ISSN: 2449 - 0539
BAYERO JOURNAL OF ENGINEERING AND TECHNOLOGY (BJET) VOL.12 NO.2, AUGUST, 2017

DESING AND SIMULATION OF CIRCULAR PATCH ANTENNA WITH A RECONFIGURABLE POLARIZATION

Bala, B.D; Muhammad[1], B.; Zakariyya, R.A.; Saleh, M.A. and Hamza, A.N.

Electrical Engineering Department, Kano University of Science and Technology, Wudil, Kano-Nigeria

ABSTRACT

A circular patch antenna with reconfigurable polarizations is proposed. Linear polarized (LP) antennas suffers from poor signal transmission during adverse weather condition and multipath effects as a result of secondary transmission from nearby environment. Therefore circular polarized (CP) antennas prove to be a good candidate in this regard. The proposed antenna uses strip lines connected via a copper strip switch to achieve both right hand circular polarization and left hand circular polarizations. The overall size of the antenna is 0.52λo x 0.52λo at the operating frequency of 2.40 GHz. The antenna is compact and versatile due to its reconfigurable ability. The simulated gain and radiation efficiency of 6.25 dBi and 84.5 % is obtained respectively for both polarization at the resonance frequency. The antenna performances in terms of reflection coefficients, electric field distributions and the radiation patterns are presented and discussed. The reflection coefficient and the gains obtained shows that the antenna has potential applications for WLAN (2.39-2.45 GHz) operations.

Keywords: Circular polarizations (CP); Linear polarization (LP); Reconfigurable; Right hand circular polarizations (RHCP); Left hand circular polarizations (LHCP); Wireless Local Area Network (WLAN);

1. INTRODUCTION

In recent years, the demand for better antenna performance measures is increasing with the development of modern wireless communication systems. Unlike Linearly polarized (LP) antennas, Circularly polarized (CP) antennas have received greater attention for applications in global satellite positioning, radio frequency identification (RFID), and sensor systems due to their insensitivity to depolarization effects, resistivity to bad weather conditions and immunity to multipath propagation (Wang, Chen, & Row, 2012). There are several wireless band standards such as IEEE 802.16 Worldwide Interoperability for Microwave Access (WiMAX) system to cover 3.3-3.7 GHz and IEEE 802.11a Wireless Local Area Network (WLAN) system in the frequency bands of 2.39-2.45 GHz, 5.15-5.35 GHz and 5.725-5.825 GHz. It is noteworthy thatthese standards requires CP antennas for effective performance. CP waves can be generated when two degenerated modes of equal amplitude and phase difference of 90° are excited (Xie, Yin, & Chen, 2013). Typically an axial-ratio of less than 3-dB is allowed for CP antennas (Monti, Corchiaand, & Tarricone, 2009). Polarization re-configurability can be achieved through the modification of the feeding network (Cao et al., 2012) and creating of the truncated or perturbation segment at the corner of the patch (Chung, Yun, & Choi, 2005).

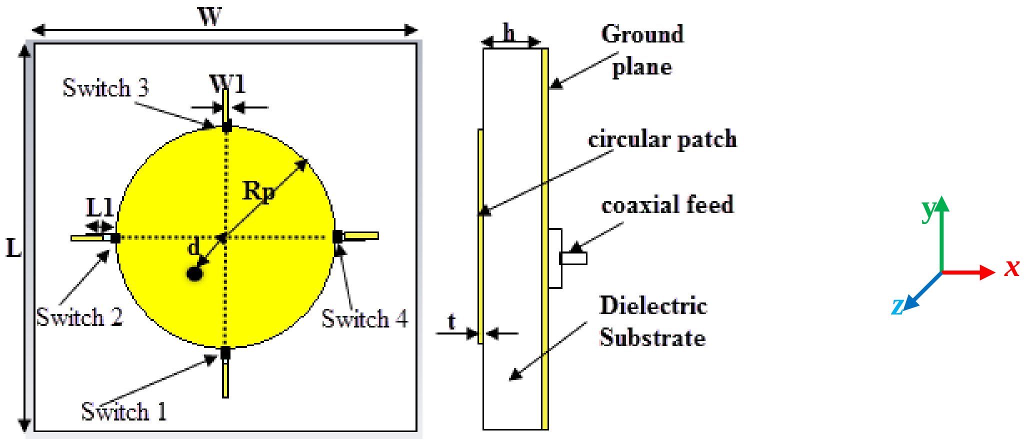
Recently several researches has been channeled towards CP antennas. A triangular spiral CP antenna was presented by (Dyson, 1995), the antenna achieved the CP characteristics but required large space and complex feeding network.Most of the previous works concentrate on the development of polarization reconfiguration between Left hand circular polarization (LHCP) and Right hand circular polarization (RHCP). Relatively, only few have presented the ability to switch between LP and CP due to difficulty to achieve simultaneously good impedance matching for both types of polarizations mode. The reason is that CP is excited by two degenerated orthogonal linear modes, where the input impedance is different from LP whichis generated by one resonant mode(Sze, Wang, & Chang, 2008). The ability to switch between LP and CP will increase the antenna versatility and functionality. Xu, He-Xiu., Wang, and Qi (2013), employed the concept of metamaterial to achieve CP at the zero order mode. The order two modes Negative order and Positive order modes are linearly polarized. In another report (Bala, Rahim, Murad, & Samsuri, 2014) RHCP was obtained with no attempt to reconfigure the polarization from LH to RH polarization.

In the current research (repoted in this paper), the researchers present a polarization reconfigurable circular patch antenna. The reconfiguration is achieved through strip lines connected via a copper switch to the circular radiating patch. The strips are oriented 90° around the circular patch. Each strip line can be switched ON/OFF via copper switch to simulteneously activate two orthogonal degenerating modes for CP. However, with proper switch selection, three distinct configurations of LP, RHCP and LHCP can be achieved. A simulated gain of 6.34 dB with an efficiency of 85% was obtained for both polarization. The antenna has potential applications of WLAN operation (2.39-2.45 GHz). The rest of the paper is organised as follows; Section 2 discusses the design methodology and simulation procedure, section 3 discusses the results obtained, section 4 concludes the paper and section 5 presents the references.

2. MATERIALS AND METHODS

The geometrical configuration of the proposed antenna is shown in Figure 1. The antenna is design on a Taconic dielectric substrate RF-35 with permittivity (ε_r) of 3.5, tangential loss (σ) of 0.018 and thickness (h) of 1.52 mm. Table 1 shows the geometric dimension of the proposed antenna after optimizations. The circular patch, of radius of R_p is etched on the top layer of Taconic substrate and finite ground plane on the bottom layer. The antenna is fed diagonally through probe feed technique at the distance of d from the center of the circular patch. Four rectangular strip lines of dimension $L1$ x $W1$ connected via four switches which are oriented 90º apart on the circular patch. The switches are provided to connect and disconnect the strip lines from the circular patch.

Assuming switch 1 is activated and others switches are deactivated. Then the surface current in the vertical direction (y-axis) is affected due to the strip line elongation along negative y-axis. However, the surface current is lengthened in the y-direction and shortened in the x-axis, and in effect, a 90°phase shift is introduced. Proper selection of strip line via the copper switch and relative position of the switch to the coaxial feed point will excite two near-degenerated orthogonal resonant modes of equal amplitude and 90º phase difference.Hence, in effect circular polarization (CP) is obtained. Alternately, LP can be obtained when all the swiches are in ON or OFF states. However, LP can also be achieved when any two of the strip lines are activated at 180° to one another, i.e switch 1 and 3, and switch 2 and 4. In the simulation set up, the switch is activated to ON state using copper strip and deactivated to OFF state using a vacuum. Table 2 shows the switch configurations for LP, RHCP, and LHCP.The antenna is simulated using Computer Simulation Technology (CST) Microwave studio (2014) software.



(a) **(b)**

Figure 1: Geometry of the proposed antenna (a) Front view (b) Side view.

Table 1: Geometrical dimensions (mm) of the proposed antenna.

Parameters	Quantity	Parameters	Quantity
W	65.0	d	5.5
L	65.0	h	1.52
Rp	18.7	t	0.035
W1	1.0	L1	5.0

Table 2: Switch configurations of the reconfigurable polarizations.

Configuration	Switch State				Polarization
	S1	S2	S3	S4	
Conf. 1	1	0	0	0	LHCP
Conf. 2	0	1	0	0	RHCP
Conf. 3	0	0	1	0	LHCP
Conf. 4	0	0	0	1	RHCP
Conf. 5	0	0	0	0	LP
Conf. 6	1	0	1	0	LP
Conf. 7	0	1	0	1	LP

3. RESULTS AND DISCUSSION

The simulated reflection coefficients (S11) of the proposed polarization reconfigurable antennas are shown in Figure 2. Good impedance matching is obtained in all the simulated results with the reflection coefficient (S11) of <-10 dB obtained. Although there is little bandwidth enhancement in the CP configurations, this is due to mode merging of the two degenetative modes. But it is noteworthy that, all results lies within the WLAN band of 2.38-2.45 GHz.

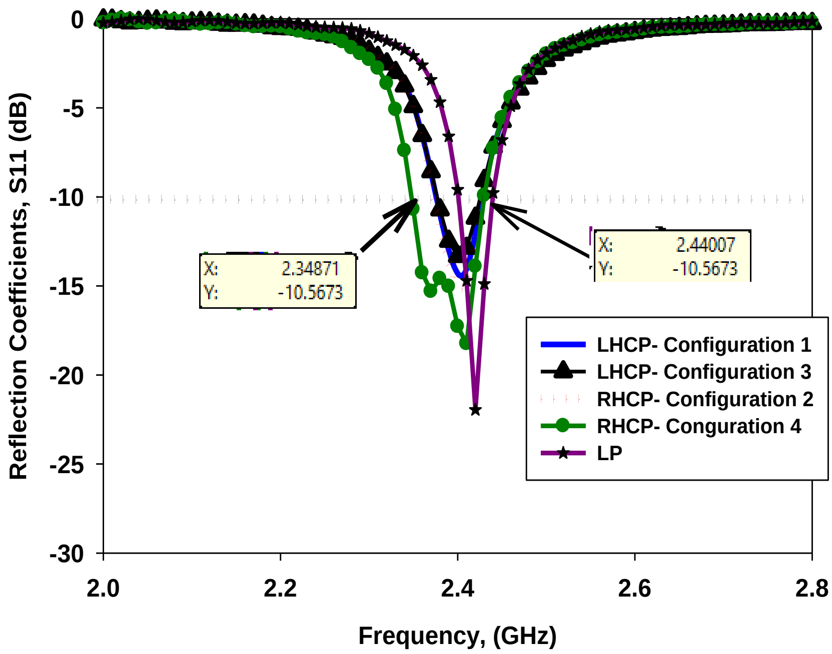


Figure 2: Reflection coefficients of the proposed polarization reconfigurable antenna

Figure 3 shows the simulated 3-dB axial ratio of both the RHCP and LHCP. The bandwidth of 17 MHz and 23 MHz is obtained for RHCP and LHCP respectively which is adequate for WLAN applications. The simulated Electric field distribution for LHCP is shown in Figure 4. The E-field distribution indicates the rotation of the E-field in anticlockwise direction for a complete revolution. While Figure 5 shows the E-field distribution for the RHCP. A clockwise rotation of the E-field is obtained with the color ramp indicating the magnitude of currents on the resonating patch. The antennas radiation efficiencies over a frequency range of 2.0-3.0 GHz is shown in Figure 6.The radiation efficiencies of 84.5 % is obtained for both configurations and 73.4 % is obtained for the LP .The isotropic gain of the antenna is presented in Figure 7. The CP gain is similar for both configurations due to perfect impedance matching obtained after the switching. A gain of 6.25 dBi is obtained at the resonance frequency of 2.40 GHz for both polarizations. Simulated radiation patterns are presented in Figure 8 for both E-plane (xy-plane) and H-plane (yz-plane).For all the polarization modes, good radiations performances with broadside radiation pattern are obtained.The 3-D radiation patterns are shown in Figure 9. The colour ramp indicates almost same directive gain of 6.84 dBi for both polarizations.

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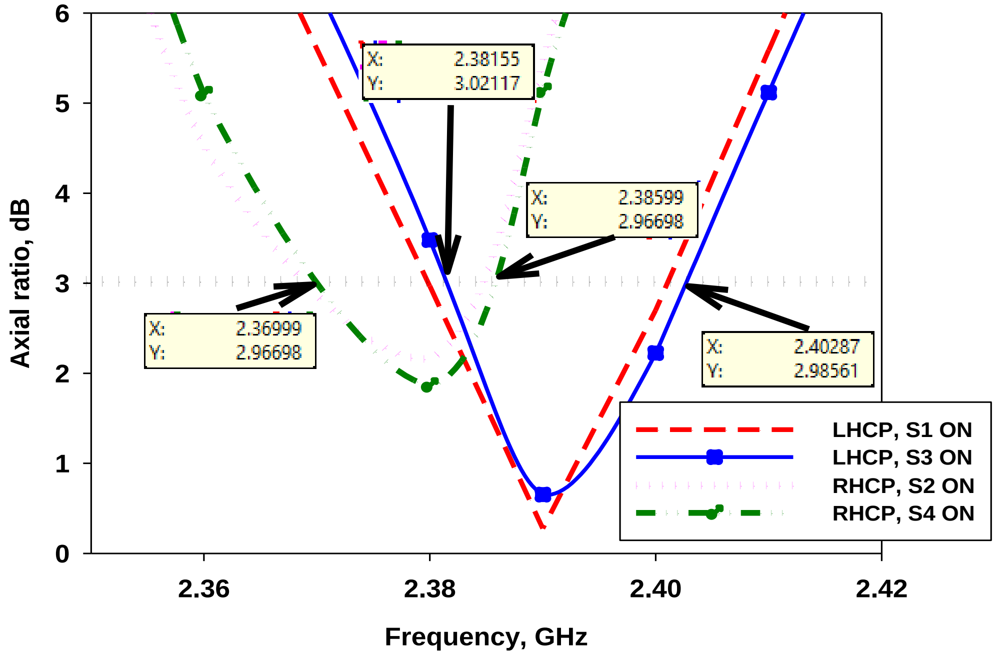
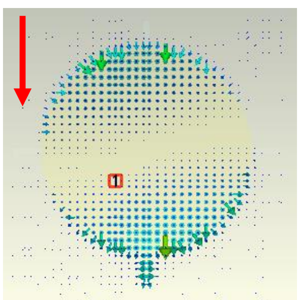
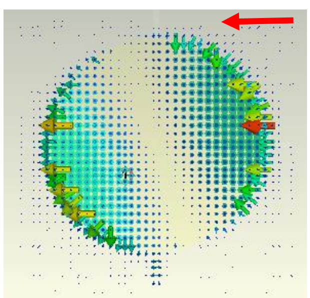


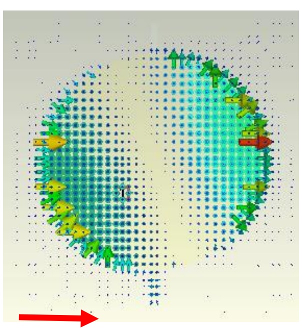
Figure 3: 3-dB axial ratios of the CP configurations



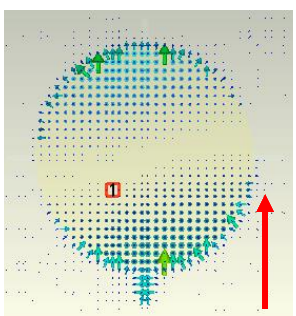
(a)



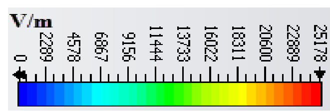
(b)



(c)

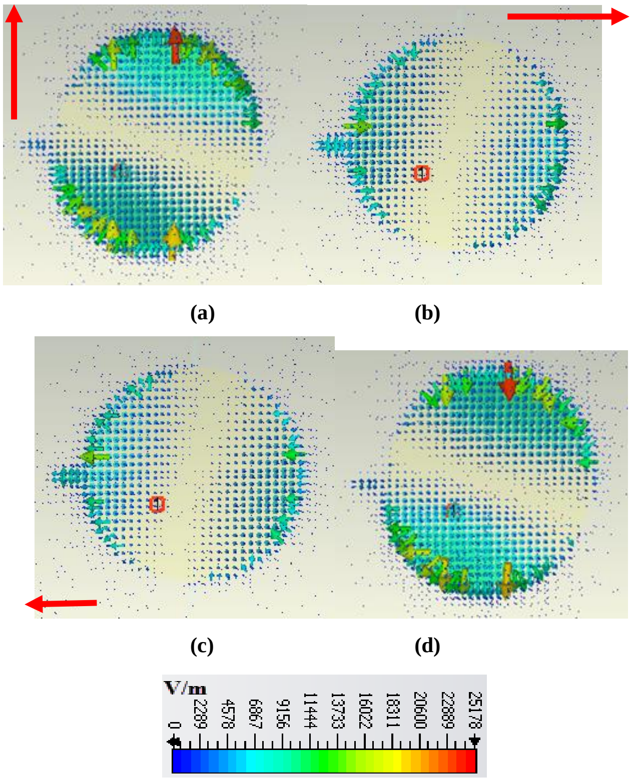


(d)



(e)

Figure 4: Electric field distributions on the patch for Configuration 1 (LHCP) at phase angle of: (a) 90 degree (b) 360 degrees (c) 180 degrees (d) 270 degrees (e) Color ramp V/m



(e)

Figure 5: Electric field distributions on the patch for Configuration 1 (RHCP) at phase angle of: (a) 270 degree (b) 180 degrees (c) 90 degrees (d) 0 degrees (e) Color ramp V/m

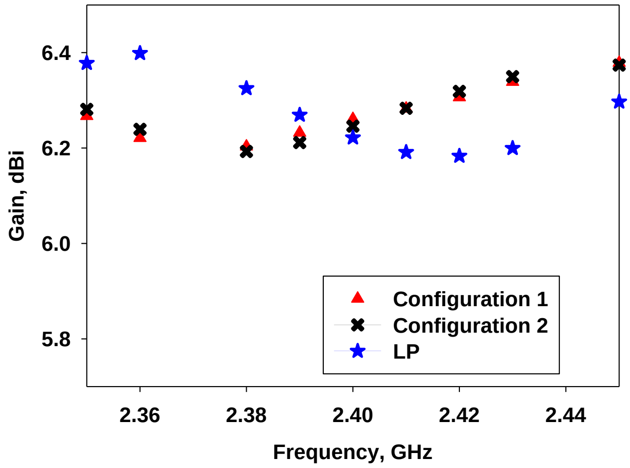
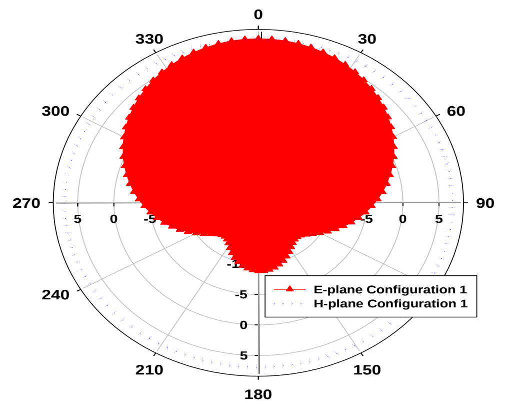


Figure 7: Realized gain (dBi) over frequency range



(a)

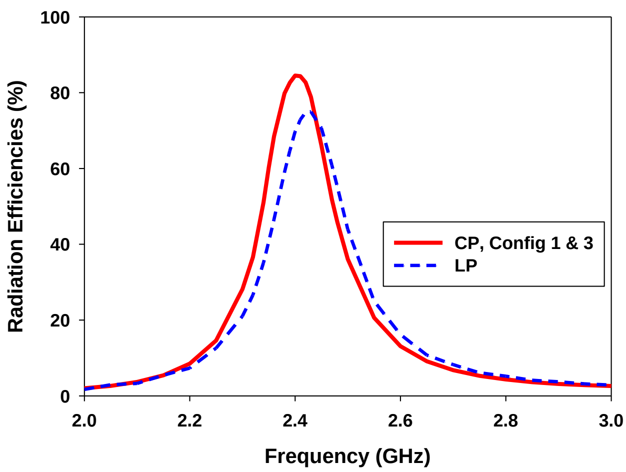
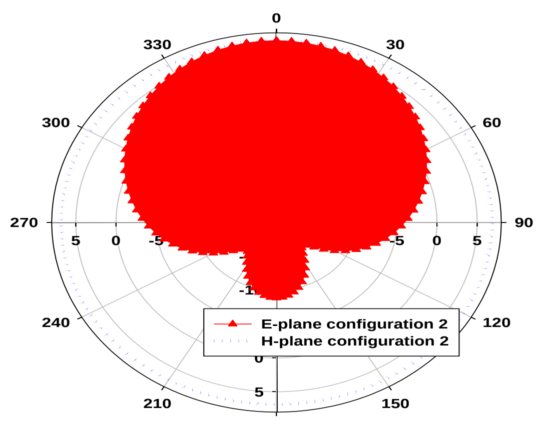
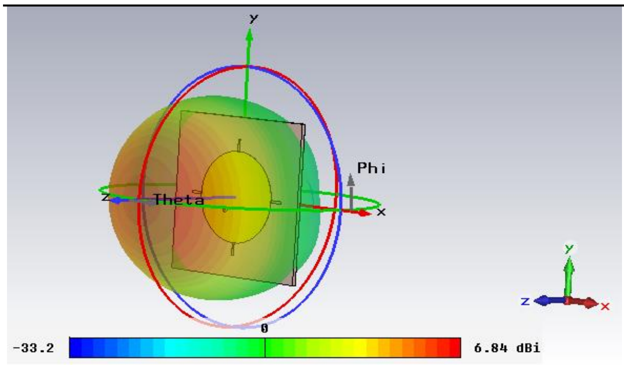


Figure 6: Radiation Efficiencies over frequency range.



(b)

Figure 8: Simulated polar plot radiation patterns for both E-plane and y-plane: (a) LHCP (b) RHCP



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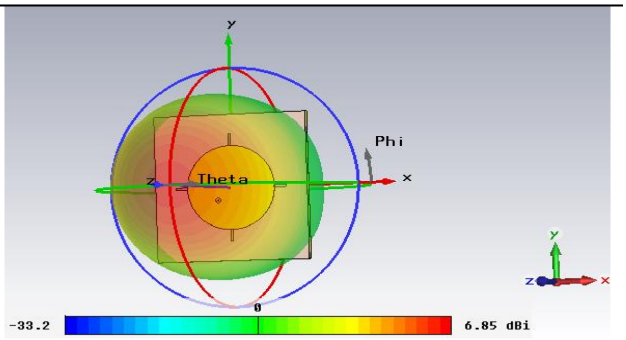

(b)

Figure 9: Simulated 3D-radiation patterns (a) LHCP (b) RHCP

4. CONCLUSIONS

A polarization reconfigurable circular patch antenna has been designed and presented. The proposed CP antenna takes the advantages of been immune to multipath effect, adverse weather conditions and high data rate when integrated to WLAN devices.Strip line were connected via copper switch to create a phase shift between two degenerated modes for CP. The realised gain, 3-dB axial ratio and the reflection coefficients (<10 dB at 2.38-2.45 GHz) obtainedshown that the antenna will be a good candidate for WLAN applications. Simulated radiation patterns and the E-field distribution were obtained to proved the concept of RHCP and LHCP.

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