



A DUAL-POLARIZATION RECONFIGURABLE ANTENNA WITH BEAM SWITCHING CHARACTERISTICS FOR S-BAND APPLICATIONS

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ABSTRACT

A simple polarization and beam switching reconfigurable antenna is presented in this paper. The circular patch with annular slot is used as the radiating element. The circular metallic conductor positioned below the substrate with the air dielectric acts as the ground plane for the antenna. The proposed antenna is intended to operate at 2.4 GHz band with switchable polarization capability. Four PIN diodes have been placed diagonally across the corresponding switchability and moreover the proposed antenna provides the beam switching characteristics. The proposed circularly polarized reconfigurable antenna is designed and simulated in ANSYS Electronics Desktop HFSS package and studied several parameters such as return loss, gain, axial ratio, current distributions etc.

Keywords: polarization reconfigurable, beam switching, PIN diodes, axial ratio, circularly polarized antenna.

1. INTRODUCTION

Patch antennas have been serving from several decades for wireless industry with their versatile features such as light weight, compact, low profile but the research has been carrying forward in the similar way on the feeding techniques and radiation parameters. Regarding the polarization parameter of the antenna, the transmitting and receiving antennas are need to be matched with polarization. Electromagnetic spectrum allocated for the domestic applications is of limited quantity. Nowadays users are increasing at a rapid growth due to advancements in several technologies. Available spectrum is to be used effectively to accommodate all the users with less interference (cross polarization) by following certain frequency reconfigurable mechanisms. For this reconfigurable antennas used at satellites and at the base station should be designed to mitigate the fading losses. Between linear polarization and circular polarization, the later has the upper hand because of the following conditions. Climatic conditions play an important role in the signal fading while travelling over long distances. Circular polarization is more immune to the rotation of the signal caused due to the climatic conditions. Installation of the antenna to achieve circular polarization is less complex as the only constraint is to make sure that the antenna is placed in the correct direction of the satellite. This also prevents the losses caused due to the misalignment of the antenna. Interference will be low and the reliability of the established link will be high. As the transmission and reception of signal is at different frequencies cross polarization i.e. interference will be of negligible amount.

A Circular polarized antenna is realized in [1] using a rectangular patch with a slot and coplanar capacitive feed. In [2], an antenna with circular polarization is realized using SIW feeding where the two patches are separated by an inductive using arrays. Circular Polarization is achieved in [3] by multi target streamlining technique using slot antenna consisting of different circular segments. Broadband CP is achieved in [4] by replacing the dipole and non-coplanar strips with

wider and coplanar strips respectively. By combining a group of patches that are excited using a coaxial probe provides circular polarization is achieved in [5]. A circular patch placed beneath the rotating rectangular patch separated by a substrate resulted in Dual band Circular Polarization [6]. LHCP is achieved in [7] using aperture antennas that are singly fed. Circular polarized antenna is realized in [8] using a two layered split-ring structure. Circular polarization in Universal Mobile Telecommunications Service band is achieved in [9] using V-shaped slits and incorporating circular slots in the middle of the patch. The polarization reconfigurability is provided in [10] for a loop antenna printed on either side of the substrate that switches between left and right handed CP radiation. Some axial ratio minimization techniques are presented in [11-12]. Polarization reconfigurability is achieved in [13] by generating a conical beam using eight reconfigurable coupling loop stubs that are placed around the patch and in [14] using SIW cavity consisting on two input ports and is etched with four radiation slots on its upper surface.

In the present article, the polarization reconfigurability is studied on an annular slotted circular patch antenna with probe feeding. This involves the study of different parameters such as return loss, gain, surface current distributions to study the CP radiation patterns, efficiency. Section 2 deals the discussion on antenna geometry, the simulation results are discussed in Section 3 and concluded in Section 4.

2. Antenna Geometry and Methodology

The detailed antenna geometry is shown in Figure-1. The design of proposed antenna is consisting of a circular patch and circular ground plane as mentioned in [15]. The circular patch is placed on the top side of the Rogers RT Duroid 5870 substrate having relative dielectric permittivity of 2.33 with thickness of ' h_2 ' mm. The ground conducting plane is kept at a distance ' h_1 ' from the bottom of the substrate. The gap between the substrate and ground serves as a dielectric filled with air which is used to enhance the bandwidth. The circular patch is



center fed with probe feeding of diameter ' p ' and provided a small gap ' g ' between the probe and ground plane. An annular slot is made in the patch and a DC bias line is connected to the radiating element which can be seen in Figure-1(a). This narrow DC line does not perturb the RF current on the radiating element as the DC line provides the high impedance at RF band. This design operates in a linearly polarized mode. The circular radiating element is

notched with two rectangular slots of dimensions 5.78mm x 5.48mm in the diametrically opposite points for ensuring circular polarized radiation. Four PIN diodes are placed diagonally and the terminals are placed such that they are diametrically opposite directions as shown in Figure-1(b). The usage of PIN diodes is to provide the polarization reconfigurability for the proposed antenna. Geometrical parameters are mentioned in Table-1.

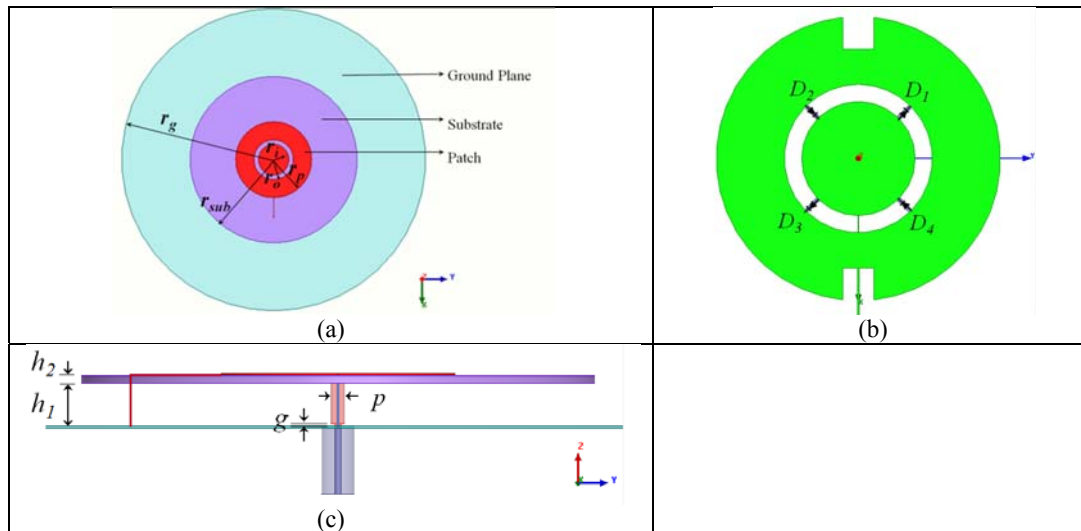


Figure-1. Geometry of Proposed Antenna (a) circular patch antenna with annular slot (LP Antenna) (b) with insertion of PIN diodes (CP Antenna) (c) side view.

Table-1. Geometrical parameters of polarization reconfigurable antenna.

Parameter	r_g	r_{sub}	r_p	r_o	r_i	h_1	h_2	p	g
Value in mm	100	13	25	13	10	9.43	1.57	3	1

3. Simulation Results

The proposed antenna geometries are modelled in the ANSYS HFSS simulation tool and simulated using the finite element analysis. The PIN diodes are modelled as lumped RLC boundary considering the equivalent lumped RLC values of BAR50-02L from Infineon Technologies.

The antenna parameters such as return loss, current distributions, axial ratio, gain, radiation patterns are studied.

(a) Return loss characteristics

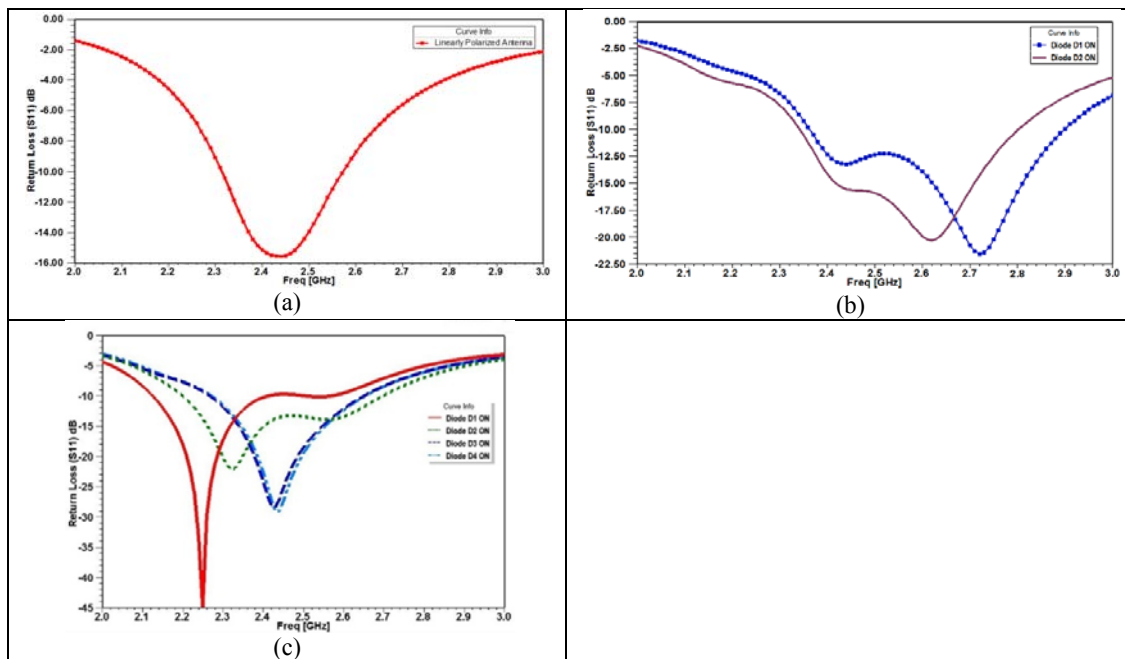


Figure-2. Return loss characteristics of (a) Circular patch antenna with annular slot (b) with two PIN diodes (c) with four PIN diodes.

The return loss characteristics of the proposed reconfigurable antenna iterations are presented in Figure-2. The -10 dB return loss bandwidth for the antenna without diodes is observed from 2.3198 GHz-2.5749 GHz with a resonant frequency of 2.44 GHz attained at S11 of -15.602 dB which can be observed from Figure-2(a). In Figure-2(b), the return loss characteristics are presented for the antenna with two PIN diodes. This structure yields the operating band from 2.3629 GHz-2.8989 GHz with resonant frequency 2.72 GHz for diode D_1 turned ON. The operating band of 2.342 GHz-2.8025 GHz is obtained while the D_2 is ON. The Figure-2(c) exploits that the reflection losses are further minimized when compared with previous iterations. The operating bands 2.125-2.414 GHz, 2.199-2.698 GHz, 2.267-2.651 GHz and 2.271-2.654

GHz are obtained respectively for the individual conducting states of the diodes.

(b) Axial ratio vs frequency characteristics

The axial ratio is the key parameter to determine whether the antenna exhibits CP radiation characteristics or not. The circular patch antenna inserted with two PIN diodes in the annular slot is obtaining the circular polarization characteristics when the conducting states of the PIN diodes are controlled as shown in Figure-3(a). The axial ratio is observed to be below 3dB and when diode D_1 is turned ON, the axial ratio bandwidth is occurring from 2.4713-2.5706 GHz whereas for the case of D_2 ON the axial ratio bandwidth ranges from 2.5365-2.6828 GHz.

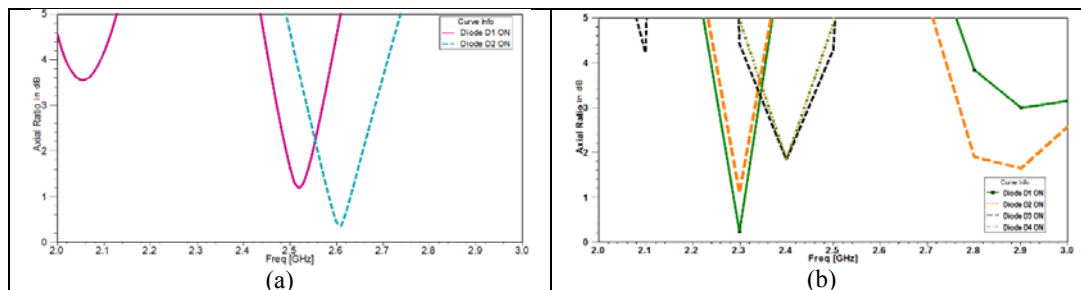


Figure-3. Axial Ratio vs Frequency characteristics of circular patch antenna (a) with two-PIN diodes (b) with four PIN diodes.

Figure-3(b) depicts the axial ratio characteristics for the antenna with four diodes. The AR bandwidths for all the cases are mentioned in Table-2.

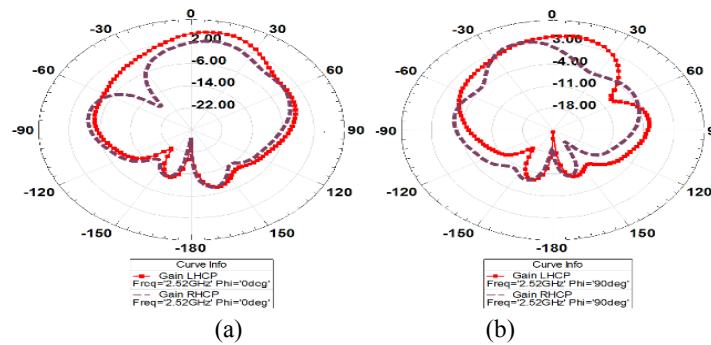
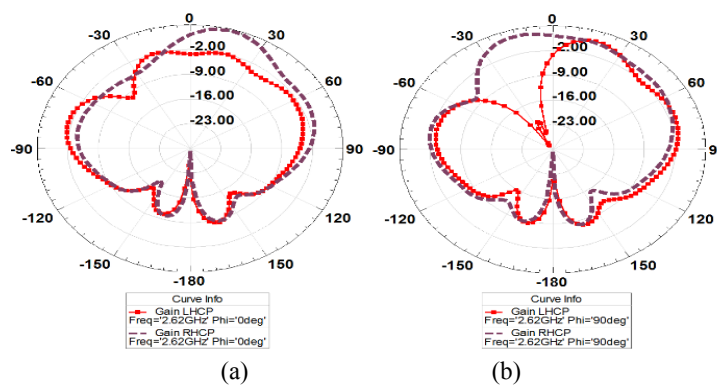
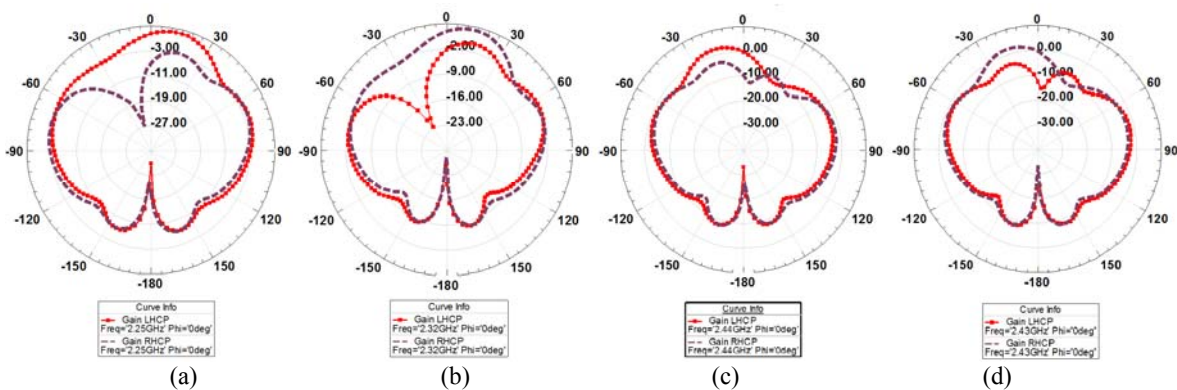
**Table-2.** Axial Ratio bandwidth characteristics for proposed antenna with different cases of PIN diodes.

D ₁ D ₂ D ₃ D ₄ (1=ON, 0=OFF)	1000	0100	0010	0001
Axial ratio bandwidth in GHz	2.255 -2.31	2.267 -2.332	2.362 -2.438	2.355 -2.447

(c) Radiation characteristics

The 2D radiation patterns are obtained using EM simulations. Figure-4 and Figure-5 shows the E-plane and H-plane pattern at resonant frequencies of antenna for the

case of D1-ON and D2-OFF, D1-OFF and D2-ON respectively. The Gain LHCP plot is dominant while D1 alone is ON state and Gain RHCP curve is dominant while D2 alone is turned ON.

**Figure-4.** 2D-radiation patterns for the case of D1-ON for antenna with two-diodes (a) E-plane (b) H-plane.**Figure-5.** 2D-radiation patterns for the case of D2-ON for antenna with two-diodes (a) E-plane (b) H-plane.**Figure-6.** 2D-radiation patterns in E-plane for Antenna with four-diodes at resonant frequencies (a) D1 ON (b) D2 ON (c) D3 ON (d) D4 ON.

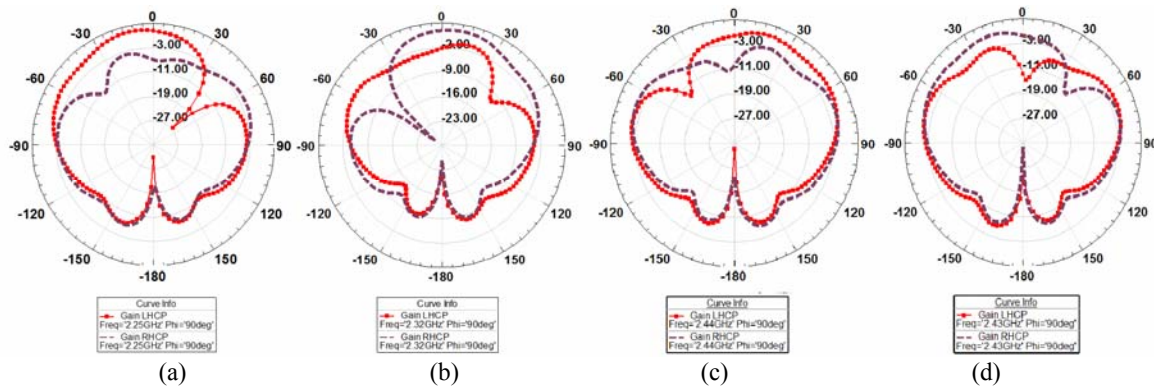


Figure-7. 2D-radiation patterns in H-plane for Antenna with four-diodes at resonant frequencies (a) D1 ON (b) D2 ON (c) D3 ON (d) D4 ON.

For the antenna with four PIN diodes, the E-plane and H-plane radiation patterns are plotted in Figure-6 and Figure-7. The polarization switching from LHCP to RHCP can be seen here as the diodes D_1 , D_2 , D_3 and D_4 are sequentially turning ON only one at an instant. The beam

switching can be better observed in Figure-8. It can be observed that the radiation pattern projects its maximum towards the diagonally placed diode which is in conducting state at that instant.

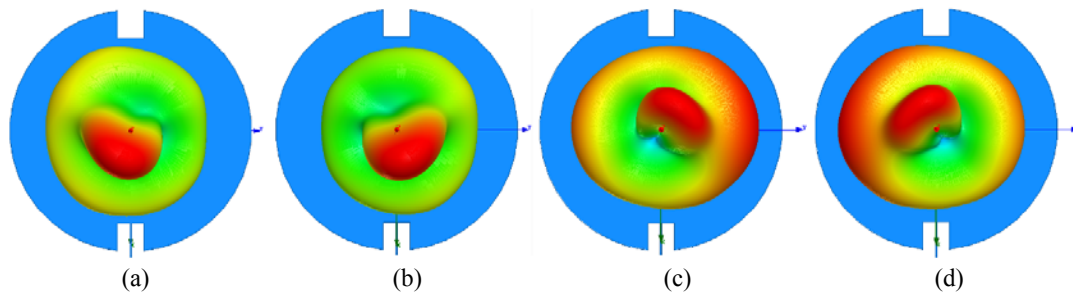


Figure-8. 3D-radiation patterns of proposed antenna with four-diodes at resonant frequencies (a) D1 ON (b) D2 ON (c) D3 ON (d) D4 ON.

(d) Current Distribution characteristics

The current distribution on the different iterations of the proposed reconfigurable antenna are plotted. Fig. 9 shows the surface current element distribution on the

circular patch antenna with annular slot at different input excitation of phases. The linearly polarized radiation can be seen from the figure.

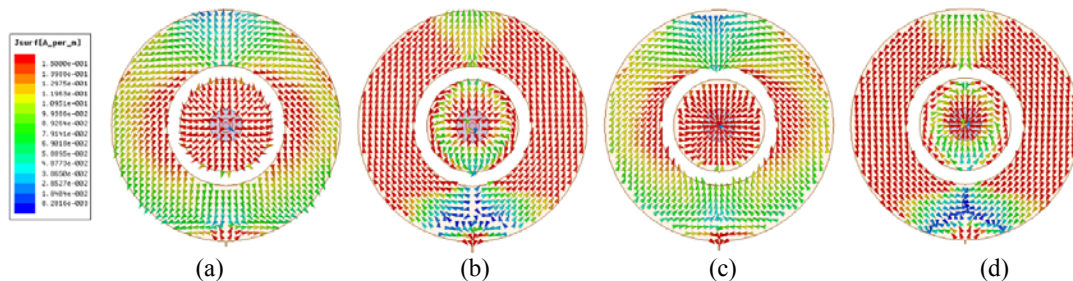


Figure-9. Simulated surface current distribution on circular patch antenna with annular slot (a) phase=0deg (b) phase=90deg (c) phase=180deg (d) phase=270deg.

The current distribution on the antenna with rectangular notches and with two PIN diodes is plotted in Figure-10. The conducting states of the diodes D_1 and D_2 can be seen with high current density at the path along

which the diodes are placed. The left handed and right handed movement of current elements can be seen in Figure-10(a) and Figure-10(b) respectively.

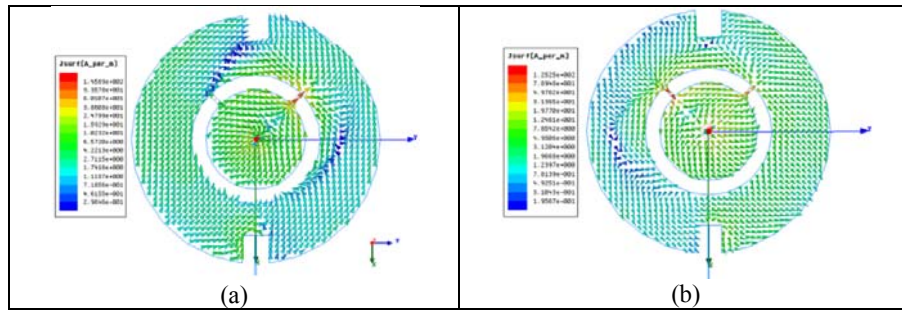


Figure-10. Simulated surface current distribution on circular patch antenna with two PIN diodes (a) D₁-ON (b) D₂-ON

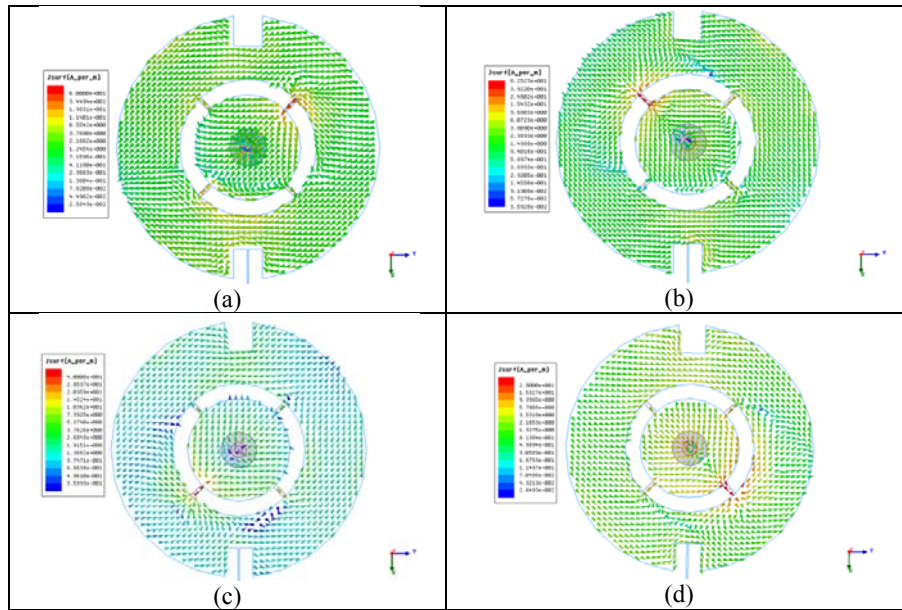


Figure-11. Simulated surface current distribution on circular patch antenna with four PIN diodes (a) D₁-ON (b) D₂-ON (c) D₃-ON (d) D₄-ON

The Figure-11 depicts the current distribution for the circularly polarized antenna with four diodes. The sequential turning on the diodes switches the current distribution path such as the converging and diverging the

current elements along the diode conducting path can be clearly observed from Figure-11.

The consolidated characteristics of the proposed polarization reconfigurable and beam switchable antenna are mentioned in Table-3.

Table-3. Consolidated characteristics of proposed antenna with different switching cases.

Conducting States of PIN Diodes	Operating Band (GHz)	Axial Ratio Bandwidth range (GHz)	Type of Polarization	Gain	Radiation Efficiency
D ₁ D ₂ D ₃ D ₄					
1 0 0 0	2.125-2.414	2.255 - 2.31	LHCP	7.039 dB	85.23%
0 1 0 0	2.199-2.698	2.267 - 2.332	RHCP	6.287 dB	84.48%
0 0 1 0	2.267-2.651	2.362 - 2.438	LHCP	4.013 dB	81.45%
0 0 0 1	2.271-2.654	2.355 - 2.447	RHCP	3.776 dB	81.82%

4. CONCLUSIONS

In this paper, a polarization reconfigurable antenna is presented. The proposed antenna is operating in

the band between 2.1 GHz-2.7 GHz band. The circular radiating element with annular slot is fed with the coaxial probe feed and the its operating band is enhanced from the



usual resonant behaviour. Further, the circular polarization performance is realized with the PIN diodes placement at quadrature angle which leads to the symmetry in the CP radiation with axial ratio below 3 dB with good efficiency more than 80% which can be confirmed through the .The proposed antenna is better suitable for S-band satellite and ISM band applications.The gain can be further increased by using array topology.

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