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A Frequency and Polarization Reconfigurable Rectangular Di-electric Resonator Antenna for Cognitive Radio Applications.

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***Abstract:** The microstrip antennas are the most important device in the domain of communication because of lucidity and compact size. In this paper, a frequency and polarization reconfigurable di-electric resonator antenna (DRA) is proposed and discussed. The proposed receiving wire is equipped for exchanging at two distinctive recurrence groups somewhere in the range of 4.2GHz and 8.4GHz. The rectangular di-electric resonator receiving wire which is nourished by u-formed microstrip feed line. By putting the switches on the associating lines of a proposed plan that feeds the di-electric component and the condition of switch is turned between on and off, certain move of well-coordinated working recurrence range is acquired. A properly situated PIN diodes can change the length of the U-formed feed line arms, which modifies the polarization condition of the reception apparatus. The proposed antenna prototype enables switching between one linear and two circular polarization senses. Alumina_92pct with a permittivity of 9.2 is taken as a di-electric resonator material. The total dimensions of the antenna are 40x45x4.6mm^3. A good impedance match (s11 <-10dB) is achieved for both linear and circular polarizations and the 3-dB axial ratio bandwidth is greater than 2.04%.HFND4005 PIN diodes are used as switches.*

***Index Terms:** Di-electric Resonator Antenna (DRA), Reconfigurable antennas, Microstrip Antennas, Linear and circular polarization.*

I. INTRODUCTION

Dielectric Resonator Antennas (DRAs) are presented as a conceivable trade for ordinary metallic radio wires in different remote correspondence framework [1]. They have a few preferences, for example, misfortune free conductivity, higher radiation effectiveness, little size, more extensive data transmission and simplicity of combination with other aloof or dynamic microwave components. DRAs experience low misfortune, in this manner they guarantee higher effectiveness without conductor misfortune. Moreover, in contrast to dipole or microstrip reception apparatuses that experience the ill effects of thin transfer speeds, DRAs have genuinely wide data transmissions [2-3].

The expanding request of the remote correspondence frameworks has included receiving wires to improve their presentation while being restricted to lessening impression. These structure requirements have constrained receiving wire analysts to think about multifunction reception apparatuses. As a noteworthy theme to examine and structure multi-work reception apparatuses, reconfigurable receiving wires have gotten loads of heed. Since their capacity of changing framework prerequisites or can grasp with natural conditions. Unrivaled favorable position, for example, estimate scaling down, reconfigurable ability, multi-reason capacities and more affordable have given tunable receiving wires advantage to be incorporated into a remote framework [4-7].

When all is said in done, working conditions of a reconfigurable reception apparatus can be accomplished by setting PIN diodes, Micro Electro Mechanical Systems (MEMS) switches, Varactor diodes, GaAs Field Effect Transistor (FET) as a tunable segments. This proposed receiving wire configuration is executed by utilizing RF PIN diodes, as it very well may be gathered effectively and it is of low cost[8]. Frequency reconfigurable radio wires are utilized for multiband cell phones and polarization reconfigurable reception apparatuses are utilized for satellite correspondence frameworks and versatile multi-input multi-yield frameworks to decrease multipath impacts and the requirement for exact polarization arrangement among transmitting and accepting antennas[9]. To achieve high information rates for progressively number of clients, the most significant factor is the effective use of transfer speed. Psychological radio is a versatile and wise radio innovation that can detect accessible directs in a remote range consequently. The fundamental focal point of the psychological radio innovation is the perfect use of range by part the UWB into numerous sub-groups [10]. In this paper, a recurrence light-footed receiving wire alongside polarization reconfiguration is exhibited. It furnishes wide-band recurrence dexterity alongside simultaneous polarization reconfiguration.

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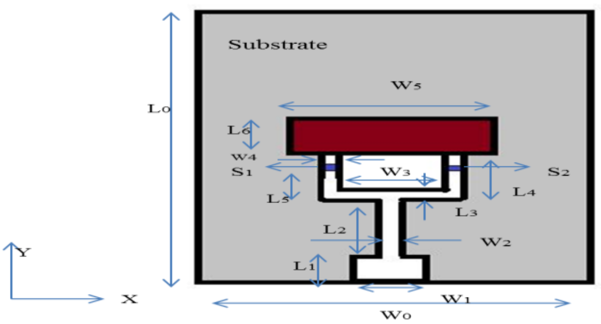
The proposed radio wire can switch between three polarization faculties i.e., one of direct and two faculties of circular polarization i.e., left hand circular polarization (LHCP) and right hand circular polarization (RHCP). A rectangular DRA is associated with U-formed microstrip feed line is utilized as an emanating component. Stick diodes are put on the arms of the U-formed microstrip feed line, by exchanging the PIN diodes at various working states which are utilized to accomplish both recurrence and polarization reconfigurability. The HFSS (High Frequency Structure Simulator) programming is utilized to examine and investigate the exhibition of reception apparatus, for example, reflection coefficient, Voltage standing Wave Ratio (VSWR), increase and radiation design. The proposed receiving wire can be utilized for a few remote applications somewhere in the range of 4.2GHz and 8.4GHz.

II. ANTENNA CONFIGURATION AND DESIGN:

The configuration of the proposed frequency and polarization reconfigurable rectangular di-electric resonator antenna is shown in fig 1. The variables and proportions of the proposed antenna are given in Table 1. The di-electric resonator has a di-electric constant of ϵ_r=9.2. Alumina_92pct is taken as a di-electric material, which is the radiating element in the proposed design. The radiating element is excited by the U-shaped microstrip feed line. Both the arms are of symmetrical lengths. Both the HFND4005 PIN diodes are placed on the arms of the U-shaped microstrip feed line. The criterion for using PIN diodes is because of its advantages like less driving voltage is needed, very reliable as it is not having any rotating part, power handling capabilities are high and of course less expensive.

The di-electric resonator antenna which is mounted on the substrate has a thickness of h=3mm and a FR-4 epoxy is used as a substrate with dimensions of 40x45x1.6 mm^3. The equivalent circuit of this HPND4005 PIN diodes in both ON and OFF states are represented in fig 2.



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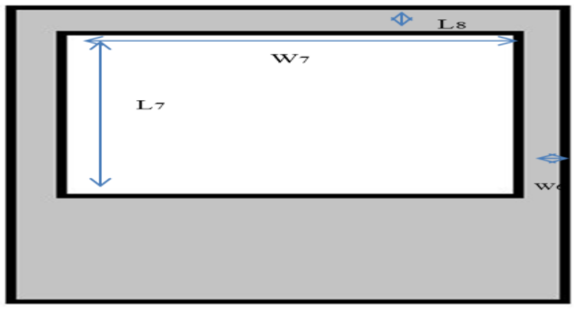

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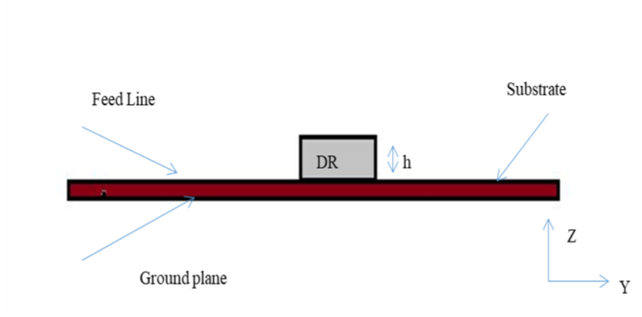
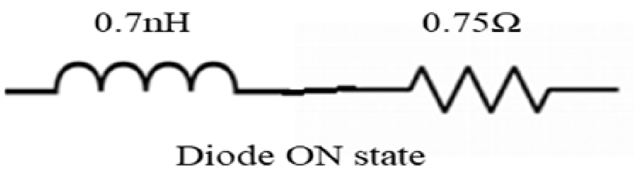


(c)

Fig 1: Schematic diagram of the proposed reconfigurable rectangular Di-electric resonator antenna
(a) Front view(b) Back view (c) Side view.

The proposed antenna operates for 4.2GHz to 8.4GHz. This proposed antenna consists of a rectangular di-electric resonator antenna, U-formed microstrip feed line and a ring molded ground plane arrangement on the rear of the substrate. The ring shaped ground plane configuration helps the proposed antenna to provide wide bands. As there are 2 PIN diodes on both arms of the feed lines thus exists four possible operating states which are 11,10,01,00 states.



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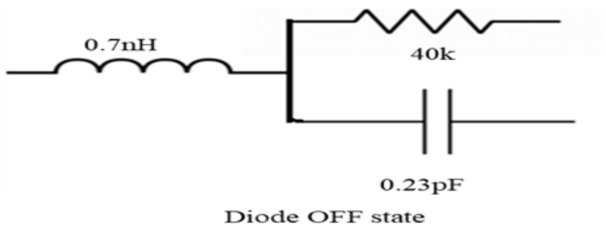

(b)

Fig 2: Equivalent circuit of HPND4005 PIN Diodes (a) ON state (b) OFF state.

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The DRA is an open resounding structure, created from a low misfortune microwave dielectric material. Dielectric resonators (DR's) have turned out to be perfect possibility for radio wire applications by uprightness of their high radiation productivity, adaptable feed game plan, straightforward geometry, little size and the capacity to create unique radiation design utilizing distinctive modes. Rectangular DRAs offer viable focal points over barrel shaped and round shape. For instance, the mode decadence can be stayed away from on account of rectangular DRA's by legitimately picking the three elements of the resonator. It might be noticed that mode decadence dependably exists on account of a circular DRA and on account of mixture methods of a barrel shaped DRA. The mode decline can improve the cross polar dimensions of a reception apparatus, in this way restricting its execution. Further, for a given full recurrence, two perspective proportions of a rectangular DRA (tallness/length and width/length) can be picked autonomously. Since the data transfer capacity of a DRA likewise relies upon its angle ratio(s), a rectangular-formed DRA gives greater adaptability as far as transmission capacity control. Figure 3 demonstrates a rectangular DRA with the relating coordinate framework. The thunderous modes can be TE to either measurement, meant as TEx, TEy, or TEz. A rectangular DR has three autonomous measurements. The methods of a DR can along these lines, be TE to any of three measurements. Alluding to the DR and co-ordinates framework appeared in figure 3, the modes with least request lists are TEz 111, TEy 111 and TEx 111 . On the off chance that the components of the DR are with the end goal that a > b > d, the modes in the request of expanding thunderous recurrence are TE111, TEy 101 and TEx011. The examination of the considerable number of modes is comparative.

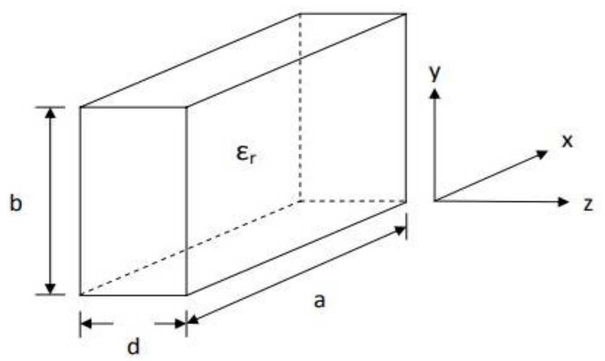

Fig 3: Isolated Rectangular DRA.

$$H_z = \frac{(K_x^2+K_y^2)}{j\varepsilon\mu_0} \text{T} \cos(K_x X)\cos(K_y Y)\cos(K_z Z)\ldots\ldots..(1)$$

$$H_x = \frac{(K_x K_z)}{j\varepsilon\mu_0} \text{T} \sin(K_x X)\cos(K_y Y)\sin(K_z Z)\ldots\ldots\ldots(2)$$

$$H_y = \frac{(K_y K_z)}{j\varepsilon\mu_0} \text{T} \cos(K_x X)\sin(K_y Y)\sin(K_z Z)\ldots\ldots\ldots(3)$$

$$E_x = \text{T}K_y \cos(K_x X)\sin(K_y Y)\cos(K_z Z)\ldots\ldots\ldots\ldots(4)$$

$$E_y = -\text{T}K_x \sin(K_x X)\cos(K_y Y)\cos(K_z Z)\ldots\ldots\ldots..(5)$$

Where T is an arbitrary constant and K_x, K_y *and* K_z mean the wave numbers along the x, y and z bearings individually, inside the DR.

$$K_x^2 + K_y^2 + K_z^2 = \varepsilon_0 K_0^2 \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$K \tan\left(\frac{K_z d}{2}\right)\sqrt{((\varepsilon_r - 1)K_0^2 - K_z^2)}\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

The elements of the emanating segment of the DR were resolved utilizing the equation (7) created for the di-electric waveguide model (DWM) for a rectangular resonator in free-space.

Where,

$$Q=\frac{2wW_e}{P_{rad}} \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$$K_x = \frac{\pi}{a};\ K_y = \frac{\pi}{b};\ K_0 = \frac{2\pi f_0}{c};\ c = 3\times 10^8\ldots\ldots(9)$$

Figure demonstrates the rectangular resonator with length a, breadth b and height d. Resonances can happen at the accompanying frequencies.

$$f_{mnp} = \frac{1}{2\sqrt{\varepsilon\mu}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{d}\right)^2}\ldots\ldots\ldots\ldots(10)$$

Where ε is the permittivity, μ is the material porousness and m, n and p are whole numbers. In this setup, TEx 011 mode is the predominant mode. Since it happens at the least recurrence at which a whole reverberation can exist. From equation (10) it very well may be seen that the recurrence at which this prevailing resounding mode can exists (the cutoff recurrence) is conversely proportional to the square foundation of the result of material parameters, ε and μ.

Table 1. Antenna Dimensions

Parameters	Dimensions(mm)	Parameters	Dimensions(in mm)
W0	40.0	L0	45.0
W1	4.2	L1	3.0
W2	2.0	L2	9.0
W3	18.0	L3	1.5
W4	1.0	L4	6.5
W5	20.06	L5	3.0
W6	3.0	L6	7.9
W7	34.0	L7	31.3
H	3.0	L8	3.0

3. Simulated and Measured Antenna Performance

The proposed antenna has three operating states, based on switching the PIN diodes.

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As mentioned, the proposed design has 2 PIN diodes which are placed on the 2 arms of the microstrip feed line. So there exists totally four operating states. The four operating states are represented as 11,10,01,00 states. But according to the proposed design, 00 operating state is invalid. When both diodes on both arms of the U-shaped feed line are in OFF state, which means a capacitance value of 0.017pF is given to the both HPND4005 PIN diodes. Current doesn't flow to the radiating element (DRA). So for this particular design only three operating cases are considered which are 11, 10, 01 cases. The return losses and voltage standing wave ratio (VSWR) for all three operating states are represented in fig 4 and fig 5. The simulation results like the return losses in fig 4 and voltage standing wave ratio(VSWR) in fig 5 for the ideal recurrence range is more noteworthy than 10dB and lesser than 2 separately. The results of the simulated frequency reconfigurable antenna performance is summarized in Table 2. The fabricated antenna is represented in fig 6 and the measured setup of this proposed antenna with 2-probe vector analyzer for return losses is shown in fig 7.

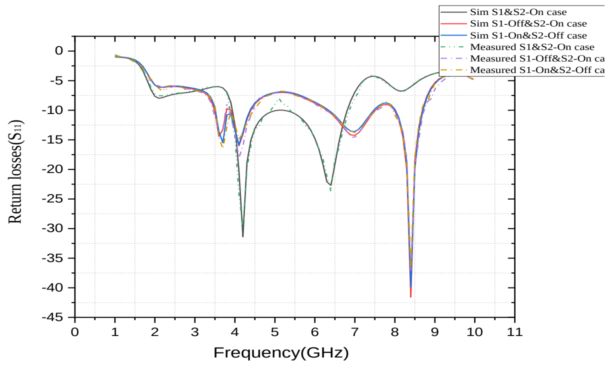

Fig 4: Return loss (S11) response of proposed design for three operating states (11, 10, 01) cases.

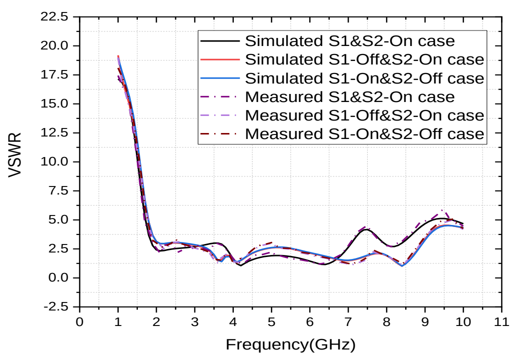

Fig 5: VSWR response of proposed design for three operating states (11, 10, 01) cases.

Table 2: Frequency reconfigurable antenna design summary.

Diode state		Bandwidth (GHZ)	Resonant Frequency (fr)	Return Losses (S11) (dB)	VSWR
S1	S2				
1	1	3.9380 - 5.0348	4.2	-31.389	1.0554
0	1	7.9924 - 8.6877	8.4	-40.2261	1.0197
1	0	8.0120 - 8.6975	8.4	-39.8750	1.0205

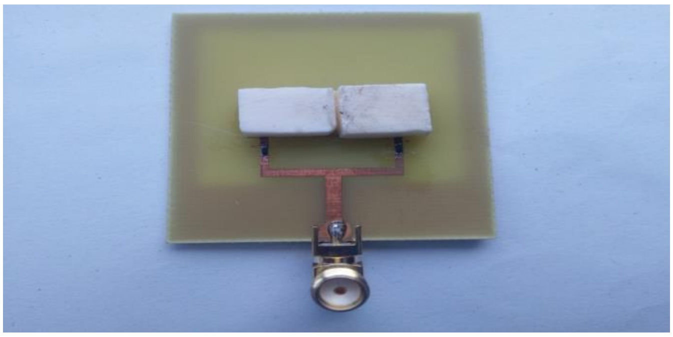

Fig 6: Representation of proposed fabricated di-electric resonator antenna.

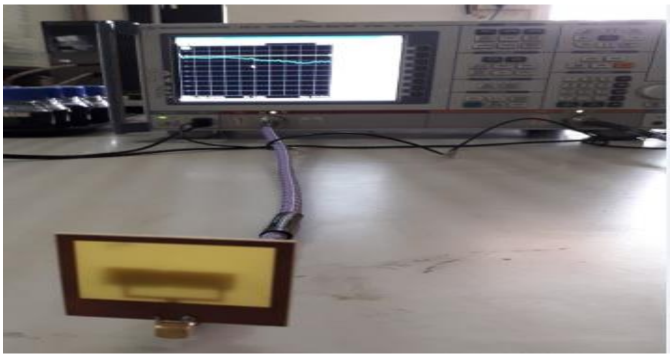

Fig 7: Measured return losses of proposed antenna with 2-probe vector analyzer setup.

The proposed receiving wire can switch between three polarization senses. One of linear and two faculties of circular polarization i.e., Left hand circular polarization (LHCP) and Right hand circular polarization (RHCP).Whereas the operating state 01 case resembles the Left hand circular polarization (LHCP) and 10 operating case resembles the Right hand circular polarization (RHCP). Fig 8 represents the axial ratio vs frequency response for both 10 & 01 operating states.

Both LHCP & RHCP in this proposed design resonate at 3.7GHz and both are having 3-dB axial ratio bandwidth is greater than 2.04%. Table 3 represents the polarization states of the proposed reconfigurable antenna.

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Table 3: Polarization states of the proposed reconfigurable antenna.

State	Diode(left)	Diode(Right)	Polarization
1	On	On	Linear
2	Off	On	LHCP
3	On	Off	RHCP

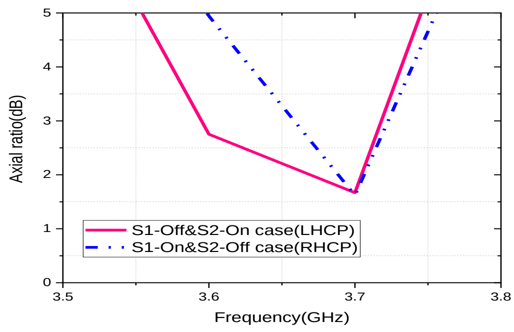
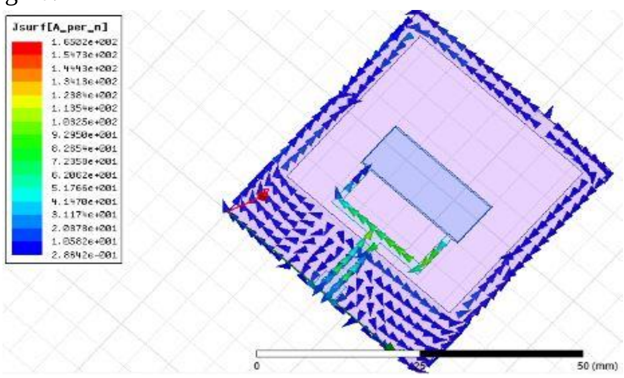


Fig 8: Axial Ratio vs frequency response for both 01(LHCP) & 10(RHCP) states of the proposed design.

Fig.9 represents the current distribution of the dominant fields in both LHCP and RHCP. The current distribution in the antenna is represented by vector_jsurf for observing the dominant fields which is either LHCP or RHCP. The radiation patterns at these resonant frequencies are shown in fig 10. The antenna is Omni-directional in H-plane. Both H-plane and E-plane patterns at their resonant frequencies for all three operating states 11, 10, 01 cases are represented in fig 10.



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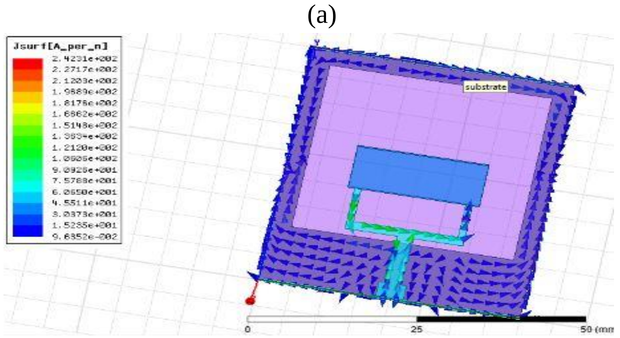
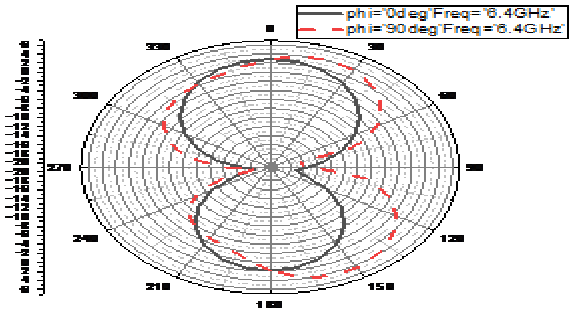


(b)

Fig 9: Representation of current distribution in dominant fields in both LHCP & RHCP.

(a) Vector_jsurf representation of dominant fields (LHCP).
(b) Vector_jsurf representation of dominant fields (RHCP).



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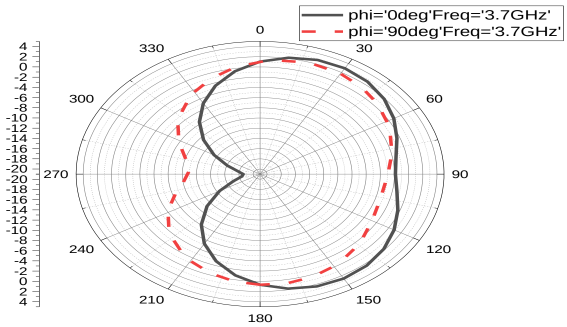

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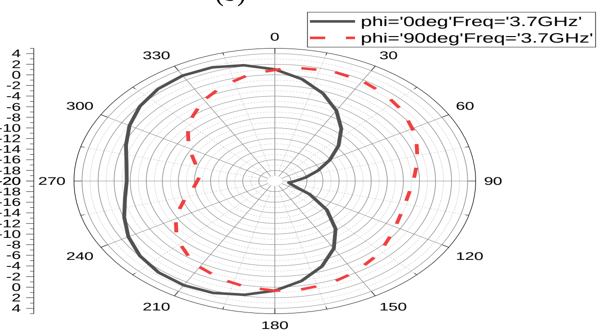

(c)

Fig 10: Radiation patterns at resonant frequencies for all three operating states. (a) Radiation pattern for 11 case. (b) Radiation pattern for 01 case. (c) Radiation pattern for 10 case.

Fig 11 represents the gain vs frequency response of the proposed design for all three possible operating states i.e., (11, 01, 10 cases). In this response, all the resonant frequencies will have a good gain values. It resembles that at a particular resonating frequency the antenna performance is good. Fig 12 represents the co & cross polarizations of simulated normalized radiation patterns at 3.7GHz for both LHCP and RHCP modes of an antenna. For this normalized radiation pattern both the phi and theta values are observed.

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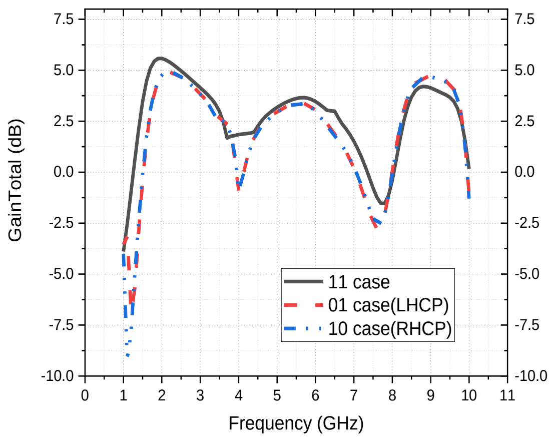
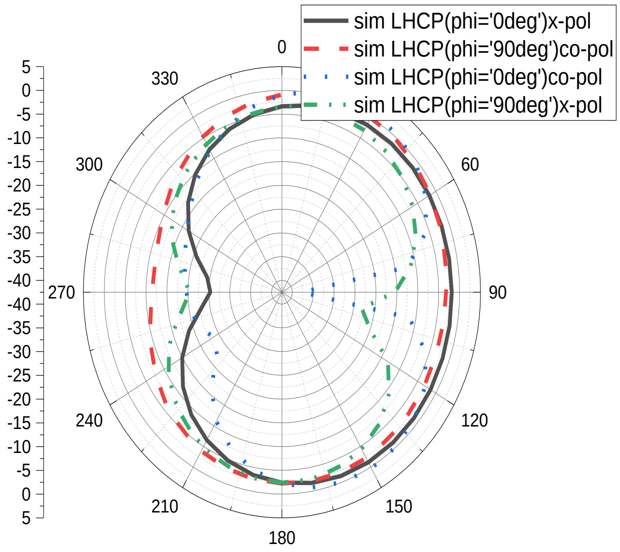


Fig 11: Gain vs Frequency response of proposed design for all three operating states.



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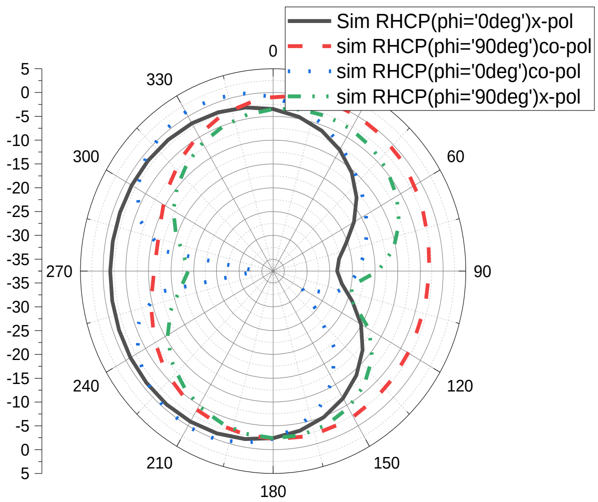

(b)

Fig 12: Co & X polarizations of simulated normalized radiation patterns of proposed design at 3.7GHz for both LHCP and RHCP.

(a) Simulated normalized radiation pattern at 3.7GHz for LHCP mode of antenna.

(b) Simulated normalized radiation pattern at 3.7GHz for RHCP mode of antenna.

III. CONCLUSION

A frequency and polarization reconfigurable rectangular di-electric resonator antenna has been demonstrated. PIN diodes are utilized to empower the receiving wire to emanate LHCP, RHCP and linear polarization. Two switches was used on the feed line path to create bands at different frequencies i.e shift in frequency and the asymmetrical U-slot can excite two orthogonal modes in the feed. Altering the location of the PIN diodes can cause the two modes have same magnitude and a phase difference of 90^0 at a given frequency, consequently empowering the antenna to radiate circular polarization with a certain axial ratio. The U-slot becomes symmetrical when both the switches are either ON or OFF state, which enables the antenna to radiate linear polarization. The proposed antenna provides frequency switching between 4.2GHz to 8.4GHz and the axial ratio bandwidth of 2.04% with the centre frequency of 3.7GHz for circular polarization modes were achieved. The outcomes stipulate that the proposed antenna will probably bolster a few kinds of remote frameworks, for example, WLAN, Wi-MAX, X-band and generally utilized for cognitive radio applications like battlefield surveillance, intelligence assistance and targeting.

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