A Low Profile Circularly Polarized Monopole Antenna for WPAN

Diptimayee Konhar, Debasis Mishra, Suvendu Narayan Mishra

Abstract*: *This paper introduces a circularly polarized ulta-wideband monopole antenna. The antenna is designed by etching two asymmetrical cuts on both sides of the conventional rectangular radiator with opposite orientation. This modification resulted ulta-wideband and circular polarization nature in the patch. The obtained impedance bandwidth and axial ratio bandwidth are 7.6 GHz (3-10.6 GHz) and 1.1 GHz (7.7-8.8 GHz). Prototype of the suggested patch having dimensions 35mm × 31mm × 1.6mm is simulated. Subsequently the patch is fabricated, experimented and compared with simulated results. The antenna can be applicable to wireless personal area network, secure military communications, microwave imaging etc.

Index Terms*: *Axial ratio, Circular polarization, Ultra-wideband

I. INTRODUCTION

Printed monopole antennas find numerous applications due to their inherent wide impedance bandwidth apart from other allied features. For simpler fabrication, planar monopole antennas with coplanar waveguide (CPW) feed are most suitable. The radiating element and the feed line can be etched on single side of the substrate, making them uni-planar. Antennas with CPW feed are more suitable to be used in compact wireless communication systems for better circuit integration with solid state devices, low radiation loss, less dispersion characteristics [1].CPW feeding of printed monopole antenna sometimes renders it with a peculiar property like ultra-wideband (UWB) characteristic. Circular polarization (CP) is regarded as one of the very essential attribute of an UWB antenna, as it helps to perform optimally in the multipath fading environment with superior signal reception. It also exhibits polarization diversity, thus supporting superior data rates, simultaneously allowing flexible receiver orientation [2]. However, it is difficult to achieve CP since; it involves two orthogonal components of E-field in exact phase quadrature.A LI shaped monopole antenna was reported to obtain UWB by utilizing different surface current paths [3]. The presence of multiple current paths enhances the bandwidth in U-shaped monopoles [4-7]. However, implementations of CP in compact printed monopole UWB antennas are not included in the above literature. Monopole antenna presented in [8] adopted a step shaped ground plane structure to enhance both return loss bandwidth (~5.96GHz) and axial ratio (AR) bandwidth (~2.64GHz). Aperture coupling technique is used in [9] to achieve CP. Slot antennas are utilized to achieve UWB and CP in [10-12]. Here, a simple patch with two asymmetric cuts each in both sides of the patch is suggested, which possesses circular polarization. By changing the geometrical dimensions of the cuts, present in the structure, the variation of the impedance bandwidth and AR bandwidth are investigated during simulation. The patch showing better results is fabricated, whose experimental findings matches with simulated outcomes.

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II. ANTENNA DESIGN

Figure 1(a) and (b) represents the structure of the proposed monopole antenna and fabricated prototype respectively. It consists of a radiator with two asymmetric cuts etched in both sides with opposite orientation and fed by a coplanar waveguide feed. FR4 material is used as substrate with length ‘L’, width ‘W’, thickness ‘h’, dielectric constant (ε_r) 4.4 and tan δ of 0.002. Both the radiator and the feed line are etched on one side of the substrate, and so are the two rectangular grounds each of length ‘Lg’ and width ‘Wg’ on the either side of the feed line. The antenna is excited by 50Ω CPW feed line of width ‘w’. Radiator is separated from the ground by a gap ‘G’. Similarly, feed line is separated from ground by a gap ‘g’. G and g are decisive parameters for proper impedance matching. Two simple step cuts of dimensions ‘a × b’ and ‘c × d’ are etched in both sides of the rectangular patch of length ‘Lp’ and width ‘Wp’, there by modifying the geometry to improve both impedance bandwidth and AR bandwidth. The intended antenna is simulated with different values of ‘a’ and ‘c’ within the UWB spectrum. The proposed patch is simulated using Finite Element Method (FEM) based ANSYS HFSS software. A 50Ω SMA connector is used to excite the antenna. The antenna parameter values are listed in Table 1.

Table 1: Antenna parameter dimensions in mm

Parameter	Value	Parameter	Value
h	1.6	Wp	21
w	3	Lp	17
L	35	Wg	13.55
W	31	Lg	11.8

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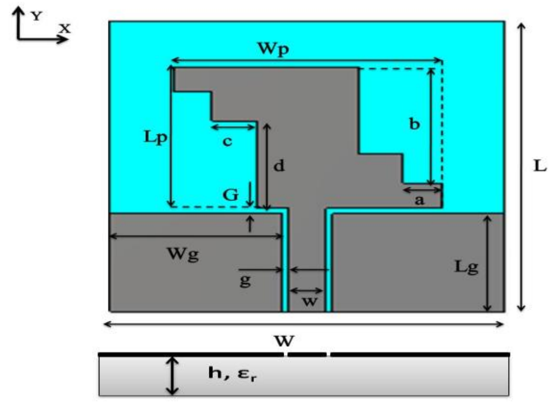
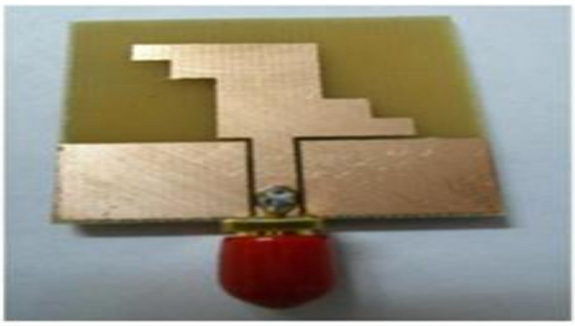
g	0.45	b	14
G	0.67	c	3.5
a	3	d	10.5



(a)



(b)

Figure. 1. (a) Proposed antenna (b) Fabricated prototype

III. PARAMETER SIMULATION STUDY

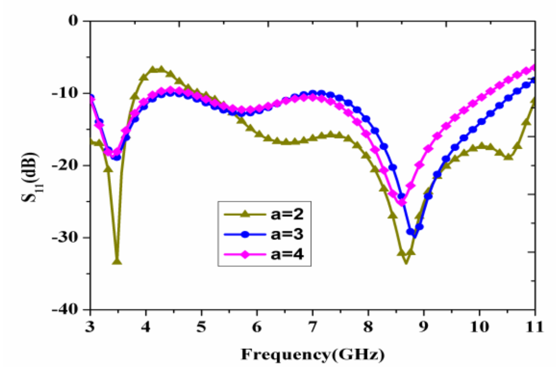
For the suggested antenna, the values of ‘g’ and ‘G’ are found to be 0.45mm and 0.67mm respectively. Impedance of the feed is matched to the source with the help of gap ‘g’ while gap ‘G’ improves the return loss. Keeping the parameters ‘g’ and ‘G’ as constants; the effects of variations of other parameters upon impedance bandwidth and AR bandwidth are studied below.

A. *Effect of first cut a x b*

Taking the parameter ‘b’ as 14mm, the effect of variation of width ‘a’ on return loss and AR result is shown in Figure 2(a) and (b) respectively. It is revealed that, the width ‘a’ has deterministic effect in improving impedance bandwidth and AR bandwidth. For the values of ‘a’ as 2mm and 4mm, the impedance bandwidth is not achievable, though the AR bandwidth is well below 3dB. But, when ‘a’ is assumed as 3mm, both the UWB and CP characteristics can be achieved.

B. *Effect of second cut c x d*

Fixing the parameter‘d’ as 10.5mm, the variation of ‘c’ from 2.5mm to 4.5mm is studied. It is observed that, small changes in ‘c’ give rise to considerable change in both return loss and AR bandwidth as shown in Figure 3(a) and (b) respectively. For any value of ‘c’ higher or lower than 3.5mm, the AR is maintained at one band and the impedance bandwidth is less than the UWB range. Figure 3(b) indicates the presence of two CP bands 4.47GHz-5.06GHz (12.3%) and 7.80GHz-8.91GHz (13.2%) when c is 3.5mm.



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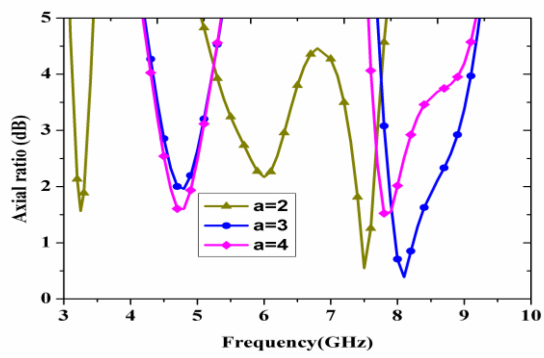

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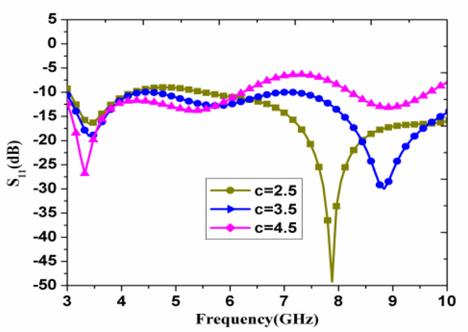
Figure. 2. Effect of varying ‘a’ on (a) S_{11} (b) AR bandwidth



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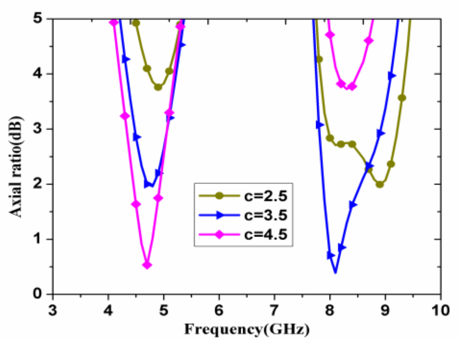

(b)

Figure. 3. Effect of varying ‘c’ on (a) S_{11} (b) AR bandwidth

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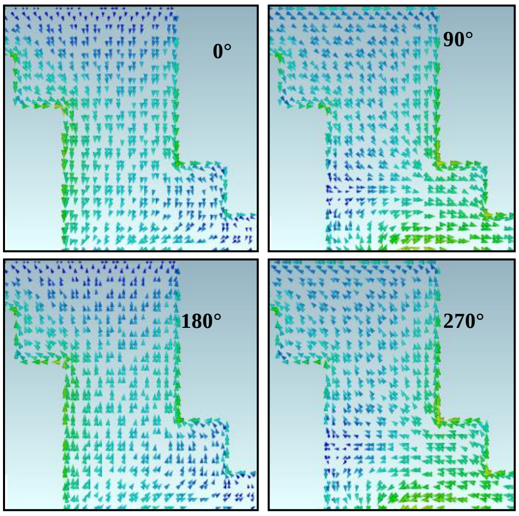
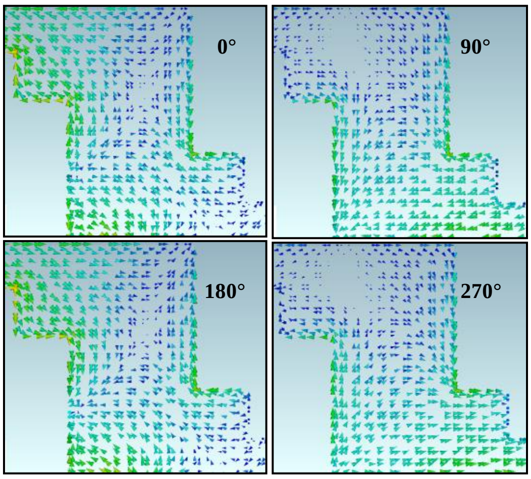
C. *Circular Polarization*

The simulation of time varying surface current distribution of the patch at the center of the AR bandwidths i.e. 4.76GHz and 8.35GHz is done at different phase instants (0°, 90°,180°,270°). The outcomes are presented in Figure 4(a) and (b) respectively. 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. Counter clockwise (CCW) rotation is monitored in the surface current distribution at both the frequencies, which implies the presence of left hand circular polarization (LHCP) behavior.



(a)



(b)

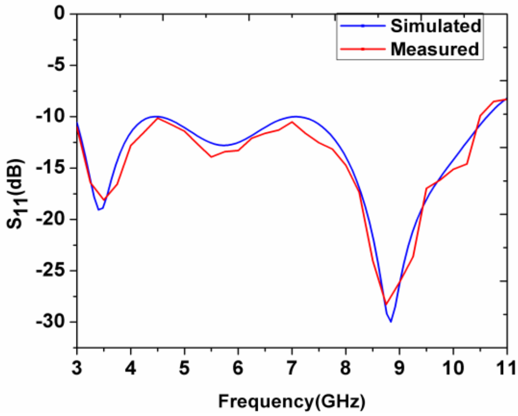
Figure. 4. Simulated surface current distribution at (a) 4.76 GHz (b) 8.35 GHz

IV. EXPERIMENTAL VERIFICATION

The aforesaid antenna structure is fabricated with the requisite specifications, on FR4 substrate. The S_{11} is measured using VNA (Rohde & Schwarz-10MHz to 20GHz). Taking dipole antenna as transmitter and test antenna as receiver the gain and radiation pattern of the antenna are measured in anechoic chamber. The experimental outcomes are discussed below.

A. *Impedance bandwidth and AR bandwidth*

Figure 5(a) indicates the fact that both the experimental and simulated curves of S_{11} are in reasonable agreement with each other. The obtained return loss values at simulated resonant frequencies 3.4 GHz and 8.83 GHz are -19.05 dB and -29.98 dB respectively. The measurement result has also two resonant frequencies i.e. 3.8 GHz with -18.1 dB and 8.75 GHz with -28.27 dB return loss values. For circular polarization, the cross polarization ratio and the corresponding AR values are computed for the frequency range 4.3-5.5 GHz and 7.5-9.0 GHz. Figure 5(b) depicts both the simulated and experimental result of axial ratio. Though simulation result involve two CP bands, i.e. 4.47-5.06 GHz and 7.8-8.91 GHz, yet the measured result shows only the higher band from 7.7 GHz to 8.8 GHz (13.3%).The variation in the result might be due to the test environment. Table 2 summarizes the above description.



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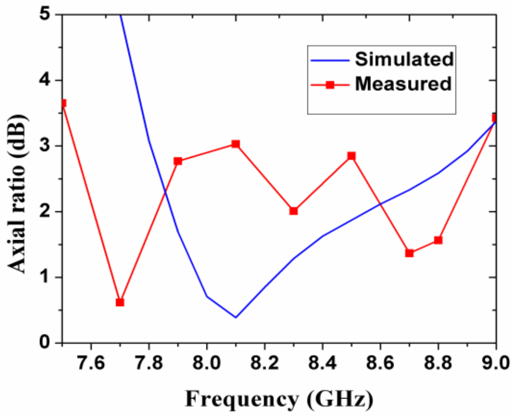

(b)

Figure . 5. Simulated and measured result of (a) S_{11} (b) Axial ratio

Table 2: Simulated and experimented results

Parameter	Impedance Bandwidth (GHz)	Resonant Frequency (GHz)	S_{11} (dB)	AR Bandwidth (GHz)
Simulated	7.6	3.4	-19.05	1.11
		8.83	-29.98	

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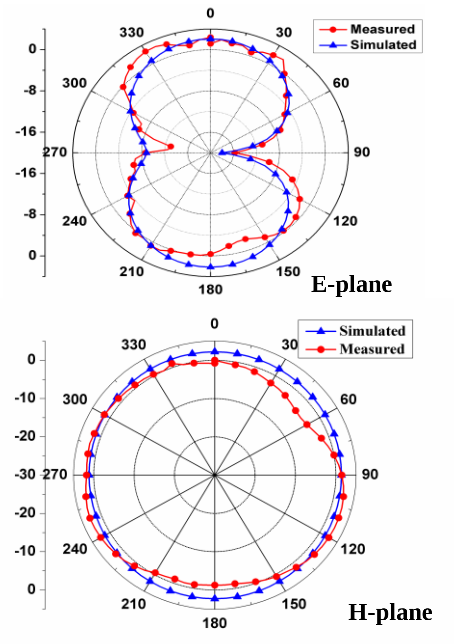
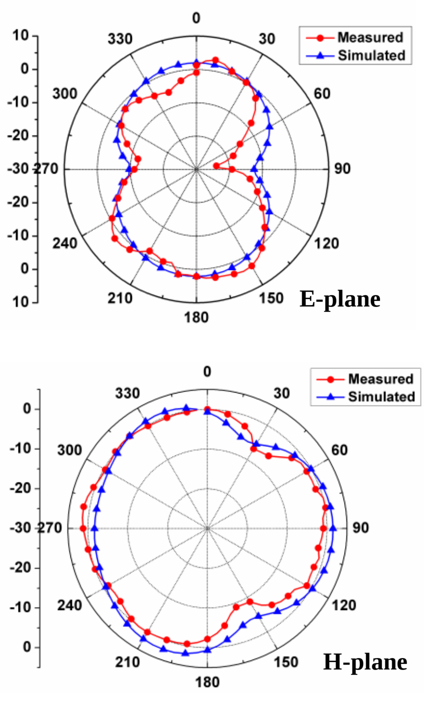
Measured	7.6	3.8	-18.1	1.1
		8.75	-28.27	

B. *Radiation pattern and gain*

Figure 6(a) and (b) represents the simulated and experimental normalized radiation patterns (E-plane and H-plane) of the patch at 3.5 GHz and 8.75 GHz respectively. Here, the normalized experimental pattern, so generated, is in resemblance with the simulated pattern, except at some places, where there exist certain differences, which is again in turn due to the test environment. The patterns at two different resonant frequencies are nearly similar to each other. The measured pattern indicates presence of monopole radiation characteristics in the broadside direction, which is inevitable for a monopole microstrip antenna.



(a)



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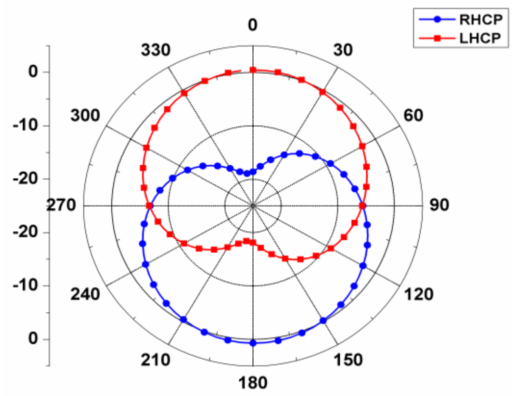

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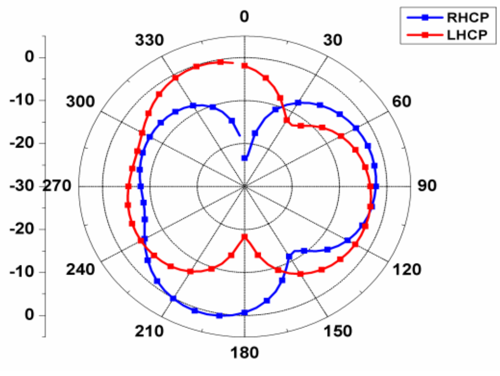

(d)

Figure. 6. Radiation patterns at (a) 3.5 GHz (b) 8.75 GHz , Simulated LHCP and RHCP pattern at (c) 4.76 GHz (d) 8.35 GHz

It can also be observed from Figure 6(c) and (d) that, the antenna radiates LHCP at both frequencies 4.76 GHz and 8.35 GHz in +ve z-direction. It validates the surface current distribution. Both the measured and simulated peak gains at different frequencies are depicted in Figure 7. The maximum experimental gain of the suggested antenna is 5.8dBi. The graph implies almost mixed response of gain with frequency.

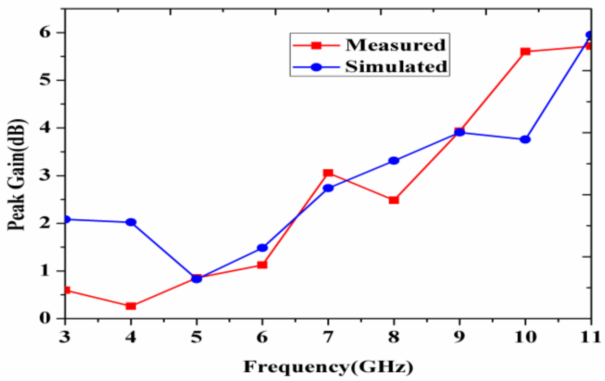

Figure 7. Measured and simulated peak gain of the antenna

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V. CONCLUSION

A low-profile monopole antenna fed with CPW feed is recommended. Ultra-wideband and circular polarization characteristic is achieved by two asymmetrical cuts. The antenna has low profile and it is easier to fabricate. The AR bandwidth of 1.1 GHz (13.3%) from 7.7 GHz to 8.8 GHz is obtained. A peak gain of 5.8dB is observed. The proposed structure is suitable for numerous applications like wireless personal area network, secure military communications, microwave imaging and situations like micro-disaster management. The antenna structure will find applications in satellite communication systems in form of array.

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