

A PERTURBED CIRCULAR MONOPOLE ANTENNA WITH CIRCULAR POLARIZATION FOR ULTRA WIDEBAND APPLICATIONS

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Abstract—This article presents a circularly polarized (7.35-7.7 GHz) ultra wideband monopole antenna, applicable to wireless personal area network (WPAN). The suggested patch having dimensions $40 \times 40 \times 1.6 \text{ mm}^3$ is simulated. Its prototype is fabricated and subsequent measurements are done. Circular polarization characteristics is achieved by introducing two transitions and two cuts in opposite ends of two diameters inclined at 90° to each other in the circular patch.

Keywords-Axial ratio, circular polarization, ultra wideband.

I. INTRODUCTION

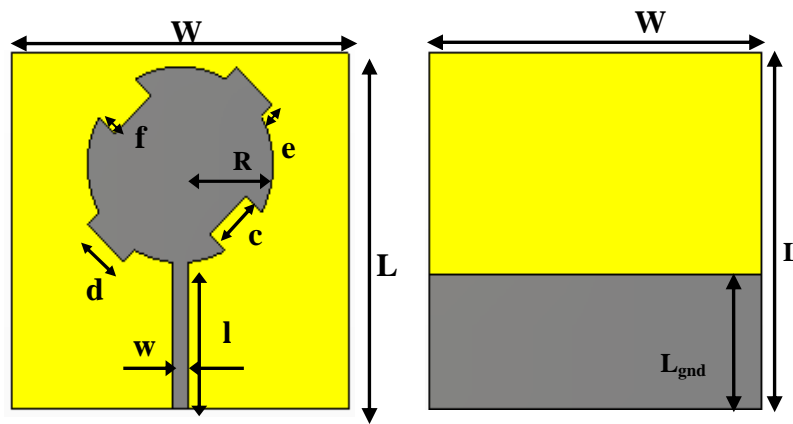
Planar microstrip antennas are normally distinguished by their low profile, simple structure, light weight and surface-adaptive qualities but simultaneously having a very low impedance bandwidth ($\sim 2\text{-}5\%$) [1]. On the other hand, printed monopole antennas possess wide impedance bandwidth along with omnidirectional radiation pattern in H-plane, thus making it a potential candidate for ultra wideband (UWB) systems, which uses 3.1-10.6 GHz frequency band, as defined by FCC [2]. Circular polarization (CP) is viewed as one of the prominent aspects of an UWB antenna, as it renders the antenna to behave optimally in multipath fading environment with better signal reception. It exhibits polarization diversity, thereby supporting superior data rates, simultaneously allowing flexible receiver orientation, which leads to application areas like radar, satellite and navigation systems, etc. Since, CP includes two orthogonal components of electric field in exact phase quadrature, sometimes it is difficult to implement.

Authors in [3] presented a dual band monopole antenna having CP characteristics (150 MHz, 900 MHz) in which an inverted L-slit was etched in the ground plane, that enhances the impedance bandwidth. The monopole antenna reported in [4], utilized a step shaped ground that improves both impedance bandwidth ($\sim 5.96 \text{ GHz}$) and axial ratio (AR) bandwidth ($\sim 2.64 \text{ GHz}$). In [5], an intricate UWB antenna with a CP band of 7.18-10.01 GHz was introduced. Presence of a ring type slot in antenna structure generates circularly polarized waves [6], whereas, shorted square-ring slot can create CP [7]. A circularly polarized square slot antenna loaded with a cross patch is published in [8].

Here, a perturbed circular patch, fed by microstrip line having a shortened ground, is introduced. This structure gives rise to not only UWB, but also CP characteristics. By changing the dimensions of perturbations present in the said structure, the variations of AR bandwidth are investigated during simulation. Also, the variations of shortened ground are studied for better achievement of impedance bandwidth. The proposed patch is simulated using Ansoft HFSS software. The patch showing improved result is fabricated where, experimental findings resembles with simulated consequences.

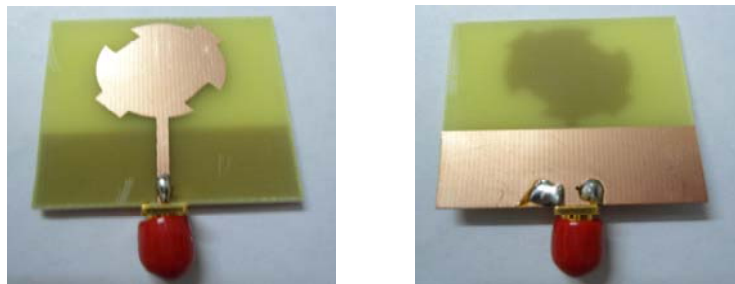
II. ANTENNA DESIGN

The structure of the proposed antenna and its printed model are shown in Fig. 1 and Fig. 2 respectively. It comprises of a circular patch of radius 'R', in which two transitions of dimension ' $d \times e$ ' and two cuts of dimension ' $c \times f$ ' are made in opposite ends of two diameters inclined at 90° to each other. A 50Ω microstrip line of width 'w' and length 'l' is used to feed the antenna. The patch is printed over FR4 substrate material of length 'L' and width 'W', having dielectric constant ϵ_r of 4.4, loss tangent $\tan\delta$ of 0.002 and height of 1.6mm. In the rear side of substrate, a truncated ground plane of length ' L_{gnd} ' and width 'W' exists. The antenna parameter values are listed in Table 1.



(a) (b)

Fig. 1. Proposed antenna (a) Front view (b) Back view



(a) (b)

Fig. 2. Photograph of the fabricated prototype (a) Front view (b) Back view

TABLE I

Antenna parameter dimensions in mm

L	W	w	l	L _{gnd}	R	c	d	e	f
40	40	3	16.55	15	11	6	6	2	3

III. PARAMETER SIMULATION STUDY

During simulation, the values of L_{gnd} , c, d, e and f are varied, keeping w and l as constants. The subsequent effects of said variations upon impedance bandwidth and AR bandwidth are studied below.

A. Effect of L_{gnd} on S_{11}

The effects of variations in length L_{gnd} of shortened ground upon impedance bandwidth, with zero perturbations in the patch, are shown in Fig. 3. It is revealed that, the truncation of ground length has a noticeable effect in improving impedance bandwidth, where L_{gnd} varied from 13mm to 16mm and UWB range is achieved when L_{gnd} is 15mm.

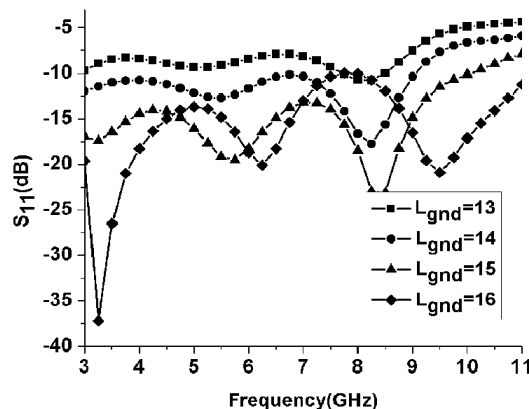


Fig. 3. Effect of L_{gnd} on S_{11} .

B. Effect of 'c' on AR

Different values of c, starting from 2mm to 8mm, is taken during simulation. From Fig. 4(a), it is noticed that, when c is 4mm, AR bandwidth becomes higher. But, when c is taken as 6mm, both UWB characteristic and AR bandwidth of 220MHz (7.53-7.75 GHz) yields.

C. Effect of 'd' on AR

Here, the effects of variations of d from 2mm to 6mm upon AR bandwidth is depicted in Fig. 4(b). It can be concluded that, increasing the value of d, increases the AR value within 7.4-7.9 GHz band. But, when d is assumed 6mm, both UWB characteristic and AR bandwidth of 500 MHz is obtained.

D. Effect of 'e' on AR

Here also, various values of e starting from 1mm to 3mm is chosen for simulation and corresponding results are indicated in Fig. 4(c). Small changes in e leads to considerable changes in AR bandwidth. When e is 2mm, both the UWB characteristic and AR bandwidth of 230 MHz is obtained.

E. Effect of 'f' on AR

When the value of f is changed from 2.5mm to 3.5mm, it can be observed that the AR bandwidth is 250 MHz when f is 3mm, as expressed in Fig. 4(d).

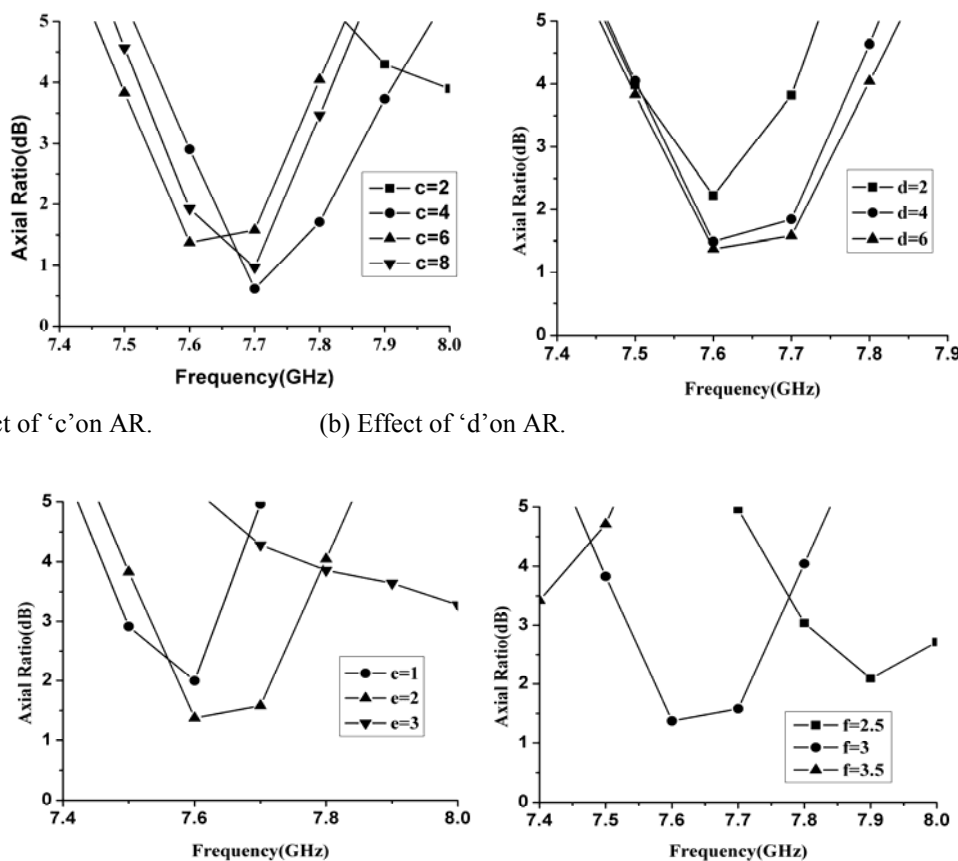


Fig. 4. Effect of various parameters on AR result

F. Circular polarization

The time varying surface current distribution of the suggested patch at 7.6 GHz is simulated at different phase instants (0°, 90°, 180°, and 270°). The results are indicated in Fig.5. The distribution of surface current upon the patch at 180° and 270° are equal in magnitude but opposite in phase to that of 0° and 90° respectively. Clockwise rotation at 7.6 GHz implies the presence of right hand circular polarization behaviour. Fig. 6. represents the cross polarization ratio (right/left) of the patch for the entire simulated frequency range. It can be observed that, for frequencies 7.55 GHz ~ 7.8 GHz the polarization ratio is above 15 dB.

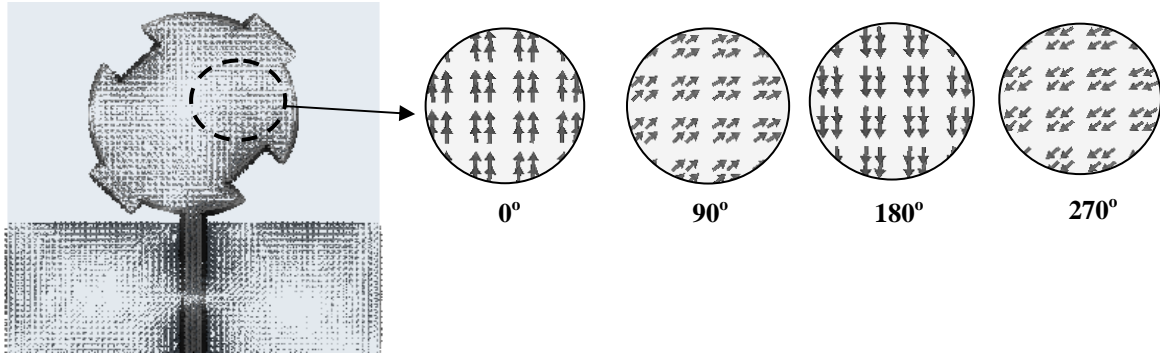


Fig. 5. Simulated surface current results on patch at 7.6 GHz

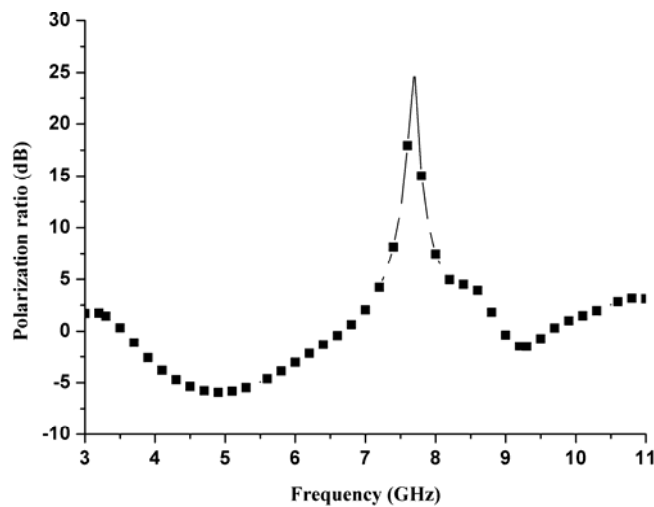


Fig. 6. Simulated polarization ratio

IV. EXPERIMENTAL VERIFICATION

The suggested structure of the antenna is fabricated on FR4 material with the essential specifications given in Table 1 and is excited through a 50 Ω SMA connector. The S_{11} result is obtained using vector network analyzer (VNA-R&S® – 10 MHz to 20 GHz). Radiation pattern and gain of the antenna are measured in anechoic chamber with dipole antenna as transmitter and experimental findings are reviewed below.

A. Impedance bandwidth and AR bandwidth

Fig. 7(a) indicates the occurrence of reasonable agreement of experimental curve with simulated curve of S_{11} . The graph of S_{11} covers entire UWB spectrum. For circular polarization, the cross polarization ratio and the corresponding AR values are measured for the frequency range 7.3-7.9 GHz. Fig. 7(b) depicts, both the

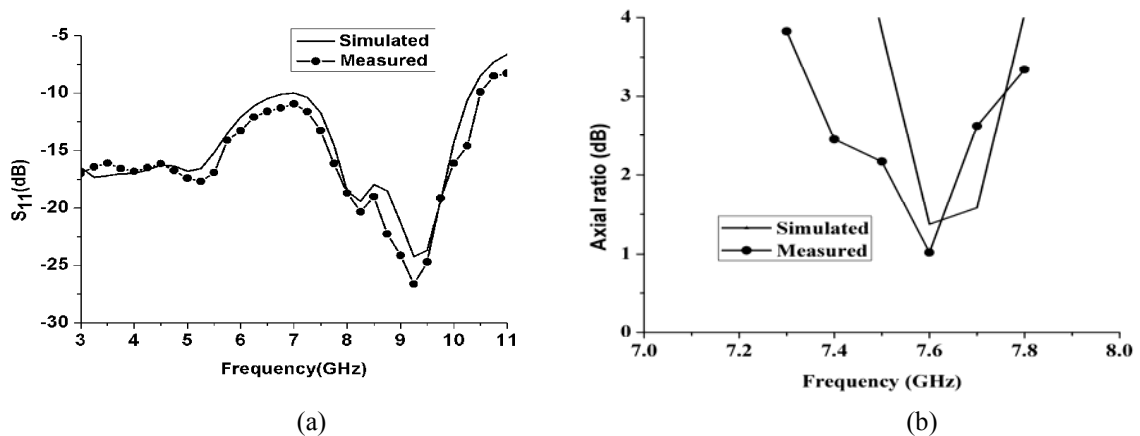


Fig.7. Simulated and measured results of the proposed antenna (a) S_{11} (b) AR

simulated and measured AR of the patch. This experimental curve implies the presence of circular polarization within the frequency range 7.35-7.7 GHz. (4.65%). The variation in the results might be due to the test environment.

B. Radiation pattern and gain

The experimental normalized radiation pattern of the fabricated patch at 4 GHz and 8 GHz are displayed in Fig.8 (a) and (b) respectively in terms of E-plane and H-plane. The patterns at two different frequencies are similar to each other. The measured pattern exhibits presence of monopole radiation in E-plane. Also, the radiation pattern in H-plane shows nearly omnidirectional behaviour. The LHCP and RHCP pattern of the proposed antenna at 7.6 GHz is shown in Fig. 9. The not so smooth radiation pattern is due to the manual alignment of the antenna during measurement.

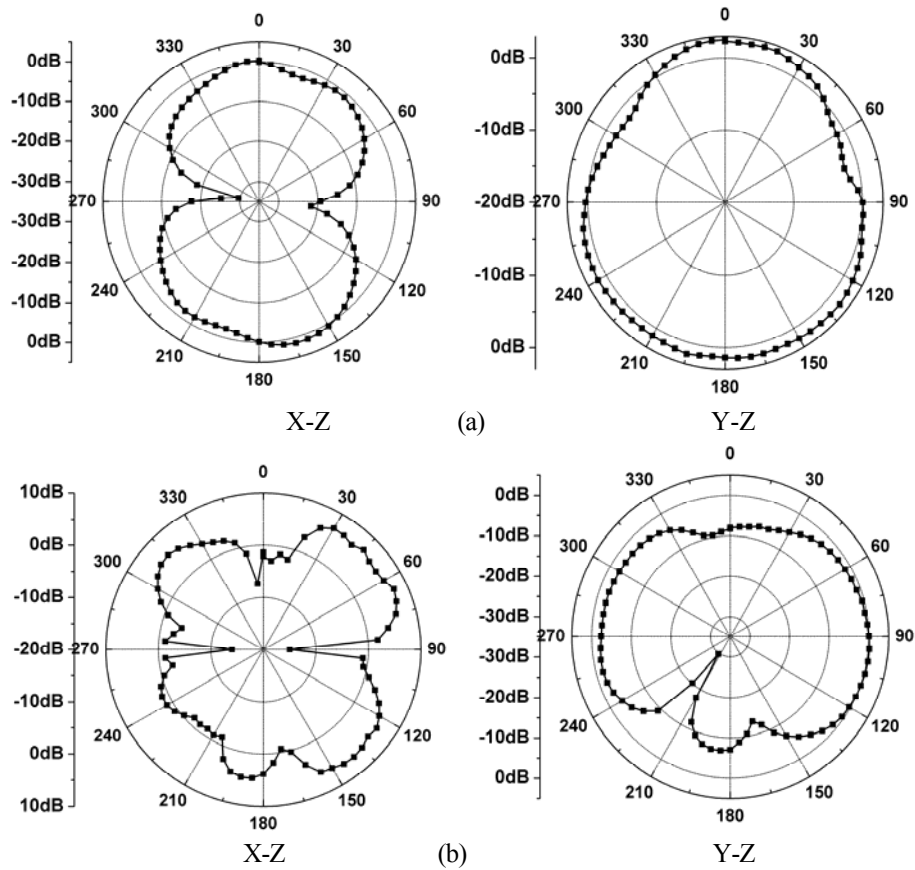


Fig. 8. Measured radiation patterns of the proposed antenna at (a) 4 GHz (b) 8 GHz

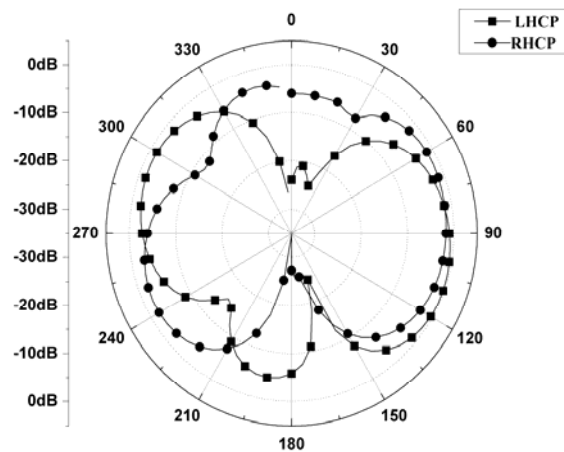


Fig. 9. Pattern at 7.6 GHz

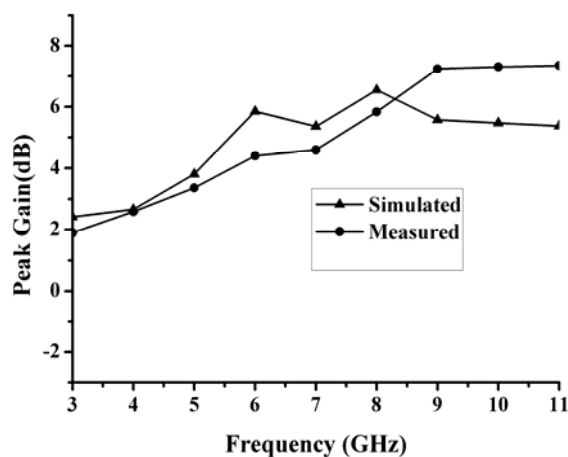


Fig. 10. Simulated and measured peak gains of the proposed antenna.

Both the simulated and measured peak gains, within the frequency range from 3 GHz to 11 GHz, are shown in Fig. 10. The maximum gain of the proposed antenna is 6.8 dB. The graph implies minimal increase of gain with frequency.

V. CONCLUSION

A monopole antenna having circular polarization characteristics is prescribed. The impedance bandwidth of the patch covers entire UWB range. The AR bandwidth of 350 MHz (4.65%) from 7.35-7.7GHz is attained, by introducing two transitions and two cuts in opposite ends of two diameters inclined at 90° to each other, in the radiator. The peak gain of 6.8 dB is achieved in the frequency range of 9-11 GHz. The recommended structure can be utilized in various application areas, viz. WPAN, military communications, microwave imaging and disaster management. This antenna structure might be applicable to satellite communication in form of array.

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