# Broadband Polarization Reconfigurable Circularly Polarized Rectangular Slot Antenna

[1]Rohit Kumar Saini, [2]Pawan Kumar

[1]Assistant Professor, [2]Assistant Professor
[1]Faculty of Engineering,
[1]Teerthanker Mahaveer University Moradabad (U.P.), India
[2]Department of Electronics and Communication Engineering,
[2]Vignan's Foundation for Science Technology and Research (Deemed to be University), Andhra Pradesh, India.

***Abstract:*** A CPW fed circular polarized rectangular slot antenna having polarization switching capability is proposed. The antenna consists of a cross shaped feedline, two rectangular parasitic patches, and two stubs connected to ground of antenna by pin-diodes. Switching of its polarization from RHCP to LHCP is obtained by proper control of on and off states of PIN-diodes. By adjusting the length of the grounded strip and size of the parasitic patches, the measured circular polarized bandwidth is obtained as high as 23.21% (1.6GHz-2.02GHz) with AR ≤ 3dB. Impedance bandwidth of 45.36% (1.5GHz-2.38GHz) with VSWR ≤ 2 is achieved.

***Index Terms* - Slot Antenna, Circular Polarization, Reconfigurable Antenna, Switchable Polarization, and Coplanar Waveguide (CPW)-feed.**

## I. INTRODUCTION

CIRCULAR Polarized (CP) antennas have become very popular as it does not cause polarization mismatch between transmitter and receiver in case of their different orientations also. However, fading caused by multipath propagation can degrade received signal quality severely. In such situation, polarization diversity becomes very popular in modern communication systems to suppress fading. Polarization reconfigurable antennas by altering polarization characteristics can be used in polarization diversity system. Several CP antenna architectures had been proposed for this purpose.

Polarization reconfigurable patch antennas with slots on their radiating patches are presented in [1]-[25], where switching between two states of polarization is achieved with the help of PIN diodes . In [6] – [7], polarization reconfigurable perturbed slot antennas are proposed where switching were done using pin diodes placed in the slots. By reconfiguring feeding arrangement, switchable CP was obtained in [8]– [10]. In [11], configurability of polarization of a CP patch antenna was achieved by changing the corner perturbation by pulling down one piezoelectric transducer and lifting up the other one. However, axial ratio bandwidth of the antennas proposed in [1]-[11] are less than 9%. Printed CP wide slot antennas have inherent broad axial ratio (AR) bandwidth [12]. Coplanar waveguide (CPW) feed has many advantages [13]. A square slot CP reconfigurable antenna fed by CPW having AR bandwidth of about 11% was proposed in [14].

In this paper, a broadband CPW- fed reconfigurable rectangular slot CP antenna having polarization switching capability between right hand circular polarization (RHCP) to left hand circular polarization (LHCP) is proposed and experimentally studied. The designed antenna has a cross shaped feedline, two rectangular parasitic patches, and two stubs connected to ground by PIN-diodes. The structure of the antenna is simple, compact, and easy to fabricate. Proposed antenna has much larger AR bandwidth in comparison to [1]-[11] and [14].

## II. ANTENNA CONFIGURATION

As shown in Fig. 1 the structure is designed on a FR4 of $\varepsilon r$ of 4.4, tan $\delta$ of 0.00205, and h of 1.6 mm. It consists of a rectangular ON-state and a capacitance of 0.21pF for the OFF-state.

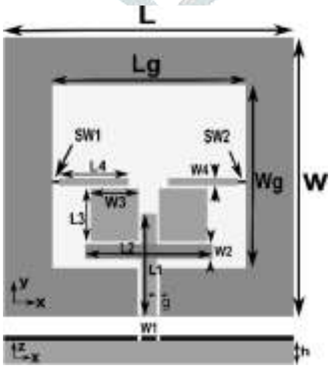


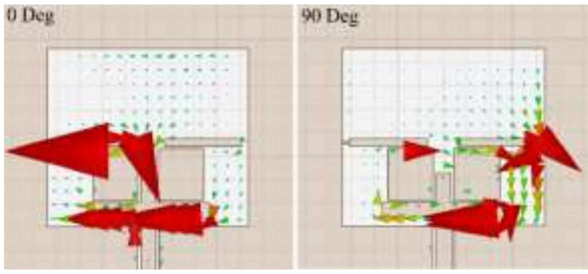

Fig.1. Geometry of the proposed polarization reconfigurable CP rectangular slot antenna.

(L=64, W=58, Lg=44, Wg=38, L1 = 21.3, W1=3.2, g=0.7, h=1.6, L2 = 26.4, W2=3.2, L3 =11, W3=10, L4 = 18.2, and W4=1.6) (Unit: millimeters).

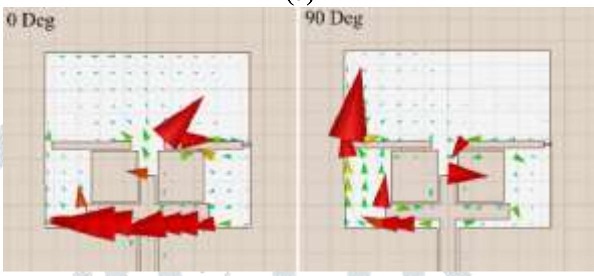
Slot of size Lg×Wg, a cross shaped feed line, a pair of patches of sizes W3×L3, and a pair of identical straight strips having lengths L4 and widths W4 connected to the centers of the two opposite inner sides of the ground plane by pin-diodes (SMP1340). CPW feed having 50 Ω characteristic impedance is used for the antenna. Two pin-diodes SW1 and SW2 are used for switching between two CP states. Turning a specific p-i-n diode on and other one off, the antenna can operate with RHCP and by interchanging the states of the p-i-n diodes, LHCP radiation can be obtained. A commercial electromagnetic solver.

### III. MECHANISM OF CIRCULAR POLARIZATION(MSD)

MCD observed from +Z direction keeping one of the PIN-diodes on and other one off at the $f_c$ of 1.75GHz at two phases: $\omega t = 0^0$, $90^0$ are shown in Fig. 2. When the SW1 is in on condition and SW2 in off condition, the MCD is in anti-clockwise direction. So, in +Z direction obtained radiation would be RHCP, and that in –Z direction would be LHCP.




(a)




(b)

Fig. 2. Magnetic current distribution at 1.75GHz (a) diode 1 on diode 2 off and (b) diode 1 off diode 2 on; for proposed antenna at two different time instants: $\omega t = 0^o$ and $90^o$

Similarly, Fig. 2(b) shows the MCD for SW1 off and SW2 on at the fc of 1.75GHz at two phases: $\omega t = 0^0$, $90^0$ observed from the +Z direction. In +Z direction obtained radiation would be LHCP, and that in –Z direction would be RHCP because rotation of magnetic current is clockwise in this case.

### IV. ANTENNA DESIGN AND ANALYSIS

Sequential improvement is shown by four antennas of Fig. 3. Taking a quarter wavelength (with respect to the first resonating frequency of the slot) long straight feed as shown in Ant 1 of Fig.3, the slot can generate linear polarized wave. Guided wavelength is considered as $\lambda g = \lambda o/\sqrt{\varepsilon e}$, where $\lambda 0$ is free space wavelength and $\varepsilon e = (\varepsilon r + 1)/2$. Then, placing two metallic strips connected to the center of the two opposite sides of the slot edges by p-i-n diodes and turning one of them on as shown in Ant 2, E- field of the slot is perturbed and two orthogonal E- field components having same magnitudes and quadrature phases are excited as the strip connected to the switched on p-i-n diode acts as grounded stub. Here, feed length is adjusted to get best possible impedance matching. Then, placement of pair of rectangle shaped parasitic patches as in Ant 3 improves axial ratio bandwidth. It reduces also the operating frequency of CP operation because due to the patches the paths of the magnetic current become zigzag and thereby lengthy. In Ant 1 to Ant 3, except length of the feed lines, other dimensions of the antennas are kept to the optimized values. Finally placement of horizontal braches of the feed line as shown in Ant 4 increases the AR bandwidth further, reduces operating frequency of CP operation more, and improves the impedance matching a lot.

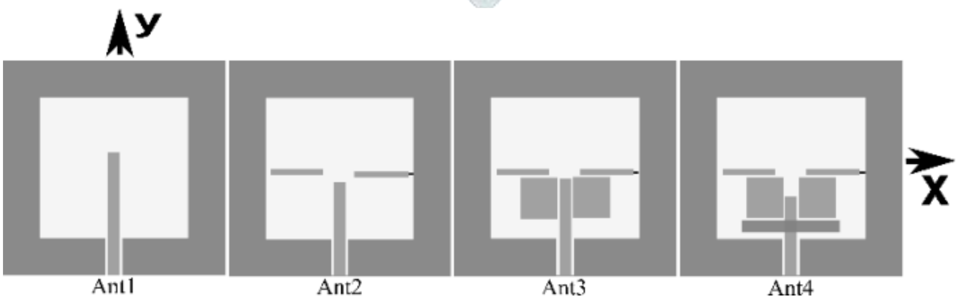
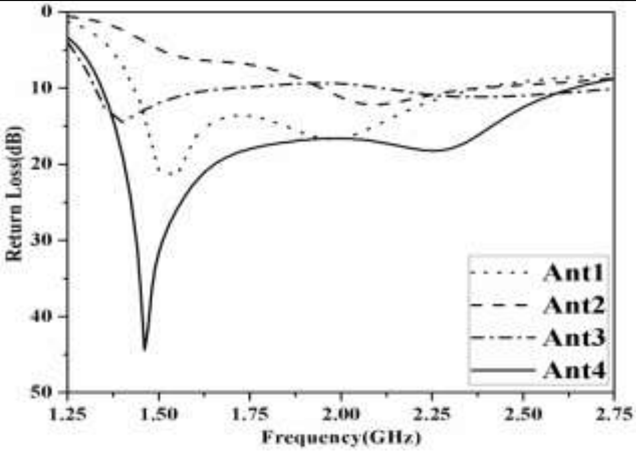
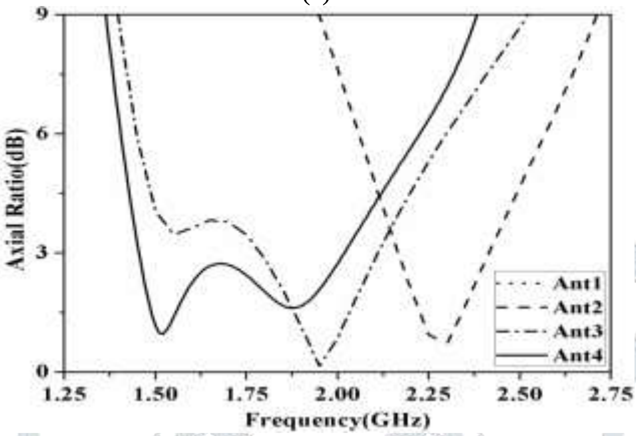



Fig. 3. Steps of improvement of the proposed antenna.



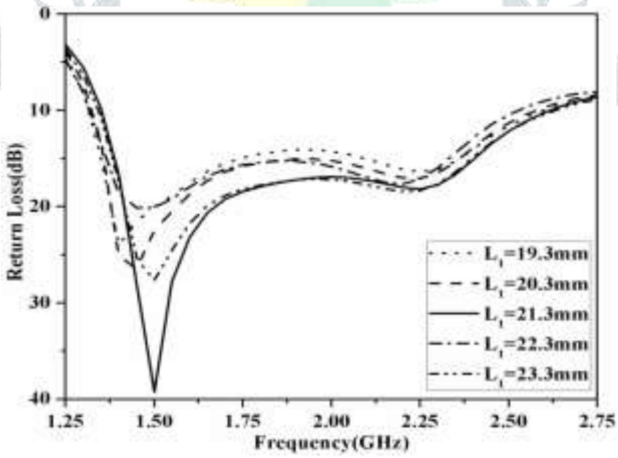

(a)



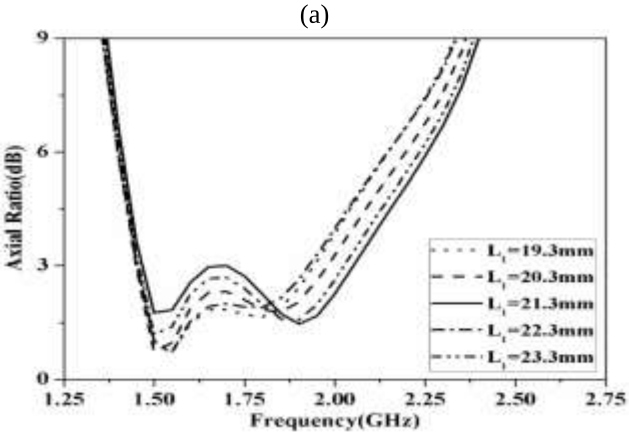

(b)

Fig.4. Simulated diagrams of (a) the return loss (dB) and (b) the axial ratio for Ant 1-4.

To obtain good performance, optimizing different parameters one by one and observing their effects on the impedance, and axial ratio bandwidth of the antenna, the different dimensions of the proposed antenna have been selected. The parameters of the feed line have more effect on impedance matching as shown in Fig. 5(a) & 6(a). However, they have also some effect on AR as shown in Fig. 5(b) & 6(b) because its dimension perturbs the MCD within the dielectric part of antenna. It is observed that max ARBW is achieved when $L_1$=21.3 mm, and $L_2$=26.4 mm.

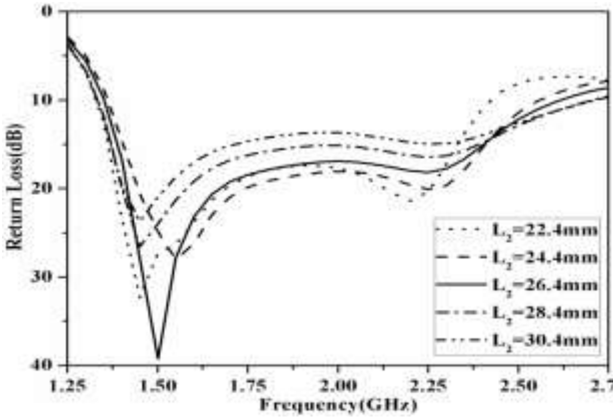



(a)

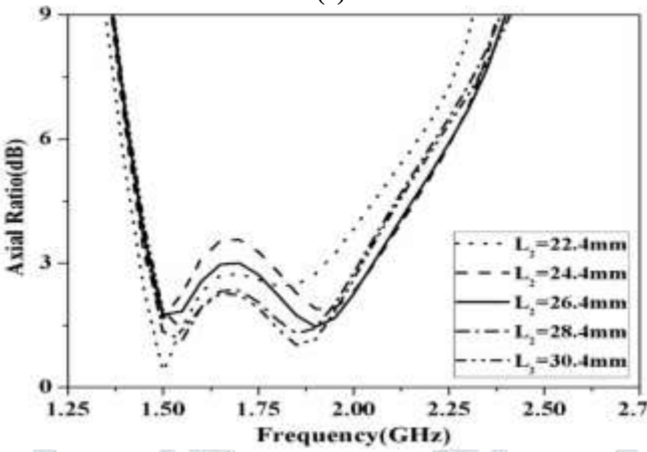



(b)

Fig. 5.Effect of parameter $L_1$on antenna parameters: (a) the return loss (b) the axial ratio.



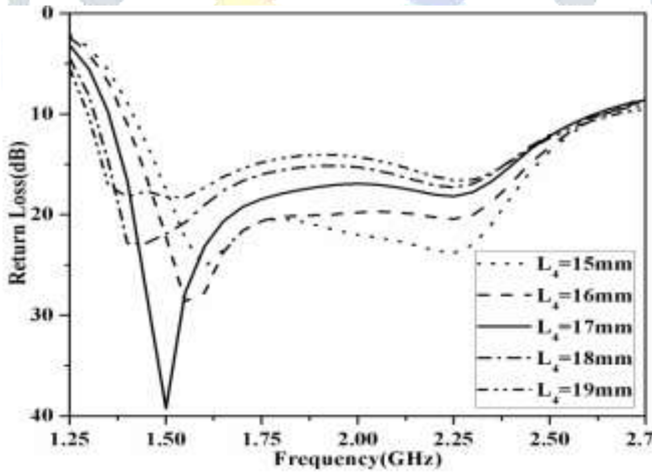

(a)



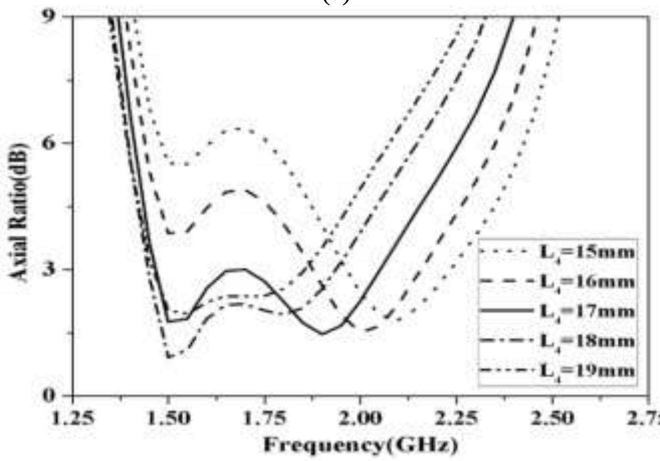

(b)

Fig. 6. Effect of parameter L2 on antenna parameters: (a) the return loss (b) the axial ratio.

Figure 7(a) and (b) show the effect of length L4 of strips on antenna performance. It has been seen that length of strips has more effect on AR and AR bandwidth is maximum when L4=17 mm.



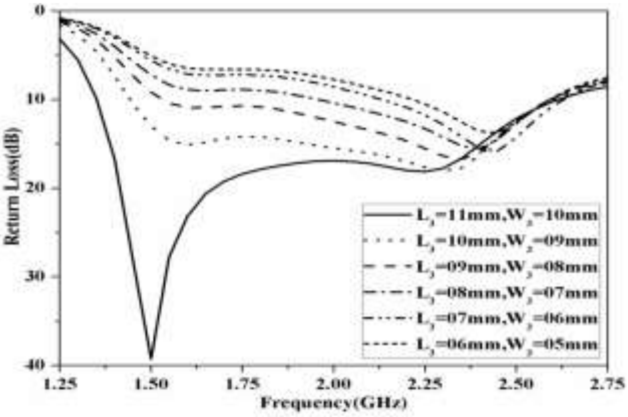

(a)



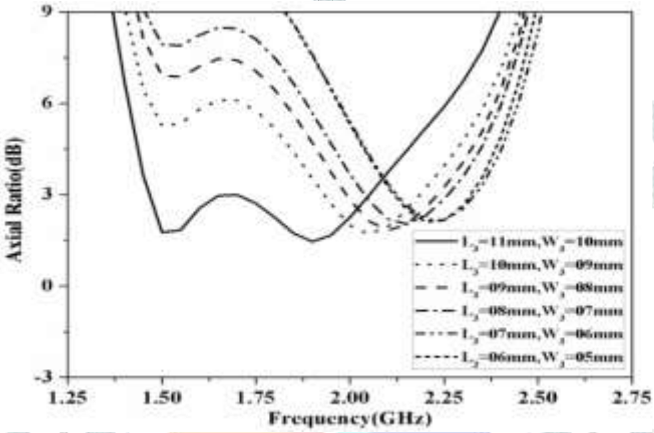

(b)

Fig. 7. Effect of the Length of strips on antenna parameters: (a) the return loss (b) the axial ratio.

Figure 8(a) and (b) show the effect of parasitic patches on antenna performance. Variations of the size of the patches are done with respect to their center points. It has been observed that patches have effect on AR because they perturb the magnetic current distribution within the slot. They have effect on impedance matching also as they are very close to feed lines. Best performance of the antenna in terms of both impedance matching and AR is observed when L3=11 mm, and W3=10 mm.




(a)




(b)

Fig. 8. Effect of the length & width of parasitic elements: (a) the return loss (b) the axial ratio.

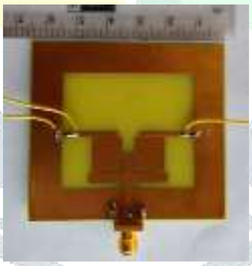


Fig.9. Photograph of the fabricated antenna

## V. RESULT AND DISCUSSION

The fabricated antenna is shown in Fig. 9. When the pin-diode SW1 is in on condition and SW2 is in off condition, RHCP is obtained. On the other hand, when SW2 in on condition and SW1 in off condition, LHCP is obtained in +Z direction.

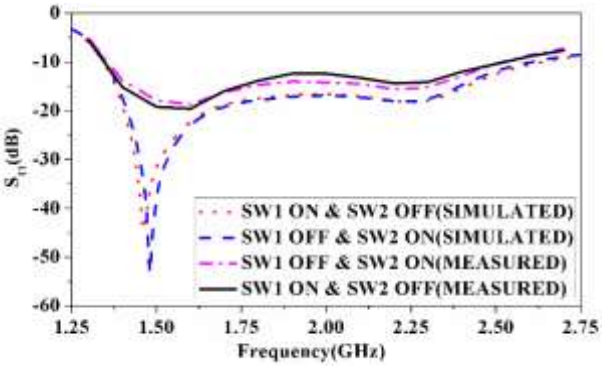



Fig. 10 Simulated & Measured S11(dB) of the proposed geometry of antenna.

The result of measured and simulated reflection coefficient are shown in Fig.10. The return-loss bandwidth of the fabricated antenna has the frequencies from 1.5GHz to 2.38GHz.

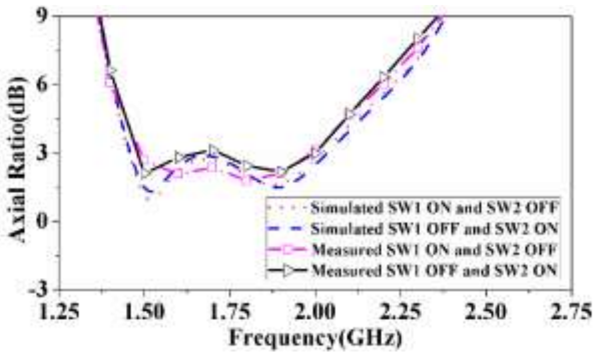



Fig. 11. Measured and simulated AR curvesof the proposed antenna.

Figure 11 illustrates the measured and simulated axial ratio. The measured CP bandwidth determined by the 3-dB AR is about 420 MHz or 23.21% (1.6GHz–2.02GHz).

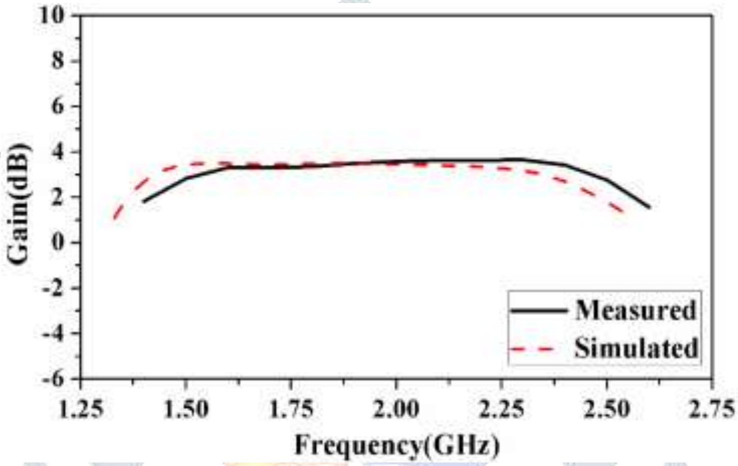
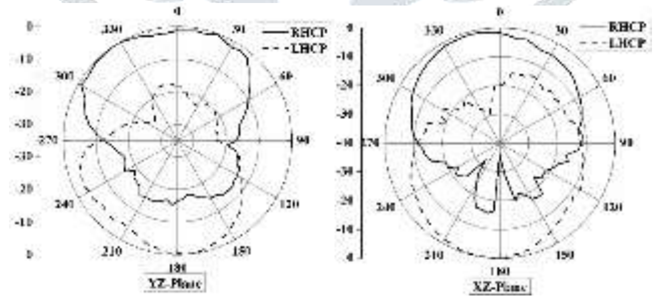
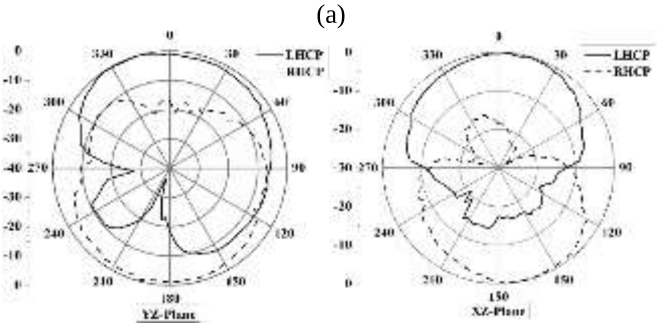



Fig. 12. Measured and simulated gain in +Z direction of the proposed antenna.

Figure 12 shows the gain of the final antenna. The gain deviates from 1.5dB to 3dB in ARBW. Figures 13 show the radiation patterns of the antenna at 1.75GHz. Cross polarization level is about 18 dB lower than co-polarization in the direction of maximum radiation (+z). When the pin-diode SW2 is in on condition and SW1 in off condition, the polarization is reversed. There is some mismatches between the results due to non-perfect fabrication.




(a)




(b)

Fig. 13. Measured radiation patterns at 1.75GHz of the proposed antenna (a) SW1 on & SW2 off and (b) SW1 off & SW2 on.

## VI. CONCLUSION

A broadband polarization diversity antenna is presented with a cross shaped CPW feed, a pair of patches and a pair of stubs. The final antenna has wide impedance bandwidth of 45.36% (1.5GHz-2.38GHz) and AR bandwidth of 23.21% (1.6GHz-2.02GHz). The proposed antenna is useful in Global Positioning System (GPS; 1.575GHz) and Digital Communication System (DCS; 1.71-1.88GHz).

## REFERENCES


[1]. Y.B. Chen, X.F. Liu, Y.C. Jiao and F.S. Zhang., CPW-fed broadband circularly polarized square slot antenna, Electron. Lett., 42(19) (2006).

[2]. C.C. Chou, K.H. Lin and H.L. Su., Broadband circularly polarized cross-patch-loaded square slot antenna, Electron. Lett, 43(9) (2007).

[3]. C.H. Chen, E.K.N. Yung, and B.J. Hu., Miniaturised CPW-fed circularly polarized corrugated slot antenna with meander line loaded, Electron. Lett., 43(25) (2007).

[4]. Chien-Jen Wang and Chih-Hsing Chen., CPW-Fed Stair-Shaped Slot Antennas With Circular Polarization, IEEE Trans. Antennas Propagation, 57(8) (2009).

[5]. Jia-Yi Sze, Chung-I. G. Hsu, Zhi-Wei Chen, and Chi-Chaan Chang., Broadband CPW-Fed Circularly Polarized Square Slot Antenna With Lightening-Shaped Feedline and Inverted-L Grounded Strips, IEEE Trans. on Antennas and wireless propagation letters, 58(3) (2010).

[6]. K. M. Chang, R. J. Lin, I. C. Deng, J. B. Chen, K. Q. Xiang, and C. J.Rong., A novel design of a CPW-fed square slot antenna with broadband circular polarization, Microw. Opt. Technol. Lett., 8(12) (2006) 2456–2459.

[7]. I. C. Deng, J. B. Chen, Q. X. Ke, C. J. Rong, W. F. Chang, and Y.T. King., A circular CPW-fed slot antenna for broadband circularly polarized radiation, Microw. Opt. Technol. Lett., 49(11) (2007) 2728–2733.

[8]. Shui-Wei Zhou, Ping-Hui Li, Yang Wang, Wei-Hua Feng, and Zong-Quan Liu., A CPW-Fed Broadband Circularly Polarized Regular-Hexagonal Slot Antenna With L-Shape Monopole, IEEE Antennas and wireless propagation letters, 10 (2011).

[9]. Jia-Yi Sze and Shien-Piao Pan., Design of CPW-Fed Circularly Polarized Slot Antenna With a Miniature Configuration, IEEE Antenna and Propagation Letters., 10 (2011).

[10]. J.-Y. Sze, J.-C. Wang and C.-C. Chang., Axial-ratio bandwidth enhancement of asymmetric-CPW-fed circularly-polarized square slot antenna, Electron. Lett., 44(18) (2008).

[11]. Javad Pourahmadazar, Ch. Ghobadi, J. Nourinia., Broadband CPW-Fed Circularly Polarized Square Slot Antenna With Inverted-L Strips for UWB Applications, IEEE Antenna and Propagation Letters, 10 (2011).

[12]. Y.W. Liu and P. Hsu., Broadband circularly polarised square slot antenna fed by coplanar waveguide," Electron. Lett., 49(16) (2013).

[13]. Nader Felegari, J. Nourinia, C. Ghobadi, and Javad Pourahmadazar., Broadband CPW-Fed Circularly Polarized Square Slot Antenna With Three Inverted-L-Shape Grounded Strips, IEEE antennas and wireless propagation, 10 (2011).

[14]. R. K. Saini, and S. Dwari., CPW-fed broadband circularly polarized rectangular slot antenna with L-shaped feed line and parasitic elements, Microw. Opt. Technol. Lett., 57(8) (2015) 1788–1794.

[15]. R. K. Saini, P. S. Bakariya, and P. Kumar., Coplanar waveguide fed dual-band, dual-sense circularly polarized square slot antenna, Int. J. RF Microwave Comput. Aided Eng., (2018) e21503.

[16]. R. K. Saini, S. Dwari, and M. K. Mandal., CPW-Fed dual-band dual sense circularly polarized monopole antenna, IEEE Antennas Wireless Propag. Lett., (2017) 2497–2500.

[17]. R. K. Saini and P. S. Bakariya., Dual-band dual-sense circularly polarized asymmetric slot antenna with f-shaped feed line and parasitic elements, Prog. Electromagnet Res. M., 69 (2018) 185–195.

[18]. R. K. Saini and S. Dwari., Dual-band dual sense circularly polarized square slot antenna with changeable polarization, Microw. Opt. Technol. Lett., 59(4) (2017) 902–907.

[19]. P. Kumar, S. Dwari, R. K. Saini, and M. K. Mandal., Dual-band dual-sense polarization reconfigurable circularly polarized antenna, IEEE Antennas Wireless Propag. Lett., 18 (2019) 64–68.

[20]. R. K. Saini and S. Dwari., Dual-band dual-sense circularly polarized slot antenna, International Conference on Electromagnetics in Advanced Applications, Verona, Italy, (2017) 472–475.

[21]. P. Kumar, S. Dwari, and R. K. Saini., Triple band dual-polarized CPW-fed planar monopole antenna, Wireless Pers. Commun., (2017). https://doi.org/10.1007/s11277-017-5115-1.

[22]. Rohit Kumar Saini., Polarization Reconfigurable Dual- Band Rectangular Slot Antenna., Journal of RF-Engineering and Telecommunications, Frequenz, 73(9-10) (2019) 339–351.

[23]. R. K. Saini, and S. Dwari., Broadband dual circularly polarized square slot antenna, IEEE Trans. Antennas Propag., 64(1) (2016) 290-294.

[24]. Rohit Kumar Saini, "CPW-fed Dual Sense Slot Antenna for Circular Polarization" Journal of Microwave Engineering & Technologies. 2021; 8(1): 1–8p.

[25]. Rohit Kumar Saini, "CPW-Fed Square Slot Antenna with Reconfigurable Circularly Polarization Characteristics for Wideband Application", SSRG International Journal of Electronics and Communication Engineering, Volume 8 Issue 4, 5-9, April, 2021.