Design and characterization of polarization reconfigurable heart shape monopole antenna for 2.4 GHz application

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ABSTRACT

This article represented a heart shape reconfigurable monopole antenna with polarization diversity. The proposed antenna is fed by a 50 Ω microstrip feed line that is printed on a flexible FR-4 (ε_r=4.4) substrate. The antenna comprises a ring-slot, a cross slot and four positive-intrinsic-negative (PIN) diodes that are soldered on ring slot. Four PIN diodes act as a switch and by controlling these PIN diodes effective current direction is changed hence four various states of polarization are achieved. Four states of polarization such as horizontal linear polarization (H-LP), vertical linear polarization (V-LP), right-hand circular polarization (RHCP) and left-hand circular polarization (LHCP) can be switched easily with the help of these PIN diodes and achieved an efficiency of more than 90%. Proposed antenna shows voltage standing wave ratio (VSWR)<2 at all working frequency and -10 dB reflection coefficients (RC) bandwidths (BW) (i.e., S11≤-10 dB) about 32.86% for linear polarization (LP) states while RHCP and LHCP states possess BW of about 31.61% and 31.67% respectively. It also shows axial ratio (AR) BW of 3.41% and 2.44% for RHCP and LHCP, respectively. Besides, the antenna has a well-suited omnidirectional pattern with a positive gain of all working frequency of interest where cross-polarization level is much lower than that of antenna gain.

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1. INTRODUCTION

Reconfigurable antenna becomes very popular nowadays as it provides personal communication service (PCS) as well as wireless local area network (WLAN) and provides numerous advantages in wireless communication over another antenna. Researchers also pay attention to the reconfigurable antenna as it can enhance the system capacity twice or more by reusing frequency and polarization diversity [1], polarization coding, multipath fading [2] and moderate mismatch of antenna polarization [3]. A reconfigurable antenna can be of any type such as frequency reconfigurable [4], pattern reconfigurable [5] and polarization reconfigurable [6], [7]. A reconfigurable antenna can change its characteristics (frequency, radiation properties) in real-time. In order to attain such real-time switching ability, an intermediate device is employed (positive-intrinsic-negative (PIN) diodes, radio frequency (RF) switches, varactor diodes or micro-electromechanical systems (MEMS) switches). Azad *et al.* [8] achieved reconfigurable characteristics of the antenna via PIN diodes. To achieve continuous frequency reconfigurability varactor diodes is used submitted in [9]. Instead of having some disadvantages of controlling the high-power voltage of MEMS due to its construction material and size, many authors have been also proposed [10].

To attain polarization characteristics in microstrip patch antenna there are many techniques are established in recent days. One of them is to feed the antenna with a 90˚ phase difference in two positions. However, this technique has needed an extra hybrid network to provide the necessary phase shift [11]. Besides, two feed lines make antenna structure cumbersome. Alternatively, circular polarization (CP) can be achieved by single feeding while a corner of the radiator is truncated [12]. Fries *et al.* [13] proposed a slot antenna that shows polarization reconfigurability between right-hand circular polarization (RHCP) and left-hand circular polarization (LHCP) states. Apart from, CP is achieved in [14], where antenna shows dual-band characteristics. Reconfigurability of polarization is also achieved using the cross slot in [15] where the patch is fed via proximity coupled technique. Coplanar waveguide (CPW) feed technique is also used in reconfigurable polarization antenna showing broadened bandwidth (BW) and low gain [16]. In most cases CP is applied in cellular communication as it can provide more reliability of receiving RF signal [17]. Also, such kinds of antenna are a good candidate for satellite communication [18].

In recent years, many authors have proposed reconfigurable antenna using parasitic patch [19]. A beamforming reconfigurable patch antenna with four parasitic patches is proposed in [20]. Antenna possessing an omnidirectional radiation pattern having CP attain much more attraction among users [21]–[24]. To achieve CP, numerous authors proposed partial ground technique and various literature has been published in recent years [25]. In an omnidirectional case, no alignment needed between the sender and receiver antenna. Such types of the monopole antenna are proposed in [26] that can exhibit polarization, frequency, and pattern diversity properties simultaneously. Ultra-wideband (UWB) monopole antenna is also proposed in [27]. Four states of polarization are also achieved by controlling conducting strips which are connected to ground via diodes [28].

In this article, an attractive heart shape polarization reconfigurable omnidirectional monopole antenna is proposed where its simple structure with employment of PIN diodes makes it simpler to design and enhancement of BW has been done up to a degree that proves its worthiness to design such an antenna. Proposed low profile structure can reconfigure its polarization states by appropriate switching of PIN diodes. In the middle of the heart shape radiator, a ring shape slot is applied, and four PIN diodes are soldered on it. Desired polarization states are achieved via PIN diodes as they can alter the current direction depending upon their biased condition. A cross slot also utilized inside of the ring shape slot. A parasitic loop is also visible in the uppermost side of this mentioned structure that can control various antennas parameters.

2. THE PROPOSED ANTENNA GEOMETRY

The proposed heart shape polarization diversity antenna's structure is depicted in Figure 1 that possesses a total size of 56×50 mm^2. The monopole antenna radiates with the help of the substrate, it always radiates towards the broadside axis (z-axis). Antenna normally radiates due to the accelerate movement of charged particles on its surface. The proposed antenna has been excited with the help of a 50 Ω microstrip line. The charged particle does not give rise to electromagnetic (EM) wave to radiate while passing through microstrip feed as it is just straight. The charge particles caused to EM wave to radiate when it enters the main patch of the antenna as they got sudden discontinuity. The edge of the proposed antenna has extreme discontinuity which leads to charge particles have an acceleration throughout the antenna and produce EM wave. The EM wave radiates when it is being excited with respect to ground and penetrates the substrate and finally gets coupled with the ground plane conductor of the antenna. Some fraction of the EM waves that are being radiated through the edge of the patch, go to the surrounding air, and then finally get coupled with the ground plane. The EM waves that go to the surrounding air add up in phase and provides radiation in the orthogonal direction. These phenomena are also known as fringing effects. This fringing effect is responsible for increasing effective length as well as the width of the antenna. This is one of the reasons for choosing the so-called heart shape structure that provides edge discontinuity in every direction of the structure, helps to increase the fringing effect. Due to this fringing effect antenna appears larger than its actual physical size causes slightly shift in resonant frequency and acts as a more suitable radiator than a narrow one. Besides, it increases radiated power that helps to increase gain, BW, makes antenna more directive and efficient [29]. The substrate helps antenna to perform its electrical function by acting as a capacitor as well as provide antenna's rigidity.

Figure 1(a) represents the front view of the proposed structure which is consists of a ring slot, a cross slot and four PIN diodes and a parasitic patch outside the resonator. Ring slot is employed here to originate a rotational movement of surface current inside the resonator. This rotational movement of surface current could be made either clockwise or anticlockwise with the help of PIN diodes etched on the radiator surface discontinuity in the resonator.

Inside this ring slot, a pair of the nearly equal cross slot is loaded to generate two orthogonal degenerate modes in order to obtain CP. These slots also help to increase the fringing effect as they introduce from Figure 1(b), it is sensible that the antenna comprises three layers. At the uppermost of dielectric substrate contain main radiator where bottom side contains one-sided ground is presented which length is denoted by *g* in Figure 1(b), where radiator and ground plane obtained same thickness of 0.01 mm and substrate FR-4 (εr=4.4 and tanδ=0.025) obtained a thickness of 0.3 mm. Four PIN diodes of model No. 'MBP-1036-B11'are placed on the ring slot in the direction of 45˚, 135˚, 225˚ and 315˚ respectively. The lumped element conditions of CST are used to employ PIN diodes and it is ON and OFF state value has been put simultaneously while carrying out simulation and this way four PIN diodes act as a switch here.

When biasing voltage is provided through the terminal of diode (ON state), a series combination of low inductance (0.6 nH) and low resistance (2.5 Ω) provides a conducting path for surface current through diode have shown in Figure 1(c) and without biasing voltage (OFF state) it acts as open circuit just like in Figure 1(d). In OFF state, blocking of current via diodes is occurred as high resistive value (10 kΩ) of resistor makes parallel composition with high capacitance value capacitor (0.040 pF).

By switching four PIN diodes appropriately, current distribution through the patch is controlled. Diodes that are soldered on 45˚ and 225˚ on loop slot are responsible to generate RHCP while combination of 135˚ and 315˚ soldered diodes are responsible for LHCP. Vertical linear polarization (V-LP) is achieved when all diodes are OFF state while ON states of all diodes are responsible for horizontal linear polarization (H-LP). Frequency bands related to these polarization states along with diode combination is presented in Table 1.

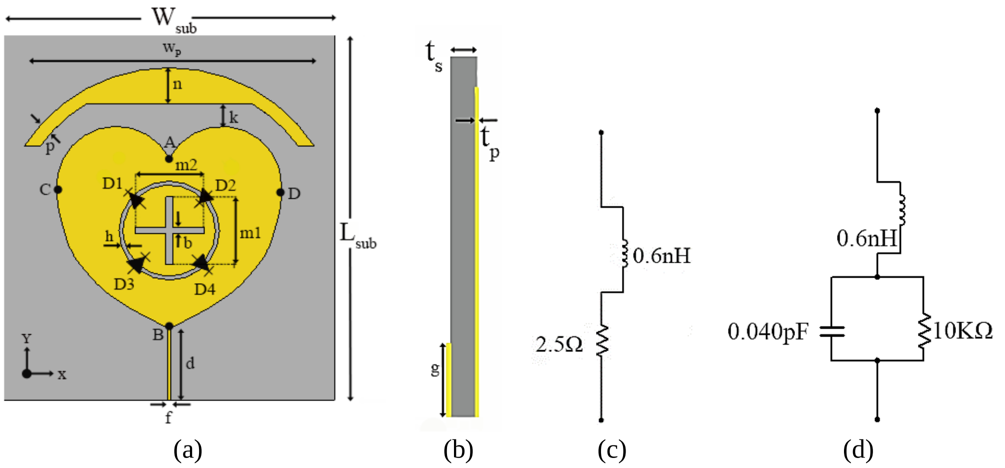


Figure 1. The proposed antenna (a) observed view where W_{sub}=48 mm, L_{sub}=56 mm, n=5.5 mm, b=2 mm, A-B=26.14 mm, C-D=33.4 mm, W_p=44 mm, m1=10.42 mm, m2=10.40 mm, f=0.56 mm, k=3.57 mm, d=11 mm, p=2.5 mm, h=1.0 mm, (b) edge view where t_p=0.01 mm, t_s=0.3 mm, g=11.9 mm and equivalent circuit diagrams of PIN diodes, (c) ON state, and (d) OFF state

Table 1. Proposed antenna bandwidth and frequency bands to corresponding states

States	Switches				Resonant Frequency (GHz)	Frequency Bands (GHz)	Impedance BW (%)	AR BW (%)
	D1	D2	D3	D4				
LP (horizontal)	ON	ON	ON	ON	2.428	2.135-2.933 GHz	32.86	N/A
LP (vertical)	OFF	OFF	OFF	OFF	2.38	2.10-2.82 GHz	30.25	N/A
RHCP	OFF	ON	ON	OFF	2.404	2.13-2.89 GHz	31.61	3.41
LHCP	ON	OFF	OFF	ON	2.4	2.12-2.88 GHz	31.67	2.44

3. SIMULATION RESULT ANALYSIS AND DISCUSSION

3.1. Effect of slot *m1* and *m2* on proposed antenna

Two slots intersect each other in the middle of the heart shape. There is a small variation in the lengths of these two slots and *m1* and *m2* represents the lengths of vertical slot and horizontal slot, respectively. Figure 2 depicts the effect of the return coefficient (RC) curve with respect to variation in *m1* where it can be seen that there is no effective shifting of RC curve while changing the length of slot m1, but small variation found out. Figure 3 also depicts effect of RC curve with respect to change in length *m2*. Either decreasing or increasing the value of *m2* antenna resonant just around 2.42 GHz and small variation can find out in RC gain.

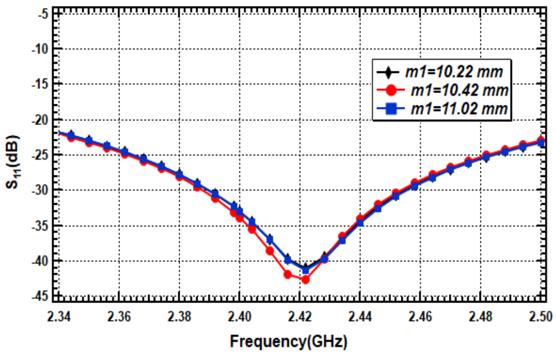


Figure 2. Effect of slot *m1* on RC curve

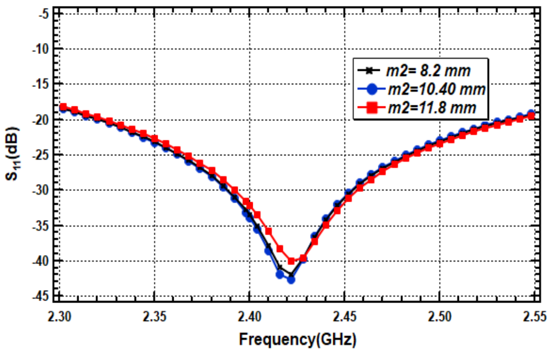


Figure 3. Effect of slot *m2* on RC curve

3.2. Effect of ground plane and ring slot on antenna

Earlier in this communication, it is mentioned that the proposed antenna consists of one sided-ground plane (monopole). Antenna's ground plane has an enormous effect on its resonant frequency and other parameters. Figure 4 depicts the effect of the ground plane on antenna RC gain. For three different lengths of ground surface *g* is chosen to show an effect on the RC curve in Figure 4.

For surface plane length *g*=11.9 mm it gives a minimal RC gain for proposed antenna. For this length antenna shows minimum RC gain characteristics. It is cognizable from Figure 4 that there is no significant change occurs on operating frequency while varying the ground plane length. Operating frequency almost remain constant around 2.42 GHz. Only significant variation found out on the RC gain of the antenna. A ring slot (or loop slot) is also introduced in the center of the resonator with inner radius *r* and outer radius *R*. This slot possesses a width of *h* and its effect on RC curve is depicted in Figure 5. It can be seen that changing widths of slot h from 0.6 mm to 1.3 mm, no significant change in operating frequency is found.

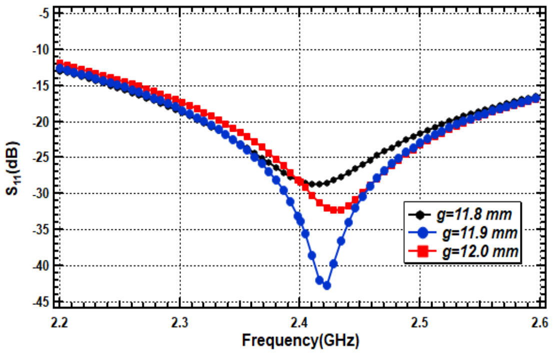


Figure 4. Effect of ground plane *g* on antenna

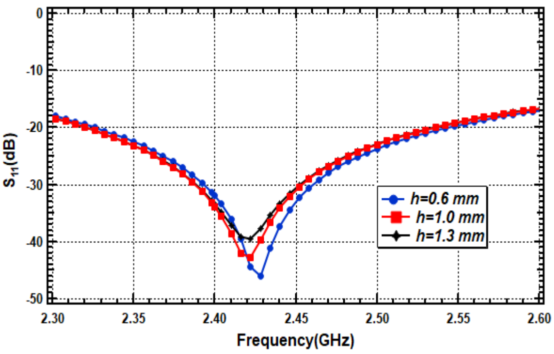


Figure 5. Effect of ring slot width *h* on antenna

3.3. Effect of parasitic element on antenna and voltage standing wave ratio (VSWR) curve

The parasitic component has a great effect on monopole antennas performance. Many researchers have investigated their effect on antenna performance and many articles have been proposed in recent years [30]. Antenna parameters such as gain, impedance BW, resonant frequency and RC also effected by parasitic components. Parasitic components are those which are not connected directly to the antenna feed. But they possess surface current through mutual induction and radiates on the same direction of the main patch. It places a great effect on antenna characteristics. Figure 6 depicts the parasitic component effect on resonant frequency and RC gain. Though a major change in a shifting of resonant frequency is not observed, resonant frequency slightly shifted to a higher frequency. There exist staring changes in RC gain (or S11). Almost there exists a difference of 9 dB on RC gain that clarifies, it can accept more input power than that of without parasitic loop condition. However, impedance matching between antenna and transmission line is degraded without parasitic loop condition which reveals through voltage standing wave ratio (VSWR). Impedance BW is slightly increased by 8 MHz. Gain is also decreased by 0.02 dB though, at a higher frequency, the antenna should achieve high gain compared to proposed condition. All the parameters of the proposed antenna except radiation efficiency show a good result compared to without parasitic loop condition in Table 2. The effect of a parasitic element has a great impact on an antenna and expressed thoroughly via Table 2.

To get an idea that how much power is reflected from the antenna to the transmission line, there is one way to see standing wave condition. The closer the value of VSWR to one, the lesser power will reflect back to source or more accurate impedance matching occurred. VSWR<2 is acceptable for various wireless applications and its value is always positive. VSWR curve in Figure 7, represents impedance mismatch between antenna and transmission line. VSWR<2 for a wide range of frequency 2.09 GHz to almost 3 GHz and it is close to one for all four states of resonant frequencies. As VSWR is closer to one it can be said that perfect impedance matching has occurred between antenna and transmission line.

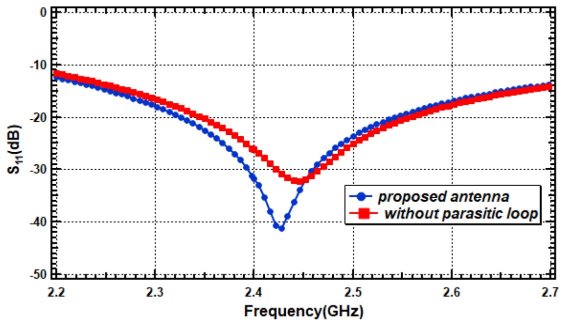


Figure 6. Effect of parasitic element on RC curve

Table 2. Performance comparison of proposed antenna with without parasitic loop condition

Antenna Parameters	Frequency	
	2.428 GHz (Proposed antenna)	2.446 GHz (Without parasitic loop)
RC gain (dB)	-41.24	-32.20
Impedance bandwidth (MHz)	798	790
VSWR	1.01	1.05
Realized gain (dB)	2.37	2.35
Gain (dB)	2.38	2.36
Directivity (dBi)	2.55	2.53
HPBW (degree)	82.4	83.0
E_{max} (dBV/m)	17.1	17.1
H_{max} (dBA/m)	-34.4	-34.4
Radiation efficiency (%)	96.05	96.13
Total efficiency (%)	95.95	95.88

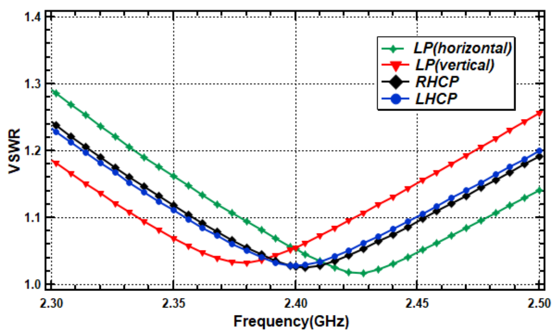


Figure 7. VSWR curve for all states

3.4. Surface current

The proposed antenna has four states, and, in every state, the antenna shows different types of polarization. By rotating surface current direction of resonator desired polarization is achieved in every independent states. Antenna’s surface current gives a wide phenomenon about its working behavior and polarization and to study an antenna’s performance, it needs to observe the antenna surface current with appropriate color map. Figure 8 depicts the surface current direction where Figure 8(a) for RHCP states with an appropriate color map where current direction is rotated clockwise and RHCP is obtained. Figure 8(b) depicts surface current direction for LHCP states by rotating surface current direction anticlockwise with the help of two PIN diodes which are etched on 135˚ and 315˚ LHCP is obtained. Figure 8(c) represents surface current distribution for V-LP states and in this case current direction is vertical with respect to antennas axis while current direction is horizontal in Figure 8(d) thus H-LP is obtained. In every state the current is also flowing in the parasitic loop through mutual induction. In Figure 8(c), all the PIN diodes kept OFF state thus effective surface current path is increased results a lower frequency of 2.38 GHz is achieved. PIN diodes kept ON state thus effective surface current path is reduced results a higher frequency of 2.428 GHz is achieved compared to other states.

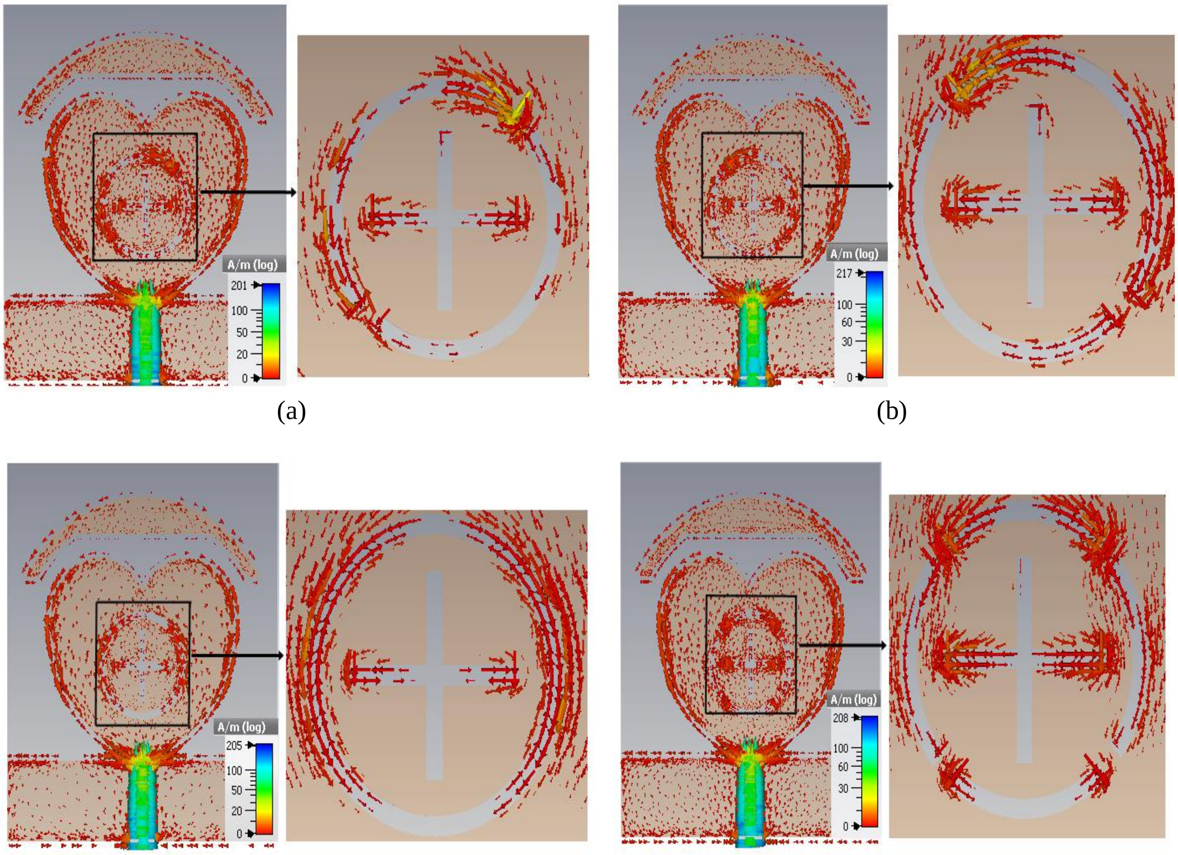


Figure 8. Proposed antenna surface current distribution (a) RHCP states at 2.404 GHz, (b) LHCP states at 2.4 GHz, (c) V-LP states at 2.38 GHz, and (d) H-LP states at 2.4 GHz

3.5. Return coefficient (RC) curve

The RC curve (or S11) of an antenna describes how much power are gets reflected to the source due to impedance mismatching between cable and antenna. This value is always negative unlikely return loss (RL). RC and RL have almost similar meaning while analyzing microwave devices but opposite in sign expressed in decibel (dB).

Apart from using diodes on the resonator surface directly is also responsible for occurring some loss hence decreasing RL value. RC is measured in terms of decibel. For an ideal antenna RC curve should be less than -10dB. The more negative the value of the RC gain, less power will be reflected back to the source thus increase RL value. Figure 9 depicts the RC curve for two states of linear polarization (LP) of the proposed antenna. RC curve is less than -10 dB and occupied a band of 2.10 to 2.94 GHz in LP states. In Figure 10, RC curve is shown for CP states and obtained -10 dB RC band from 2.12 to 2.89 GHz. It is sensible that antennas operating frequency, impedance BW, gain is remained indistinguishable for different working states.

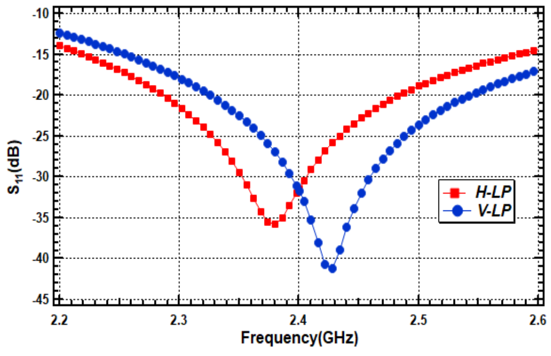


Figure 9. RC curve for H-LP and V-LP states

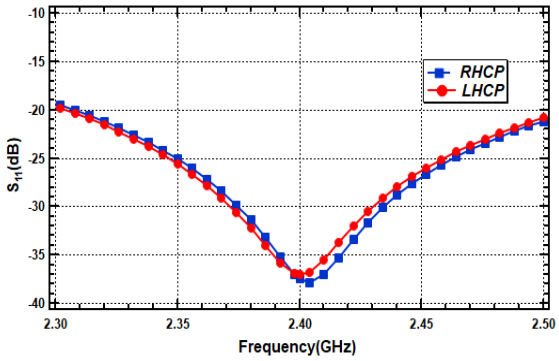


Figure 10. RC curve for LHCP and RHCP states

3.6. Axial ratio (AR) and efficiencies curve

E-field and H-field are main ingredients of EM wave, and the vibration direction of E-field normally determines the axis of polarization. There are three types of polarization exists such as LP, CP, and elliptical polarization (EP). In the case of LP E-field vibrates only one axis but for CP and EP it vibrates in two axes. AR normally indicates these ratios of orthogonal components of E-field in EP. If AR<3 dB it assumes that antenna has CP as practically antenna cannot attain 0 dB.

An ideal axial ratio value for CP is 1 or (0 dB) because in that case two components of E-field possess equal magnitude and remain separate by 90˚ out of phase. In simulated cases of an antenna shows a defective polarization and tailed out to EP in lieu of CP. Also, worth noted that in authentic LP, its axial ratio amplified to infinite due to one E-field component. In Figure 11, the AR value (at φ=90˚, θ=90˚) for both RHCP and LHCP states is shown with respect to operating frequency. In that, both cases CP is achieved. It achieved AR value of 2.39 dB and 2.47 dB at 2.404 GHz (RHCP) and 2.4 GHz (LHCP) respectively. The 3 dB BWAR for RHCP and LHCP is 3.41% and 2.44% respectively. The authenticity of CP is increased when AR value is going closer to one. Antenna efficiencies for all four states are depicted in Figure 12. Normally antenna efficiencies are estimated in terms of percentage (%) but Figure 12, indicates efficiencies curve where efficiency level are indicated in terms of decibel unit. By converting into a percentage, efficiencies values are for RHCP is 95.84%, LHCP is 95.88%, V-LP is 95.80% and H-LP is 95.95%.

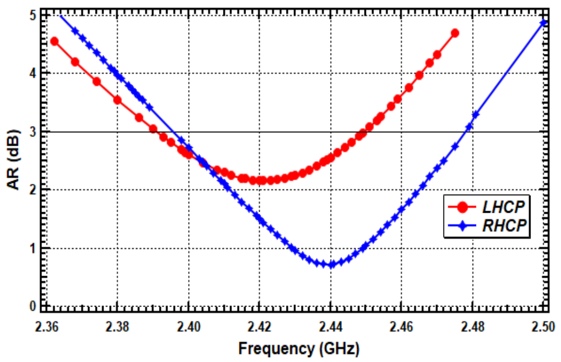


Figure 11. Axial ratio curve of LHCP & RHCP states

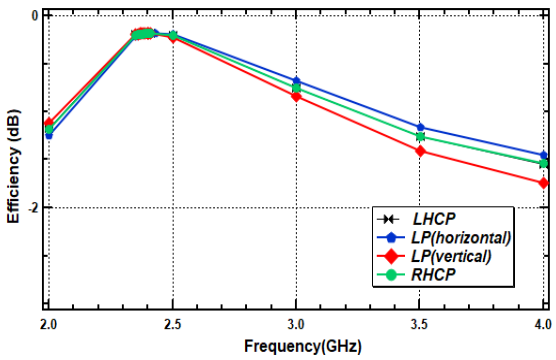


Figure 12. Efficiencies curves for all states

3.7. Gain, directivity and realized gain

Table 3 represents the listed value of different antenna parameters for all four states of the proposed antenna. In all four states RC gain is far lower than <-10 dB and VSWR is just closer to unity. After taking a closer look it can be observed that if RC gain goes to more negative, than VSWR goes to closer to unity. Directivity is just equal to all states. Also observe that, realized gain is less than gain (IEEE standard) as realized gain takes various losses into considerations associated with the antenna. But in H-LP states, reverse characteristics were found. In case of considering radiation efficiency antenna shows an appreciable measurement. In all four states of proposed antenna the radiation efficiency and total efficiency are more than 90% and almost the same for all states. HPBW values of these states are also satisfying which actually reveals the difference between angular separations of the leading beam where the radiation pattern is decreased by -3 dB compared to the peak of the leading beam.

Table 3. Simulated performance of all four states of proposed antenna

Antenna parameters	Frequency			
	2.428 GHz (Horizontal LP)	2.38 GHz (Vertical LP)	2.404 GHz (RHCP)	2.4 GHz (LHCP)
RC gain (dB)	-41.24	-35.78	-37.82	-37.04
VSWR	1.01	1.03	1.02	1.02
Directivity (dBi)	2.55	2.58	2.56	2.56
Realized gain (dB)	2.38	2.39	2.38	2.38
Gain (dB)	2.39	2.4	2.38	2.39
Radiation efficiency (%)	96.05	95.99	96.01	96.06
Total efficiency (%)	95.95	95.80	95.84	95.88
E_{max} (dBV/m)	17.1	17.2	17.1	17.1
H_{max} (dBA/m)	-34.4	-34.4	-34.4	-34.4
HPBW (degree)	82.4	82.7	82.5	82.5

3.8. Co-polarization and cross-polarization

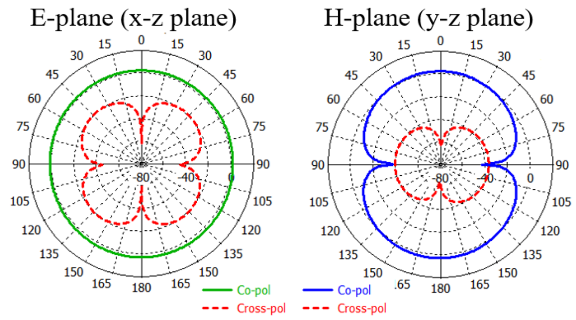
To understand the purity of desired polarization of an antenna, there is one way to see the cross-polarization states. Cross-polarization can be defined as orthogonal radiation of desired polarization. Normally gain of cross-polarization be negative. For EM radiation both E-plane (x-z plane) and H-plane (y-z plane) convey some important information.

For this proposed heart shape polarization reconfigurable antenna, both E-plane and H-plane radiation patterns with co-polarization states are depicted in Figure 13. Table 4 represents the listed value of both E and H-plane with cross-polarization states is given for all four states of the proposed antenna. In Figure 13 represents radiation pattern and for Figure 13(a) H-LP with cross-polarization states. At 2.428 GHz, the E field is omnidirectional with gain 2.37 dB where the cross-polarization level is -19.8 dB. And H field possesses a dumb-bell shape radiation with a gain of 2.38 dB where the cross-polarization gain is -37.1 dB and it is much smaller than co-polarization gain. For both E and H field cross-polarization is much lower than desired polarization. In Figure 13(b), at 2.38 GHz E field is an omnidirectional with cross-polarization level is -20.2 dB and H field is just like dumb-bell shape with cross-polarization level is -44.5 dB. In H-field cross-polarization also possess a dumb-bell shape but orthogonal to co-polarization state.

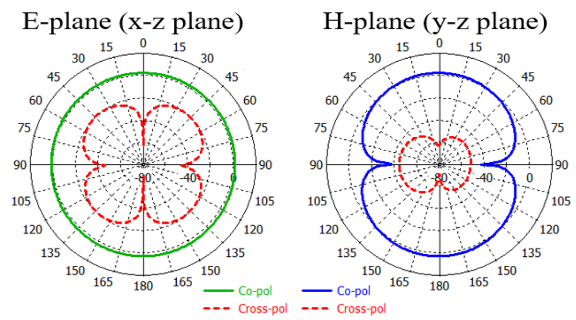
For RHCP mode at 2.404 GHz in Figure 13(c), the proposed antenna is omnidirectional at E plane like previous states and possesses a gain of 2.36 dB where cross-polarization level is -19dB with main lobe direction +45˚. In H plane it possesses just dumb-bell pattern as previous but cross-polarization is quite omnidirectional with a gain of -32.2 dB. However, the radiation pattern for the E field remains omnidirectional and H field is also dumb-bell shape in LHCP mode at 2.4 GHz in Figure 13(d). But cross polarization in E-plane is -45˚ directional with gain -19 dB and cross-polarization in H field is quite omnidirectional. Every state difference between co and cross-polarization is larger, and it reveals a good sign of undistorted polarization.

3.9. Comparison with other work and discussion

The contribution of that research is clear from Table 5. It was made possible to reduce the size of the antenna employing a doable method to attain CP as well as increase the effective BW of antenna compared to previously published work listed in Table 5. In every state of polarization, it shows more than 30% of the BW. Apart from to attain the polarization diversity antenna employs a simple cross slot with flexible FR-4 substrate with the simplest line feeding technique makes this antenna stands out from others. To carry out the switching operation practically, PIN diodes should be grounded after drilling the substrate with via and then a copper wire of small diameter is concatenated with via to ground plane which radiation is ineffectual to antennas main radiation. It increases the complexity of heart shape to make PIN diodes grounded but still such kinds of one-sided ground plane reduce antennas low BW response and obtained wide range of BW fidelity that is better compared to some of the previously published antenna mentioned in Table 5. Being an irregular shape, the complexity is elevated, and symmetricity was maintained during the course of designing.



(a)



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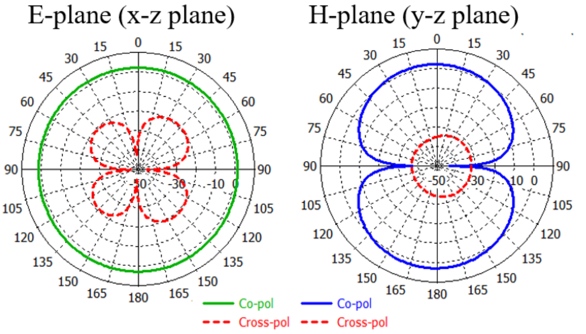
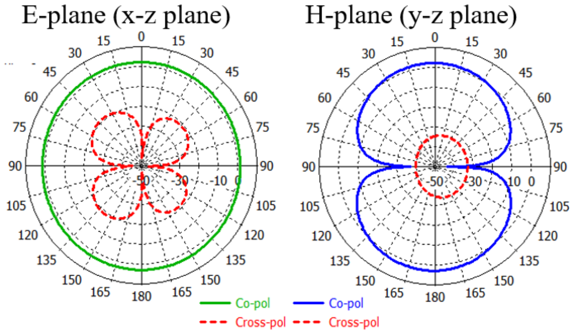


(c)



(d)

Figure 13. Normalized radiation pattern for both E and H field at (a) 2.428 GHz (H-LP), (b) 2.38 GHz (V-LP), (c) 2.404 GHz (RHCP), and (d) 2.4GHz (LHCP)

Table 4. Comparison between co-polarization and cross-polarization gain of proposed antenna

Characteristics	Frequency							
	2.428 GHz(H-LP)		2.38 GHz(V-LP)		2.404 GHz (RHCP)		2.4 GHz (LHCP)	
	E field	H field	E field	H field	E field	H field	E field	H field
Co-polarization	2.36dB	2.38dB	2.39dB	2.41dB	2.36dB	2.38dB	2.37dB	2.39dB
Cross-polarization	-19.8dB	-37.1dB	-20.2dB	-44.5dB	-19dB	-32.2dB	-19dB	-33dB

Table 5. Performance comparison with recently published work

Ref []	Characteristics							
	Total Size (λ_g^2)	Height (λ)	Centre frequency (GHz)	Polarization States	Impedance BW (%) (LP, CP)	Substrate	No. of Switches	AR BW (%)
[31]	1.52λ×1.52λ	0.030λ	3.1	V-LP, H-LP, RHCP, LHCP	1.29(LP) 2.55(CP)	RT5880	4-PIN diodes	0.32(RHCP) 0.25(LHCP)
[32]	1.67λ×1.67λ	Not mentioned	2.4	LP, RHCP, LHCP	2.21(LP) 2.91(CP)	FR-4	4-PIN diodes	2.48(CP)
[33]	2.64λ×2.83λ	0.062λ	5.7	V-LP, H-LP, RHCP, LHCP	23.4/23.4(LP) 27.2/27.2(CP)	R04350	4-SPDTs switches	19(RHCP) 17.5(LHCP)
[34]	1.347λ×1.347λ	0.027λ	2.46	LP, RHCP, LHCP	21.54 (LP) 12.6/12.6(CP)	FR-4	8-PIN diodes	4.7(CP)
[35]	1.029λ×1.029λ	0.0183λ	2.44	LP, RHCP, LHCP	1.13/1.18(LP) 3.60/3.63(CP)	RT5880	8-PIN diodes	0.72(RHCP) 0.74(LHCP)
[36]	0.948λ×0.948λ	0.013λ	2.45	RHCP, LHCP	16.32(CP)	FR-4	2-short circuit pins	6.10(CP)
[37]	1.183λ×1.183λ	0.013λ	2.40	RHCP, LHCP	4.58(CP)	FR-4	8-PIN diodes	1.25(CP)
[38]	0.865λ×0.865λ	0.010λ	2.40	LP, RHCP, LHCP	1.25(LP) 2.5(CP)	Amber	2-PIN diodes	0.83(CP)
[39]	1.339λ×1.339λ	0.013λ	2.45	V-LP, H-LP, RHCP, LHCP	18/30.7(LP) 12.3/30.7(CP)	FR-4	3-PIN diodes	2.2(RHCP) 4.50(LHCP)
This work	0.939λ×0.805λ	0.005λ	2.4	H-LP, V-LP RHCP, LHCP	32.8/30.25(LP) 31.6/31.6(CP)	FR-4	4-PIN diodes	3.41(RHCP) 2.44(LHCP)

4. CONCLUSION

A loop and cross slot have been employed to achieve CP and parasitic patches helps to increase BW and gain of the proposed antenna. With the help of four PIN diodes orthogonal degenerate modes of the proposed antenna are controlled hence polarization reconfigurability is achieved. It shows a radiation pattern of switchable polarization almost over the 2.4 GHz ISM band that is meaningful for numerous wireless applications. A comparison chart is also presented with some previously published switchable polarization antenna and from this it is clear that antenna achieves BW fidelity with compact size holding a simple switchable polarization mechanism. After observing all the simulated results of the represented reconfigurable antenna, its performance seems quite good, and this simple structure is available for 2.4 GHz to 2.5 GHz wireless applications.

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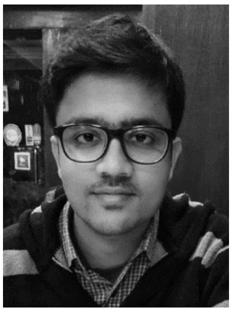

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