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# Circularly Polarized Uwb Monopole Antenna

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***Abstract***— This paper presents the design and analysis of a circularly polarized monopole antenna with an asymmetrical U shape radiator, a rectangular slot, and a ground plane. The antenna is fabricated using FR4 substrate having εr = 4.4, tanδ = 0.02. The antenna achieves a 3 dB axial ratio bandwidth of 4.0 GHz. The surface current distribution analysis reveals the excitation behavior and circular polarization generation of the antenna. The simulated radiation patterns demonstrate the left-handed circular polarization radiation in the broadside direction. The proposed antenna design offers wideband circular polarization performance and shows potential for various wireless communication applications.

**Index Term— Circular Polarization (CP), LHCP, Monopole, RHCP, UWB**

## I. Introduction

The circularly polarized ultra-wideband (UWB) monopole antennas have gained significant attention in modern wireless communication systems due to their ability to support wide bandwidths and circular polarization. These antennas are particularly suitable for applications such as wireless sensor networks, radar systems, and satellite communication, where efficient and robust signal transmission is crucial. Traditionally, circularly polarized antennas have been designed using microstrip patch technology. Microstrip circularly polarized (CP) antennas have been extensively studied, leading to innovative designs and improvements in their performance. The development of circularly polarized UWB monopole antennas addresses the increasing demand for high-performance wireless communication systems. Their wide bandwidth support allows for efficient transmission of UWB signals, which are characterized by their ability to carry large amounts of data over a wide frequency range. Furthermore, the circular polarization characteristic of these antennas offers advantages over linearly polarized antennas. It ensures that the rotational orientations of the transmitter and receiver antennas are unimportant in relation to the received signal strength, leading to more reliable and robust communication links. Printed monopole antennas are especially favored for their wide bandwidth support, compactness, affordability, lightweight nature, and ease of integration. Consequently, there has been considerable interest in developing printed monopole antennas capable of delivering wideband circular polarization. Various innovative designs in microstrip structure have been proposed in literature to enhance circular polarization response and achieve wide bandwidth performance, including lightning-shaped feed lines, L-shaped strip feeding, shorting-pin loading, and switchable slots [1]- [8]. CPW fed inverted L shaped circularly polarized monopole antenna is proposed in [9]. A split ring resonator shaped circularly polarized multiband monopole antenna is proposed in [10] for portable RF energy harvesting in IoT applications. Notably, a novel rhomboid shaped printed monopole antenna has been introduced in [11], designed specifically to achieve wideband circular polarization. Its geometry and configuration enable support for circular polarization across a broad frequency range, with added advantages of compactness, cost-effectiveness and lightweight design, rendering it suitable for diverse practical applications. Moreover, a broadband circularly polarized planar monopole antenna has been devised for ultra-wideband communication in [12]. This antenna features a modified annular ring patch fed by a tapered microstrip line, coupled with a rectangular partial ground plane on the substrate's opposite side. Wide axial ratio bandwidth is attained through the incorporation of a rectangular slot and a stub in the ground plane. An edge-placed printed monopole antenna using theory of characteristic modes for UWB is studied and presented in [13]. Another notable contribution is a planar monopole equipped with a fractal slot defected ground structure for circularly polarized radiation [14]. Circular polarization characteristics are achieved by enhancing the cross-polar component of the linearly polarized antenna through the integration of a fractal slot in the ground structure.

In this paper, a CP monopole antenna over a wide bandwidth is presented, achieving circular polarization through an asymmetric arm U shaped monopole structure placed asymmetric with respect to ground plane. The design yields a wideband axial ratio bandwidth.

## II. DESIGN PROCEDURE OF CIRCULARLY POLARIZED UWB MONOPOLE ANTENNA

### A. Geometry of the proposed antenna

The geometry of the presented antenna is shown is Fig. 1. It is composed of an asymmetrical U shape radiator with a rectangular slot and a ground plane. The antenna is designed using FR4 substrate with a relative permittivity εr = 4.4, tanδ = 0.02 and 1.6 mm thickness. The overall dimensions of the antenna are $23x29.7x1.6\ mm^3$. As printed monopole antenna is one of the best radiators having wideband impedance matching, the monopole is considered for the proposed design to achieve wideband CP characteristics. The proposed CP monopole antenna consists of a symmetrical U shape monopole combined with a slot and rectangular structure at its right arm. This asymmetrical monopole structure with offset feed excites the two orthogonal modes and provides the necessary 90degree phase difference between two orthogonal modes required for generating CP. The proposed structure is derived from a basic U shape monopole antenna.

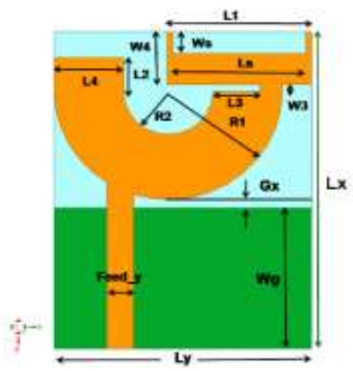


Fig. 1. Proposed UWB Monopole Antenna Structure

Table. 1. Dimensions for UWB Monopole Antenna Structure

| **Parameter** | **Value in mm** | **Parameter** | **Value in mm** |
|---|---|---|---|
| Lx | 29.7 | L4 | 6.2 |
| Ly | 23 | Ls | 11.7 |
| R1 | 10.2 | Ws | 2 |
| R2 | 4 | W3 | 0.7 |
| L1 | 12.7 | Gx | 0.8 |
| L2 | 3.2 | W4 | 4.9 |
| L3 | 4.2 | Feedy | 2.4 |

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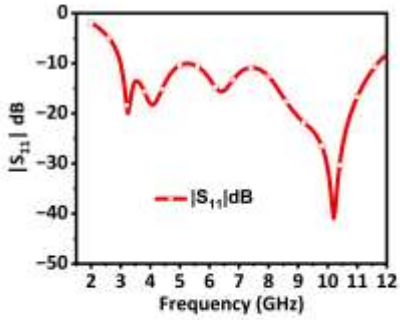



Fig. 2. Reflection coefficient vs Frequency

B. Working Principle and impedance matching

An asymmetrical U shape structure is created by reducing length of the left arm of a basic shape. Due to this current path length is reduced and impedance matching at lower frequencies is degraded. To increase the current path length and improve impedance matching the feed is offset from the center towards left arm of the antenna. Gap ‘Gx’ is optimized to achieve the required impedance matching. As most of the currents are vertical, a narrow slot is introduced at the right arm to increase the horizontal current direction. Narrow slot dimensions and locations are optimized 4.2x2 $mm^2$ and 15 mm from the ground plane respectively, length of left arm, ’L1’ and ground plane dimensions ’Ly’, ’Wg ’ are optimized to achieve wide impedance as well as axial ratio bandwidth. A rectangular structure of 12.7x3.2 $mm^2$ is introduced at the right arm to improve the orthogonal mode excitation. Further a slot is introduced in the rectangular structure to increase current path length and its dimensions are optimized to 11.7x2 $mm^2$.

## III. RESULTS AND DISCUSSION

Detailed study is conducted to get thorough understanding and analyzing the impact of various parameters, specifically rectangular slot dimensions, L1, Ls, W4and Ws on impedance matching and axial ratio. It is observed that the parameters contribute in maintaining the AR less than 3 dB within the AR bandwidth. The lower resonant frequency corresponding to 3 dB AR band is dependent on the asymmetric ground plane length on one side of antenna and the length of modified U shape radiator. Optimized dimensions of the proposed antenna are given in Table 1. Fig. 2 shows the S Parameters vs Frequency Graph and Fig. 3 shows the axial ratio (AR) variation with frequency. The impedance matching spanning frequency from 2.99 GHz to 11.79 GHz is achieved, along with the 3 dB axial ratio bandwidth from 5.57 GHz to 9.57 GHz. A surface current distribution is studied in order to understand the excitation behavior and and CP generation by the proposed antenna.

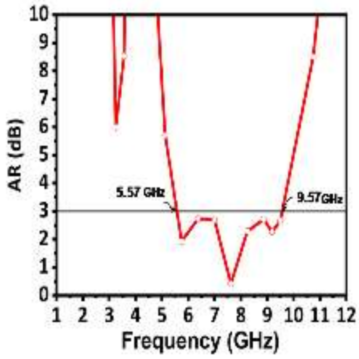
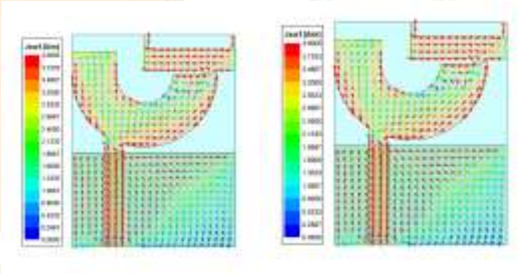


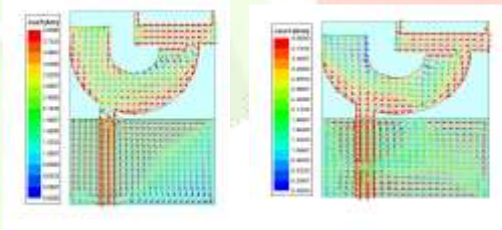

Fig. 3. Axial ratio of proposed CP UWB antenna

## IV. CURRENT DISTRIBUTION ANALYSIS

Fig. 4. shows the simulated surface current distributions at different phase angles instant $\Phi = 0^{\circ}$, $\Phi = 90^{\circ}$, $\Phi = 180^{\circ}$, $\Phi = 270^{\circ}$ of the wave at 6 GHz. Induced current at left side of U shape near to feedline rotates in clockwise direction, which indicates LHCP generation.



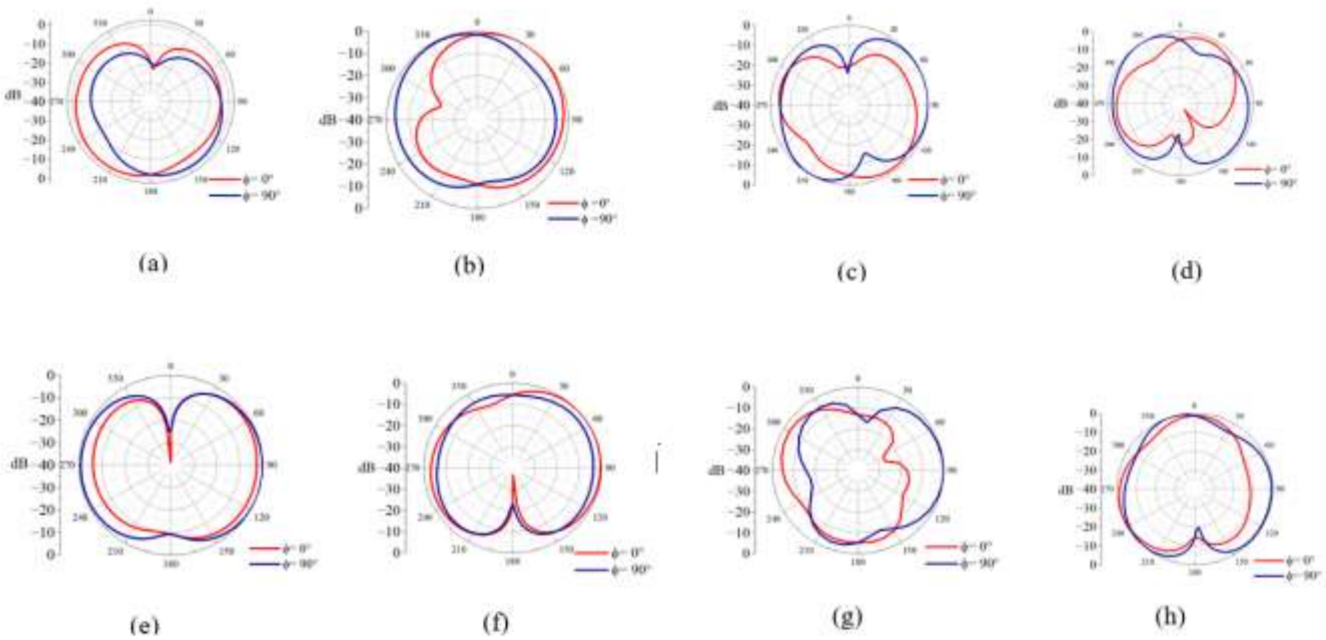
(a) (b)



(c) (d)

Fig. 4. Current Distribution Analysis of UWB monopole Antenna
(a) $\Phi = 0^{\circ}$ (b) $\Phi = 90^{\circ}$ (c) $\Phi = 180^{\circ}$ (d) $\Phi = 270^{\circ}$

## V. RADIATION CHARACTERISTICS




## VI. FABRICATION AND MEASUREMENTS

The proposed CP UWB monopole antenna is fabricated and measured as shown in Fig. 7. The measured reflection coefficient varying with respect to frequency is shown in Fig. 9. The measured results shows the good agreement with th

Fig. 5. Radiation Pattern (a) LHCP at 6 GHz,(b) RHCP at 6 GHz, (c) LHCP at 7.5 GHz ,(d) RHCP at 7.5 GHz ,(e) LHCP at 9 GHz, (f) RHCP at 9 GHz ,(g) LHCP at 10 GHz ,(h) RHCP at 10 GHz

Fig. 5. Shows the simulated radiation patterns in X-Y and Y-Z planes at four different frequencies of 6 GHz, 7.5 GHz, 9 GHz and 10 GHz respectively. It is clearly seen that the proposed antenna radiates a right-handed circular polarization (RHCP) wave in broadside direction. The radiation pattern is not very symmetrical with respect to the Z-direction due to the asymmetry of the offset feeding network and the ground plane in the direction of maximum radiation the co-polarized (RHCP) field is more than 10 dB stronger than corresponding cross polarized (LHCP) counterparts for most of the frequencies, showing good polarization of CP field. Fig. 6 shows VSWR of the proposed design. Here, the aim was to achieve maximum AR bandwidth. 3 dB, AR bandwidth of 4.0 GHz is achieved using the proposed antenna geometry.

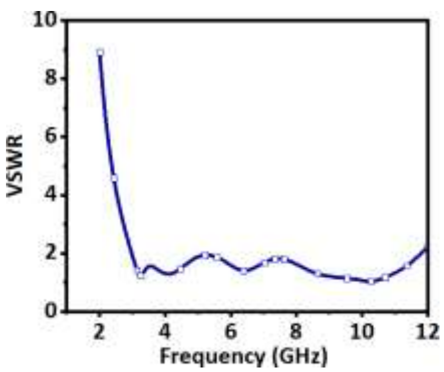



Fig. 6. UWB antenna VSWR

Fig.7. Fabricated UWB Monopole Antenna


Fig. 8. Experimental setup to measure transmission and reflection for the Exponentially Tapered SIW based FSS structure.

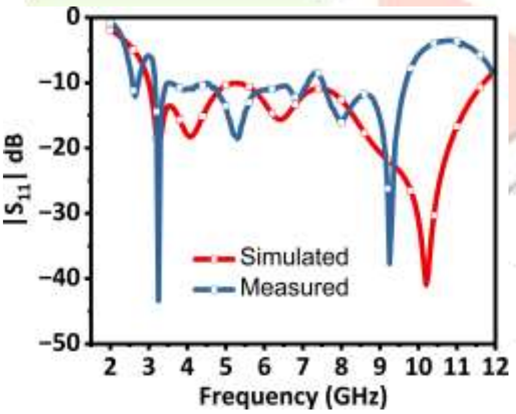



Fig. 9. Comparison of Measured and simulated Reflection Coefficient vs Frequency response of fabricated UWB Monopole antenna

## VII. CONCLUSION

In this paper, a UWB monopole antenna with wideband circular polarization is presented. An asymmetric structure is helpful in generating the CP characteristics by exciting vertical and horizontal component equally. The antenna achieved a 3dB axial ratio bandwidth if 4 GHz making the antenna suitable for wideband circular polarization applications. The surface current distribution illustrates the mechanism of circular polarization generation. Simulated and measured return loss are compared shows good agreement.

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