrip antenna is designed by modifying the circular patch by inserting an omega type slot at the centre and arcs at the edges. The simulation work is carried out using Ansys HFSS software and measured practically. The proposed antenna is fabricated on commercially available low coat FR-4 substrate with relative permittivity of 4.4 having physical dimension of 55.4 × 44 × 1.6 mm^3. The proposed antenna is resonates at six particular frequencies 2.30, 3.45, 6.67, 8.10, 8.89 and 10.25 GHz with -10 dB impedance bandwidth of BW_1= 4.7% (2.27-2.38 GHz), BW_2= 5.50% (3.37-3.56 GHz), BW_3= 8.39% (6.40-6.96 GHz), BW_4=6.04% (7.82-8.31 GHz), BW_5=4.88% (8.68-9.08 GHz) and BW_6 =12% (9.67-10.90 GHz). Also the virtual size reduction of 38.66% is achieved when compared to conventional antenna. The proposed antenna shows broadside radiation characteristics with a gain of 6.9 dB and finds application in wireless communication.

***Keywords:* Inset-Fed, Modified Circular Patch, Omega Slot, Impedance Bandwidth, Hexa-Band Antenna, Wireless Communication.**

I. INTRODUCTION

Increasing progress in communication system increases the demand of compact, cost effective and easily fabricated antennas. So, this requirement of present time is full-filled by the invention of patch antenna [1-5]. They are light weight, affordable, easy to manufacture and can easily be used in hand-held devices. Microstrip patch antenna is a metallic plate mounted on a dielectric substrate of any kind. Low dielectric constant and thicker material is used for the designing of patch antenna [6-7]. The radiating patch has different shapes like circular, rectangular, ring and elliptical respectively. Another metallic plate is mounted at the bottom of dielectric which is known as ground plane. Ground plane provides sufficient reflections to the fringing fields which occurred due to the change in length of patch antenna. Microstrip patch antenna can be fed by various techniques such as probe feed, microstrip line feed, inset-feed, proximity coupled feed and aperture/slot-coupled feed. Recently, triple, quad-band patch antennas are investigated because of coverage of different wireless communication services such as GSM, DCS, CDMA and PCS [8-9]. But, the ability to provide an antenna with small size is an important requirement for the design and development of multiband operations.

In this paper, we present an inset-fed modified circular microstrip patch antenna by inserting an omega type slot at the centre and arcs at the edges of circular patch. The proposed antenna resonates at six different frequencies covering different wireless communication bands. The details of the antenna design, simulation and experimental results are presented and discussed in next sections.

II. ANTENNA DESIGN

"Fig. 1" shows the geometry of the conventional inset-fed circular microstrip patch antenna. The proposed antenna is designed to operate at 3.8GHz by using low cost glass epoxy FR4 dielectric material with relative permittivity (εr) of 4.4 with thickness (h) of 1.6 mm is chosen. The circular radiating patch with radius R=11.5 mm is fed by simple 50Ω inset-fed having dimensions of length L_f=17.18 mm and W_f = 3.17 mm on the top side of the substrate and bottom of the substrate as ground plane with Lg = 55.4 mm and Wg= 44 mm. For a better impedance matching between radiating patch and simple 50Ω inset-fed, a microstrip feed-line with width I_W= 1.53 mm and length of I_L= 5.78 mm are chosen to achieve the optimum results.

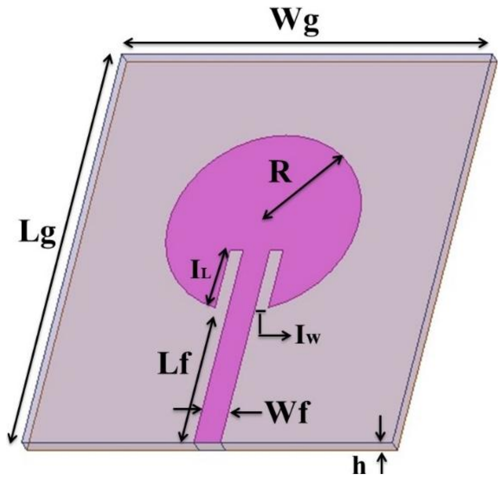


Fig. 1 Geometry of the conventional inset-fed circular microstrip antenna

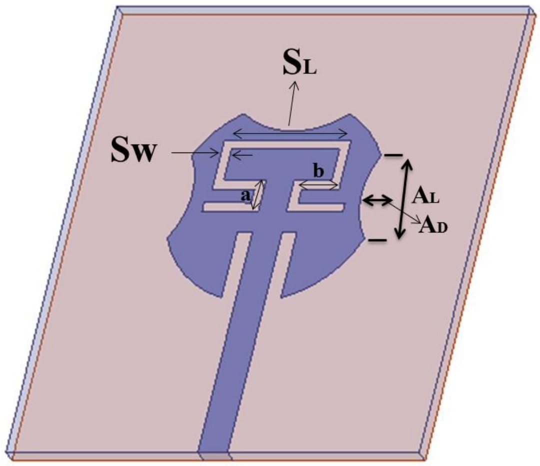


Fig. 2 Geometry of the modified inset-fed circular microstrip patch antenna

"Fig. 2" shows the geometry of the modified inset-fed circular microstrip patch antenna. The circular patch is modified with inserting omega type shaped slot at the centre and arcs at edges of the patch with A_L= 9.29 mm, A_D=1.07 mm, S_L=13.5 mm, S_w= 1 mm, a= 3.5 mm, and b= 4.5 mm. The prototype of the proposed antenna model is designed by using commercially available Ansys HFSS electromagnetics simulation tool [10]. The optimized antenna design parameters and their dimensions are given in "Table I."

Table I: Optimized dimensions and parameters of the conventional and proposed antenna

Antenna parameters	W	L	R	W_f	L_f	I_W	I_L	h	A_L	A_w	S_L	S_W	a	b
Dimensions (mm)	55.4	44	11.5	3.17	17.18	1.58	6.98	1.6	9.29	1.07	13.5	1	3.5	4.5

III. RESULTS AND DISCUSSION

The parameters of the proposed antennas are measured by Vector Network Analyzer (VNA) (Rhode and Schwarz, Germany make ZVK model 1127.8651). "Fig. 3 and 4" shows the comparison of simulated and measured return loss characteristic of the conventional and modified circular microstrip patch antenna. From the Fig. 3 it is observed that the conventional antenna resonate at f_r= 3.75 GHz with -10dB return loss with impedance bandwidth of BW= 4.26% (3.69-3.85 GHz). From the "Fig.4" it is observed that, by inserting omega type shaped slot at the centre and arcs at edges of the circular patch, the antenna resonates at six frequencies i.e. f_{r1} = 2.30 GHz, f_{r2} =3.45 GHz, f_{r3}= 6.67 GHz, f_{r4}= 8.10 GHz, f_{r5}= 8.89GHz, and f_{r6}=10.25GHz, with -10 dB return loss with impedance bandwidths of BW_1= 4.7% (2.27-2.38 GHz), BW_2= 5.50% (3.37-3.56 GHz), BW_3= 8.39% (6.40-6.96 GHz), BW_4= 6.04% (7.82-8.31 GHz), BW_5= 4.88 (8.68-9.08 GHz) and BW_6 = 12% (9.67-10.90 GHz) respectively.

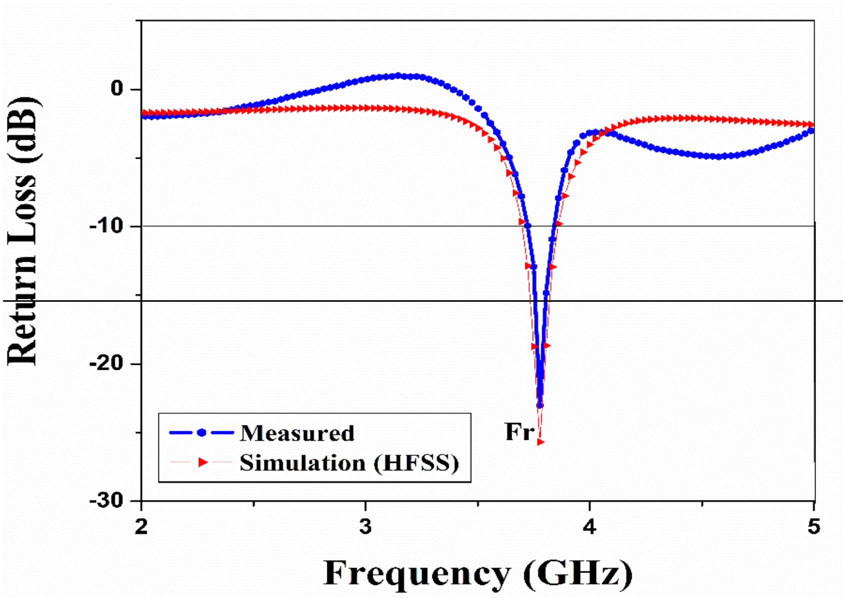


Fig. 3 Comparison of simulated and measured return loss characteristics of conventional circular patch antenna

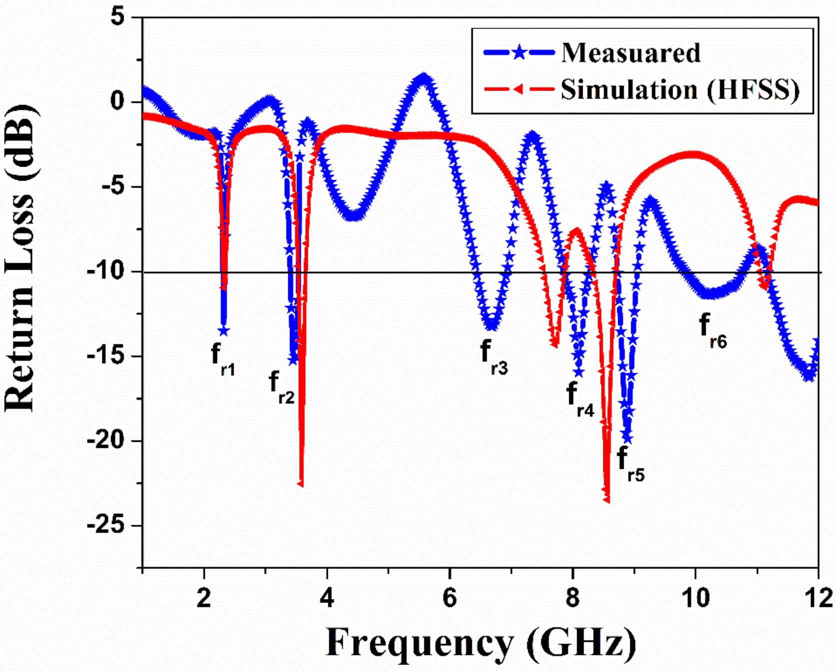


Fig. 4 Comparison of simulated and experimental return loss characteristics of modified circular patch antenna

The simulated surface current field distribution on the radiating patch of the conventional antenna and the proposed antennas are shown in "Fig. 5" and "Fig. 6 (a) – (b)." From "Fig. 5" it is observed that the current on radiating patch of conventional antenna is uniform. But, from "Fig. 6(a)-(b)". It is clear that the more current is accumulated at the omega shaped slot. This phenomenon leads to good virtual size reduction and good radiation performance of the proposed antennas.

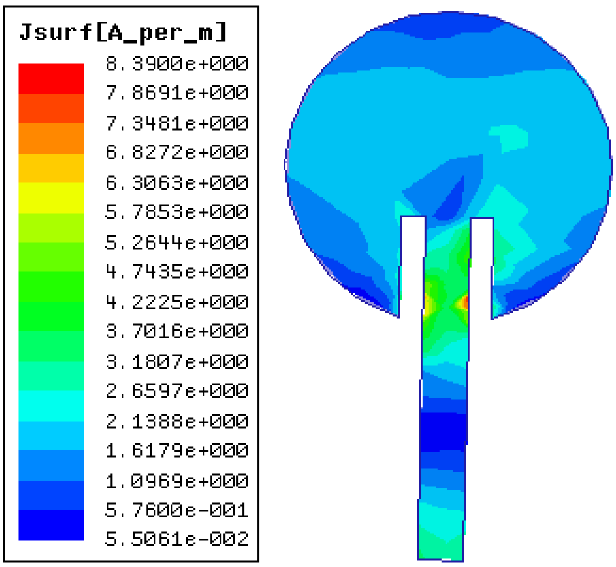
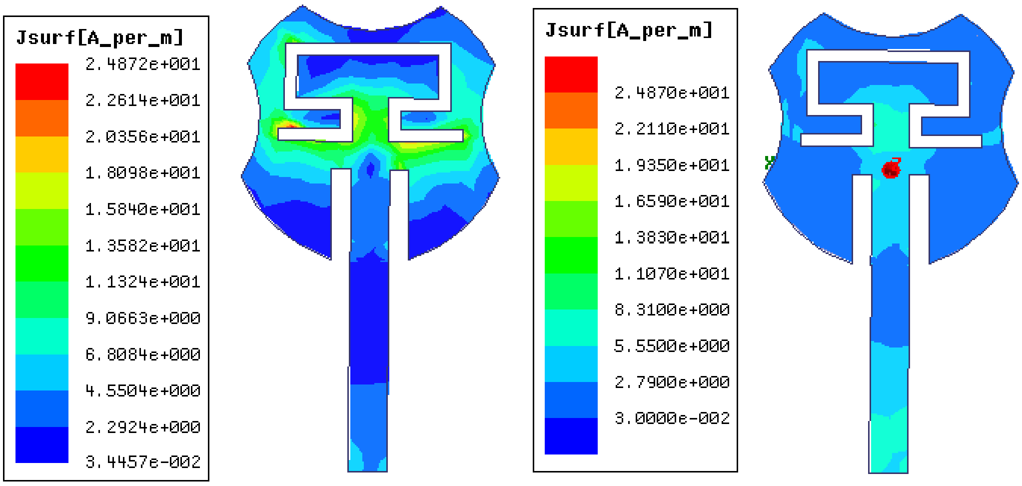


Fig. 5 simulated surface current distribution of the conventional antenna at 3.75 GHz



(a) (b)

Fig. 6 simulated surface current distributions of the proposed Hexa –band antenna observed at (a) 2.30 GHz, (b) 3.45 GHz.

The desired normalized co-polarization and cross- polarization plots in both E-plane and H-plane radiation patterns at the resonating frequencies of the conventional antenna and proposed antennas are shown in "Fig. 7" and "Fig. 8(a)-(f)". The radiation patterns are observed to be broadside in nature and linearly polarized at respected resonating frequencies. Also the proposed antenna exhibits similar radiation characteristics in its remaining operating bands.

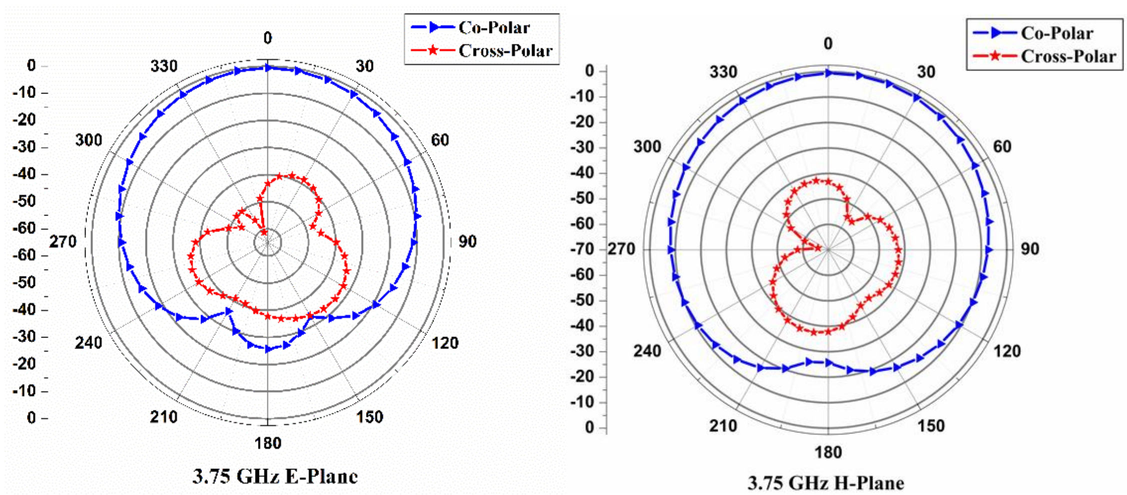
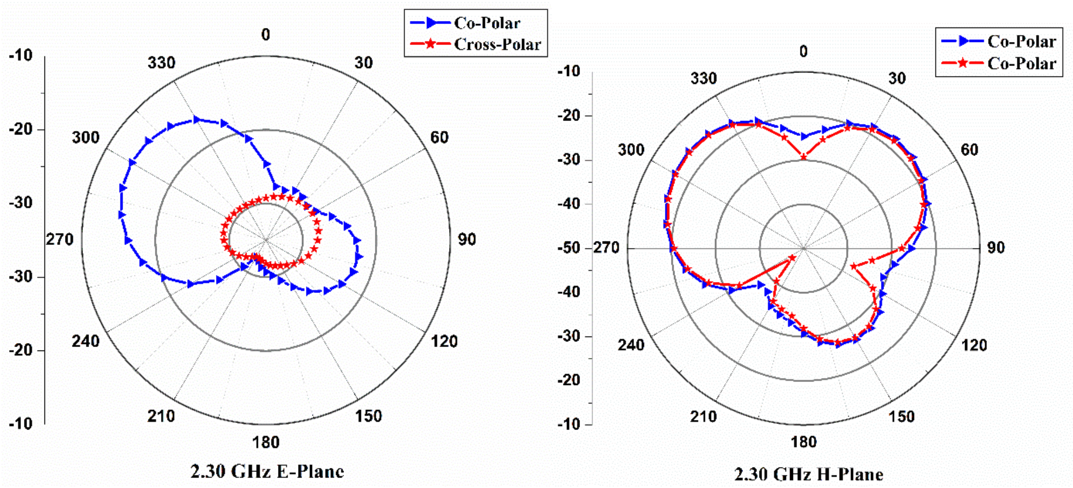
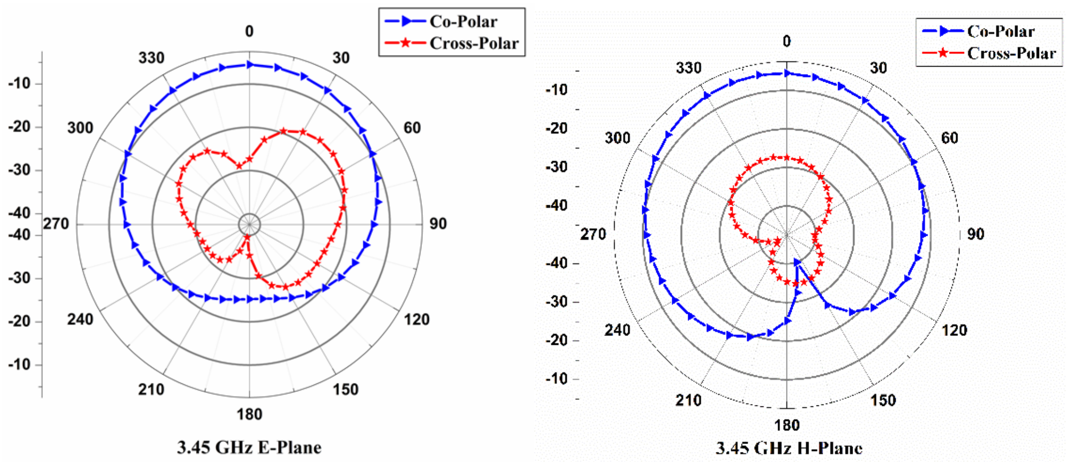


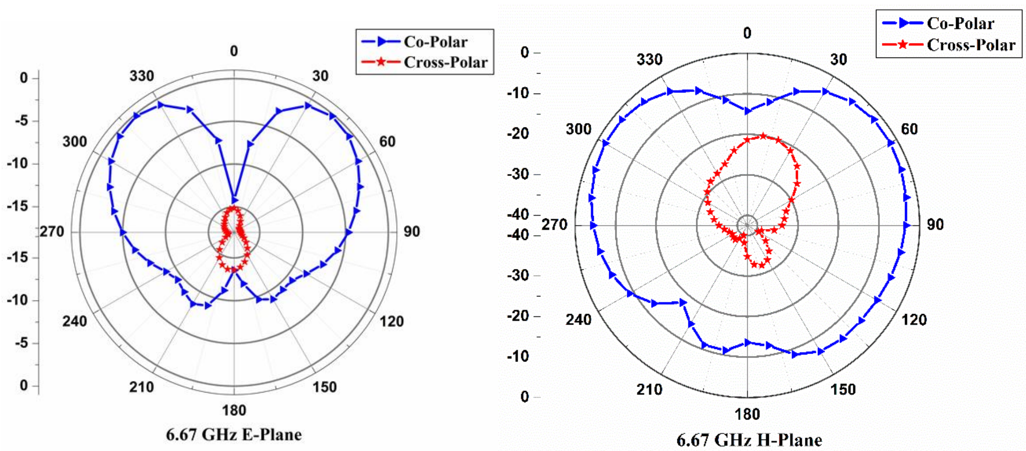
Fig. 7 typical co-polarization and cross- polarization in E-plane and H-plane radiation patterns of the conventional circular microstrip patch antenna measured at 3.75 GHz


Co-Polar
Cross-Polar
0
30
60
90
120
150
180
210
240
270
300
330
-10
-20
-30
-50
-40
2.30 GHz E-Plane
Co-Polar
Co-Polar
2.30 GHz H-Plane

(a)


Co-Polar
Cross-Polar
0
30
60
90
120
150
180
210
240
270
300
330
-10
-20
-30
-40
3.45 GHz E-Plane
Co-Polar
Cross-Polar
3.45 GHz H-Plane

(b)


Co-Polar
Cross-Polar
0
30
60
90
120
150
180
210
240
270
300
330
-5
-10
-15
6.67 GHz E-Plane
Co-Polar
Cross-Polar
-20
-30
-40
6.67 GHz H-Plane

(c)

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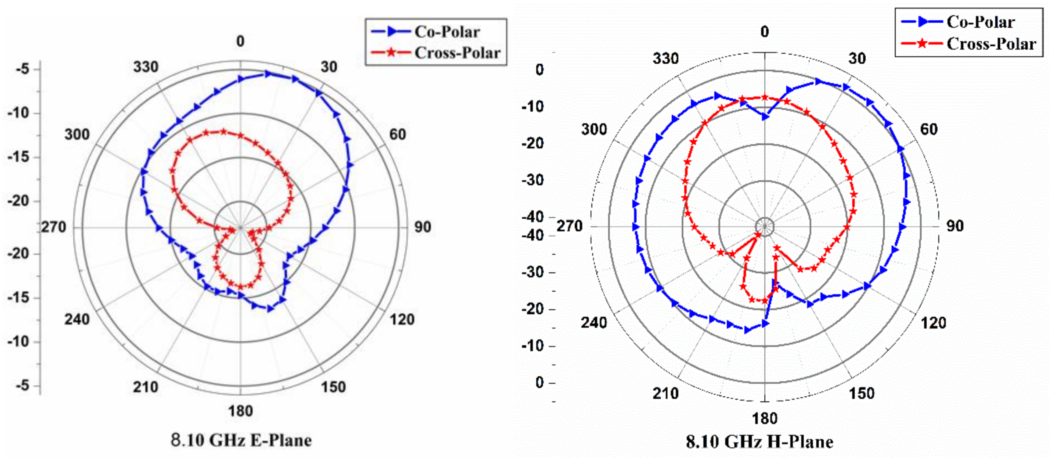
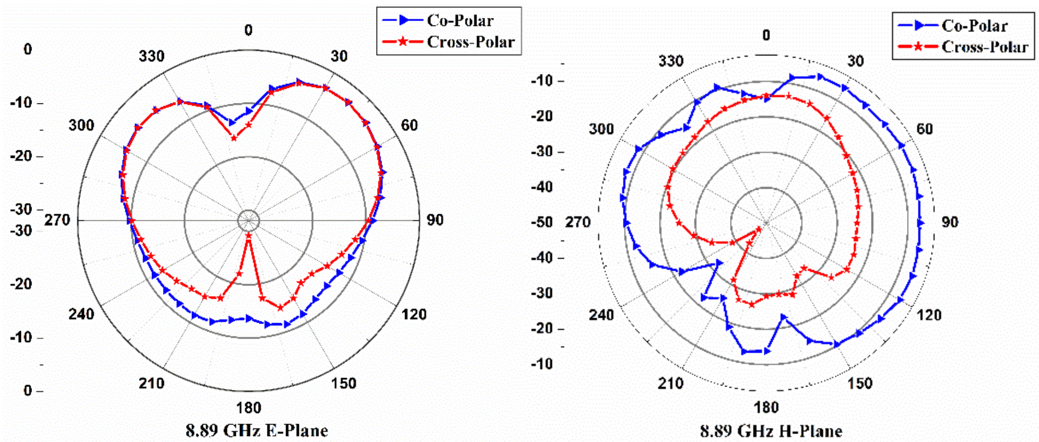
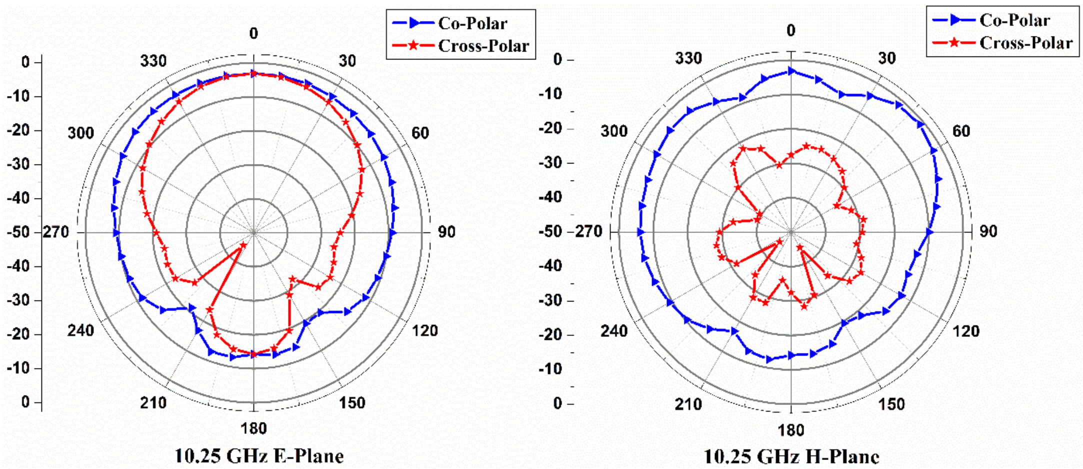


(d)



(e)



(f)

Fig. 8 typical co-polarization and cross- polarization in E-plane and H-plane radiation patterns of the proposed antennas measured at (a) 2.30 GHz, (b) 3.45 GHz, (c) 6.67 GHz, (d) 8.10 GHz and (e) 8.89 GHz (f) 10.25 GHz

IV. CONCLUSION

From the detailed experimental study, it is clear that by modifying circular patch with inserting an optimized omega type shaped slot at the centre and arcs at the edges of the patch, the antenna resonates for six frequencies and achieved virtual size reduction of 38.66% when compared to conventional antenna. The proposed antennas shows broadside radiation patterns with maximum gain of 6.9 dB. The proposed antenna is simple in its construction with low cost substrate material. This antenna may find application in wireless communication system.

V. ACKNOWLEDGEMENTS

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