

Circularly Polarized Antenna Design Using Microstrip-To-CPW Transition for Ultra-Wideband Applications

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Abstract— This paper introduces a circularly polarized monopole UWB antenna with a microstrip-to-coplanar waveguide (CPW) feed. By giving two symmetrical cuts on both sides of the radiator with opposite orientation, the impedance bandwidth as well as axial ratio bandwidth can be enhanced. An experimental prototype is fabricated and subsequent measurements are carried out. The measured impedance bandwidth covers the ultra-wideband range (3.1-10.6 GHz). The measured axial ratio bandwidth is about 1.55 GHz (16.2%) from 8.75 GHz to 10.3 GHz.

Index Terms— Axial Ratio; Transition; Ultra-Wideband

I. INTRODUCTION

In recent years, printed monopole antennas have made more interest among researchers, since they possess many attractive features such as low profile, simple structure, light weight, wide impedance-bandwidth, and omnidirectional radiation patterns. In these antennas, microstrip transmission line is most commonly used. However, a coplanar waveguide (CPW) feed makes planar antennas more suitable for wireless communication system because of its features like uniplanar structure, easy fabrication and circuit integration with solid state devices, low radiation loss, less dispersion etc. [1]. Thus, a transition from microstrip-to-CPW is required. Transitions minimize the mismatch and coupling between different circuit elements [2]. A coplanar waveguide to microstrip transition has been reported by M. E. Safwat et.al. in [3]. For better performance in the multipath fading environment and for superior signal reception, the antenna must have polarization diversity characteristic. As this characteristic is found to be effective in combating the destructive effects of multipath fading and thus supports higher data rates [4]. For this, circular polarization (CP) has become accepted as one of the very important characteristics of an ultra-wideband (UWB) antenna. However, it is difficult to achieve, because it depends upon two orthogonal components of the electric field in exact phase quadrature. In [5], a LI shaped monopole antenna is presented to obtain UWB by utilizing different surface current paths. An overlapping harmonic frequency responsible for UWB configuration is suggested in [6]. However, [7]-[9] applies multi current path concept in U-shaped monopoles to enhance the bandwidth.

Monopole structure presented in [10] adopted step shaped ground plane configuration to enhance return loss bandwidth (~5.96 GHz) as well as axial ratio (AR) bandwidth (~2.64 GHz). Circular polarization using aperture coupling technique is reported in [11]. A circular polarization

reconfigurable antenna is presented by W. Lin and H. Wong [12]. To achieve CP characteristics, they used Wilkinson power divider, which feeds two sequential arms located on different substrates. D. M. Elsheikh et.al. achieved CP characteristics by etching a small gap in the elliptical loop monopole [13]. An UHF/ UWB tag antenna of circular polarization is suggested by X. Gao and Z. Sen [14]. They utilized two pairs of asymmetrical meander lines to realize miniaturization and CP. Techniques presented in [15]-[17] gives UWB as well as CP configuration, but the antennas are larger in size.

In antenna array configurations, via hole/pin technique is used to convert the microstrip modes to CPW modes, which are not cost effective and deals with fabrication difficulties. So microstrip-to-CPW transition method can be adopted to solve the problem. Initially, a simple patch is designed using CPW feed. Two symmetric cuts with opposite orientation are given in both sides of the patch to achieve UWB and CP radiation. Later, a microstrip section and a transition section is designed. The impacts of different parameters on the characteristics of the antenna are investigated in next subsections. Finally, an experimental prototype is fabricated and measured.

II. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Figure-1. The proposed structure consists of a radiator with two symmetric cuts on both sides, fed by a coplanar waveguide and a microstrip-to-CPW transition. Here, a simple microstrip-to-CPW transition technique is proposed using stubs in the ground plane of CPW which also helps in mode matching. The proposed antenna is printed on a FR4 substrate of size 'L × W' with a dielectric constant 4.4, thickness 1.6mm and a loss tangent of 0.002. Both the patch and the feed line are etched on the same surface of the substrate, and so are the two rectangular grounds of CPW with size 'L_{gc} × W_{gc}', which are on the both sides of the CPW feed line having width 'w_{cf}'. The ground plane of microstrip is shortened with size 'L₁ × W₁' and is etched on the back side of the substrate. The gap between the ground and feed line of CPW 'g' is maintained to have 50Ω impedance. At the microstrip section, impedance decided by feed width 'W_{mf}' matches the source impedance of 50Ω. The proposed radiator and the photograph of the fabricated prototype is shown in Figure-2. Step cut method is used in

the antenna structure to increase the impedance and AR bandwidth. The proposed antenna can be operated within the UWB spectrum by optimizing these parameters. Transition from microstrip to CPW is achieved by stub 's1 × s2'. For simulation, Ansoft (HFSS) v.13 software is used. A 50Ω SMA connector is used to excite the antenna. The optimized parameter values (unit-mm) are listed in Table-1.

Table 1
Optimal parameter values of the proposed antenna.

Parameters	Value in mm
h	1.6
L	46.47
W	31
Wp	21
Lp	17
Wgc	14.53
Lgc	11.8
Wcf	1.5
g	0.22
Wmf	2.6
a	3
b	14
c	3.5
d	10.5
G	0.67

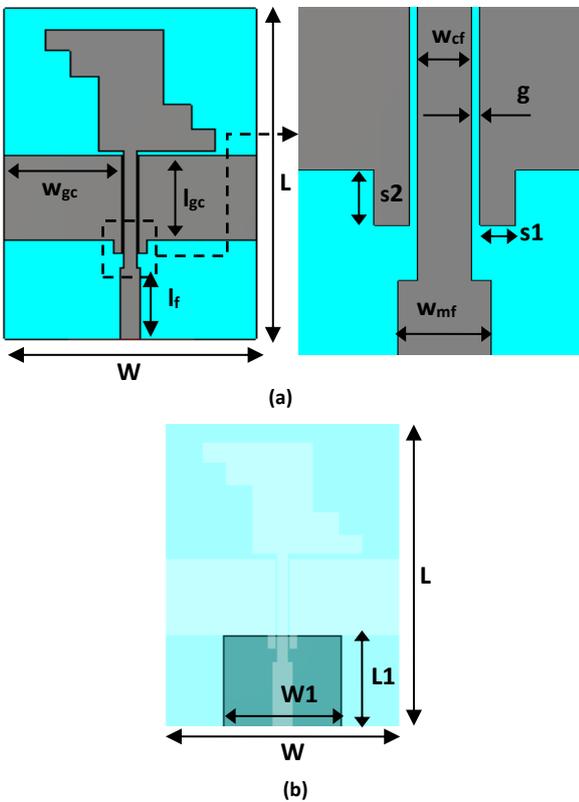


Figure 1: Proposed antenna (a) Front view (b) Back view

III. EVOLUTION OF THE ANTENNA

For the proposed antenna the optimized values of g and w_{cf} are taken as 0.22mm and 1.5mm respectively. Several simulation studies have been done for 'G', which helps in impedance matching between the feed and patch. The best value of G is 0.67mm. The improvement in the return loss

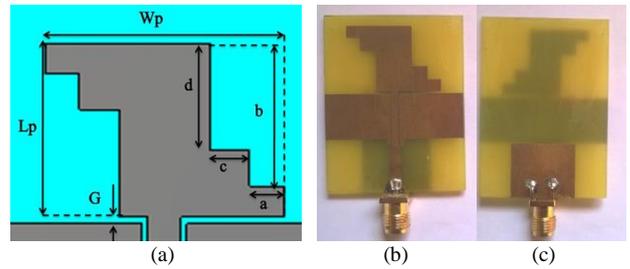


Figure 2: (a) Proposed radiator (b) Photograph of the fabricated prototype-front view (c) Photograph of the fabricated prototype-back view

and axial ratio (AR) are achieved through changes in the geometry of the radiator step-by-step as shown in Figure-3 and Figure-4 respectively.

It can be observed that, the initial geometry L_p × W_p does not give significant result in impedance bandwidth and CP is not obtained. Slight improvement in impedance bandwidth is achieved by introducing the first cut having dimension b × a. But, CP is not achieved.

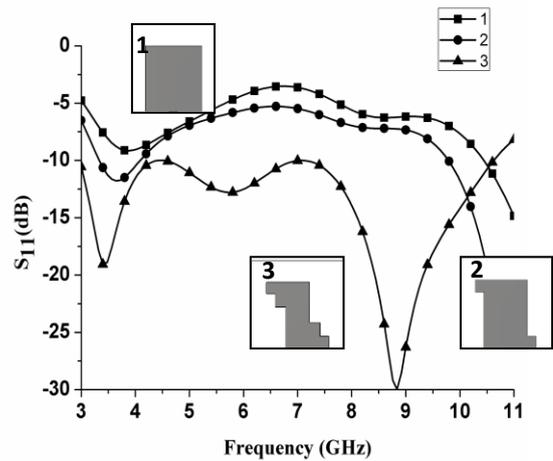


Figure 3: Simulated return loss at three different patch configuration.

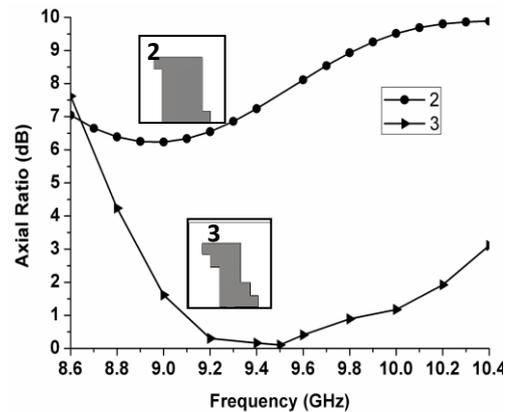


Figure 4: Simulated AR at two different patch configuration

The second cut d × c in both sides enhances the impedance bandwidth that covers entire UWB spectrum. The final structure exhibits CP from 8.89 GHz to 10.39 GHz. From the above study, the sizes of the first and second cuts are found to be 14 × 3 mm² and 10.5 × 3.5mm² respectively. The analysis of cuts on impedance bandwidth and AR bandwidth were done without implementing the microstrip-to-CPW transition.

IV. PARAMETRIC STUDY

Repeated simulations have been carried out by judiciously choosing each parameters of the proposed structure. In every study only one parameter is varied, while others are taken constants. Behaviors of the antenna to each parameter is gathered in next sub sections.

A. Effect of $L1$ on S_{11} result

The effect of variation of shortened ground plane length ' $L1$ ' on return loss result is shown in Figure-5, while the parameter $W1$, $s1$, $s2$ are taken constant. $L1$ is varied from 11mm to 15mm. It can be studied that, S_{11} is below -35dB for 11mm, 12mm and 15mm but it is not covering the entireUWB band. The entire UWB range is covered for the values of $L1$ as 13mm and 14mm. The optimized value of $L1$ is obtained as 14mm viewing a good AR andUWB bandwidth.

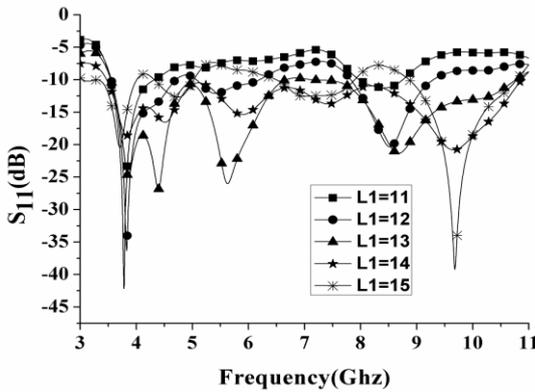


Figure 5: Effect of variation of $L1$ on S_{11} result

B. Effect of $W1$ on S_{11}

Here, the shortened ground plane width ' $W1$ ' is varied from 13.5mm to 21.5mm as shown in Figure-6keeping $L1$, $s1$, $s2$ parameters of the antenna as constant. From various simulations it can be found that the antenna covers entire UWB band when the value of $W1$ is between 13.5mm~15.5mm. The value of $W1$ is judiciously chosen as 15.5mm for good return loss bandwidth as well as good AR bandwidth.

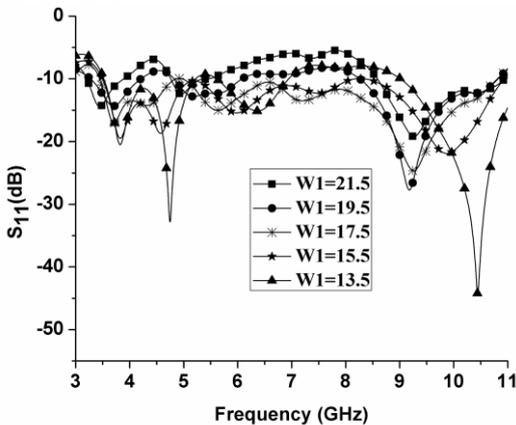


Figure 6: Effect of variation of $W1$ on S_{11} result

C. Effect of $s1$ and $s2$ on S_{11}

The effect of variation of stub parameter $s1$ and $s2$ is studied, keeping the shortened ground plane size $L1 \times W1$ constant as shown in Figure-7 and Figure-8respectively. For a good AR and return loss bandwidth the parameter $s1$ is

varied from 0.8mm to 1.4mm and parameter $s2$ is varied from 0.4mm to 2.4mm. The optimized values of ' $s1$ ' and ' $s2$ ' are obtained as 1mm and 2mm respectively.

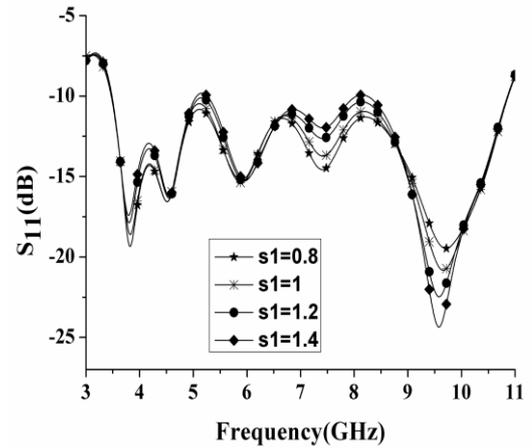


Figure 7: Effect of variation of $s1$ on S_{11} result

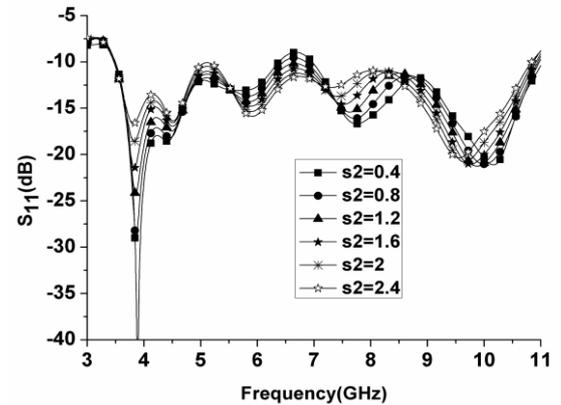
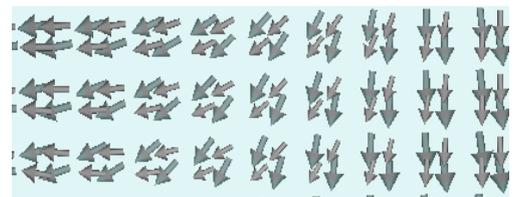


Figure 8: Effect of variation of $s2$ on S_{11} result

D. Circular Polarization

The implemented cuts in the structure, excites both vertical and horizontal components of surface current as shown in Figure-9(a). These two components are responsible for CP characteristic of the patch. The simulated time varying surface current distribution of the patch at 9.5 GHz in phase instants of 0° , 90° , 180° and 270° are shown in Figure-9(b). 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° . Clockwise rotation is observed in the surface current distribution which implies the presence of right hand circular polarization (RHCP) behavior



(a)

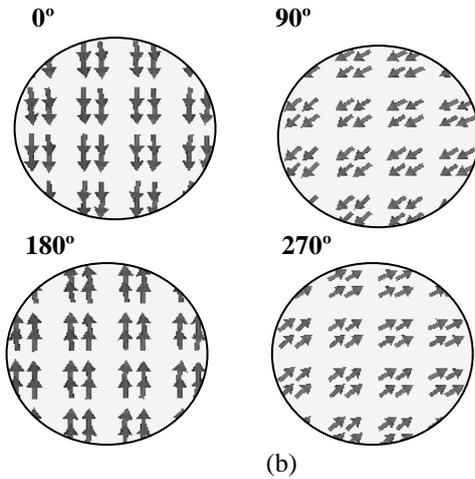


Figure 9: (a) Presence of horizontal and vertical current on the surface of the patch (b) Simulated surface current distribution at 9.5GHz

V. EXPERIMENTAL VERIFICATION

A. Impedance bandwidth and AR bandwidth

The implemented dimensions of proposed structure are chosen to achieve the optimum performance as described in section-4. The impedance bandwidth of the proposed structure is measured using vector network analyser (R&S® – 10 MHz to 20 GHz). The simulated and experimental results are in agreement with each other except at some points as shown in Figure-10. The discrepancy is due to the fabrication and soldering of the connectors, which was done manually. The measured RL bandwidth, defined by $S_{11} < -10\text{dB}$, covers UWB range. The simulated and measured AR of the proposed antenna is presented in Figure-11. Measured result exhibits 1.55 GHz (16.2%) AR bandwidth from 8.75 GHz to 10.3 GHz. The mismatch in the simulated and measured results are due to the test environment.

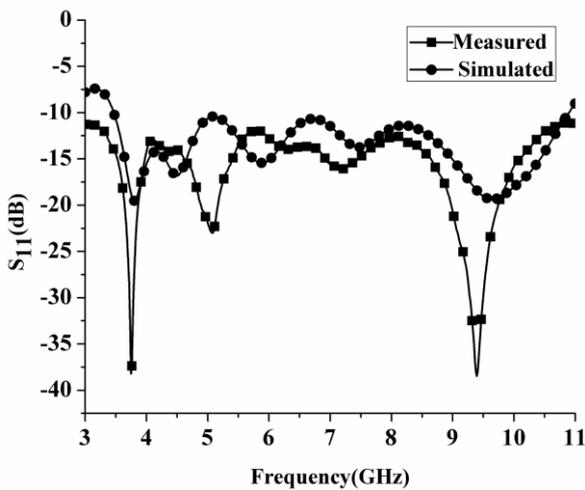


Figure 10: Simulated and measured S_{11} result

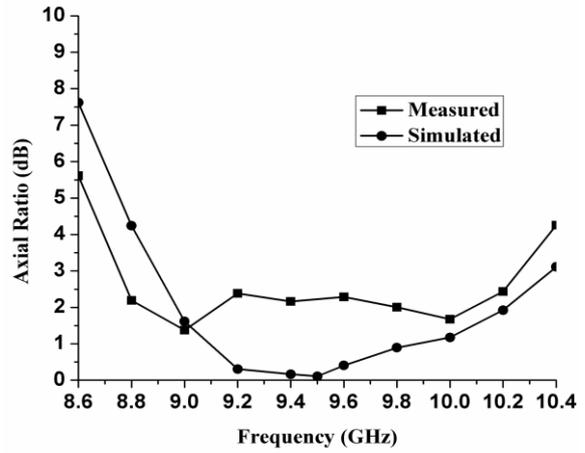


Figure 11: Simulated and measured AR result

B. Radiation pattern and gain

The measured normalized radiation pattern of the proposed antenna at 5 GHz and 7 GHz are shown in Figure-12(a) and (b) respectively. It can be observed that, the patterns obtained matches with the conventional monopole antenna, except at some places. The mismatch is due to the manual alignment of the antenna during measurement. The measured peak gain of the proposed antenna is shown in Figure-13. It shows a minimal variation of gain with frequency

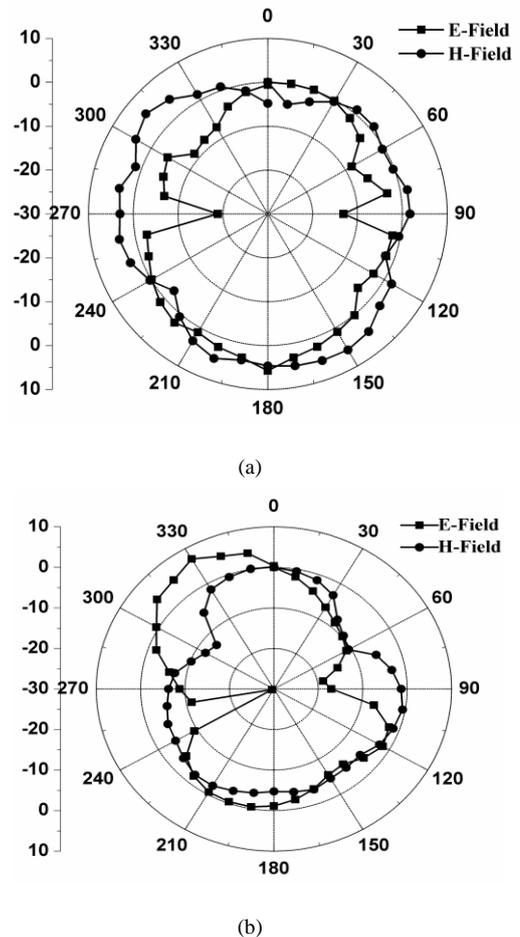


Figure 12: Measured radiation patterns at (a) 5GHz (b) 7GHz

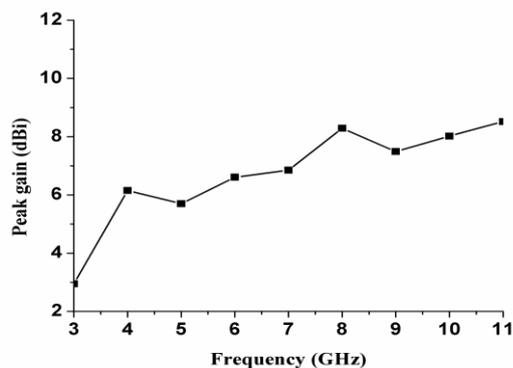


Figure 13: Measured peak gain of the antenna

VI. CONCLUSION

A monopole antenna has been designed with circular polarization characteristics using microstrip-to-CPW transition. The proposed antenna is easier to fabricate. The impedance bandwidth covers the UWB range and an AR bandwidth of 1.55GHz (16.2%) from 8.75GHz to 10.3GHz is achieved. The peak gain of the antenna is 8.5dBi. The recommended antenna structure can be implemented in various application areas, viz. WPAN, microwave imaging, military communications, radar and satellite communications.

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