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A New Diminutive Octa Polarization Reconfigurable Circular Patch Antenna

K.Suriya, S.Sophia

Abstract: ***This proposes a new diminutive octa polarization reconfigurable circular patch antenna design. This new antenna can operate in eight different polarizing states (6 different angles of linear polarization and 2 circular polarization states) with the help of a reconfigurable probe feed network. The antenna comprises of a circular layer of radiation with four equally spaced slits at the boundary of the circular patch to obtain size reduction. The bias voltages of six pairs of PIN diodes are controlled to produce different linear polarization states with 30° interval between each state. A 3 dB hybrid coupler and a RF switch are used to produce reconfiguration between circular polarization states of the right and left hand. The proposed antenna was designed using CST microwave studio, fabricated as a prototype model and tested which produces desired values for various parameters of antenna including compact size. The designed antenna operates within 2.4-2.5 GHz frequencies suitable for wireless applications.***

Keywords: Diminutive circular patch, octa polarization, polarization reconfigurable, reconfigurable probe feed network.

I. INTRODUCTION

Reconfigurable antennas are given more importance in the recent research scenario which can change their radiating topology by frequency, polarization, radiation and compact size within the same physical dimension. Polarization switchable antennas play a vital role in the modern scenario due to the remarkable growth in the wireless communication system. These antennas have a number of advantages like avoidance of detrimental fading loss caused due to multipath effects and improvement in channel capacity by means of frequency reuse.

Polarization diversity can be achieved by the use of any one of the following principles: dynamic reactive loading, RF switches like PIN diode[1][2], Varacter diode[3], RF MEMS[4] switch, Switchable phase shifters[5] or Switchable feed network. Reconfiguration can take place between different linear polarization states [6] [7], between RHCP and LHCP [8]-[10] or between polarization in circular and linear form [11]-[17].

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A center- fed antenna using shorting posts was implemented in [6] to produce four linear polarization states at 45° interval. In [7], a circular patch which radiates is fed by a switchable feeding network consisting of four PIN diode pairs to produce quadri linear polarization was proposed. A slotted square patch with diode in each slot feeded at the center of the two adjacent sides was implemented in [12]. To overcome the disadvantage of dual feed line structure, single feed polarization reconfigurable patch antennas with PIN diodes were proposed in [13]. In [14] – [17], polarization reconfigurable antennas realized using switchable feeding structure was implemented. However these antennas can provide at most switching between only two linear and two circular polarization states or four linear polarization states.

The proposed work deals with a miniaturized circular patch microstrip antenna design which operates in eight different polarization states at the same frequency. Miniaturized reconfigurable antennas using switchable probe feed network have become the focus of this research work. Compact size of the antenna is achieved by incorporating four equal length slits on the boundary of the circular radiating patch that leads to 12% reduction in size.

II. PROPOSED ANTENNA DESIGN

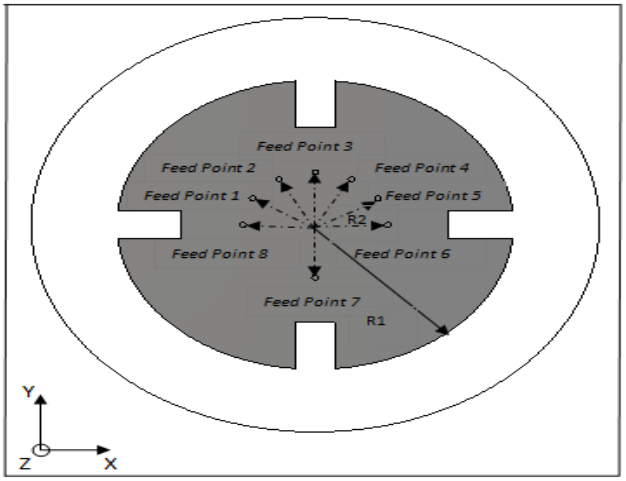
The antenna shown in Figure 1 is composed of two substrates. On substratum 1 a radiating circular patch of 15 mm radius is etched, and the switchable probe-fed network functions as substratum 2.

Four equal slits 5 mm in length and 3 mm in width are incorporated on the boundary of the circular patch at an interval of 90° between each other for the purpose of reducing the antenna size. The antenna is etched on 3.2 mm thick FR4 epoxy substratum with Єr =4.4. Excitation is given by means of a switchable probe feed structure.

Octa polarization is achieved by using a switchable feed network which consists of six pairs of PIN diodes, RF switch and 3dB hybrid coupler which acts as substrate 2 as shown in Figure 2. PIN diode operating states are changed to reconfigure the antenna feed point. Six different linear polarization states at 30° interval (0°, 30°, 60°, 90°, 120°, 150°) were achieved.

From the middle of the circular patch are six probes of 0.4 mm radius that acts as a switchable feed network, etched to a substratum of 0.4 mm thickness. The feed network is made up of a feed line at the input with six PIN diode switch pairs and transmission paths with standard impedance of 50 Ω. To ensure the continuity of the RF signals a capacitor (47 pF) is integrated into the feed line which also provides isolation to the DC signals.

To avoid poor cross polarization performance due to the six transmission paths which acts as loading for the circular patch, the transmission path length should be very small. DC biasing is effected by attaching the radiating patch to a small square pad using a shorting PIN. The radiating patch and square pad are linked through a 47 nH inductor. The six transmission paths are connected to the DC lines through 47 nH inductor. Also the feed line at the input is connected to the square pad using 47 nH inductor. The square pads are attached to the ground power supply terminal to supply 0 V to the cathodes of all the diodes and the DC lines are attached to the positive power supply terminal to deliver positive voltages to the anodes of all the diodes.



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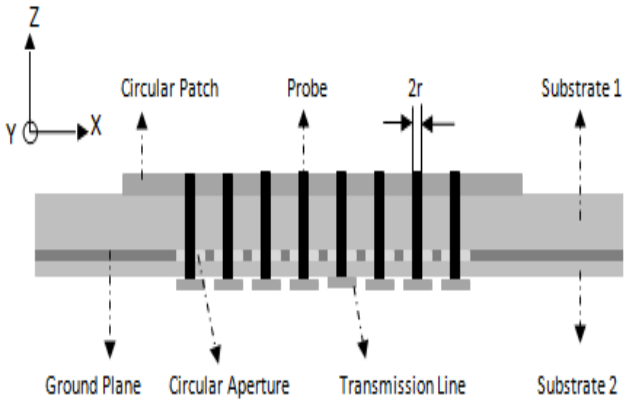
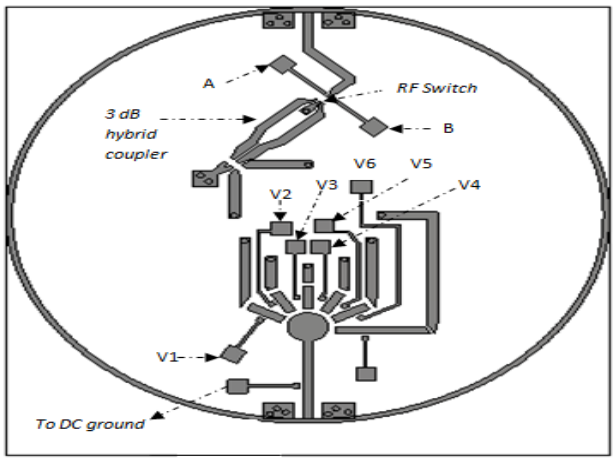


(b)

Figure 1. Designed antenna geometry: (a) top view (b) side view. The parameters of antenna are R1=15mm, R2=5.5mm, r = 0.4mm.

PIN Diode [18] is biased forward when powered by a bias voltage that produces 10 mA of current. This forward biased condition is known as ON state and unbiased PIN diode is said to be in OFF state.

Circular polarization is achieved by using a four port 3 dB hybrid coupler. A SPDT switch is located between the input ports of the coupler to provide switching between RHCP and LHCP states. A 3 dB hybrid coupler divides the input signal evenly within the output ports with the resulting 90° phase shift. The RF switch which is placed at the input of the coupler produces switching between Right and Left circular polarization based on the connection with port A or port B. Frequency offset problem is avoided because both (LHCP and RHCP) states operates at 2.45 GHz frequency. The frequency range in which the SPDT switch and 3dB coupler operates is 1-6 GHz and 2.3-2.7 GHz respectively.



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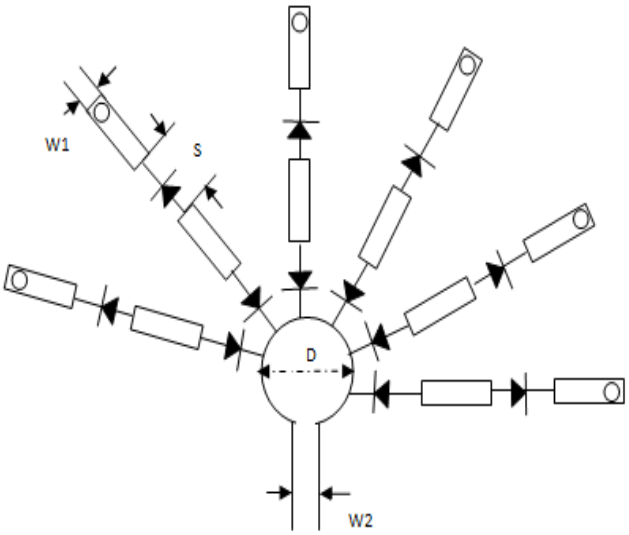
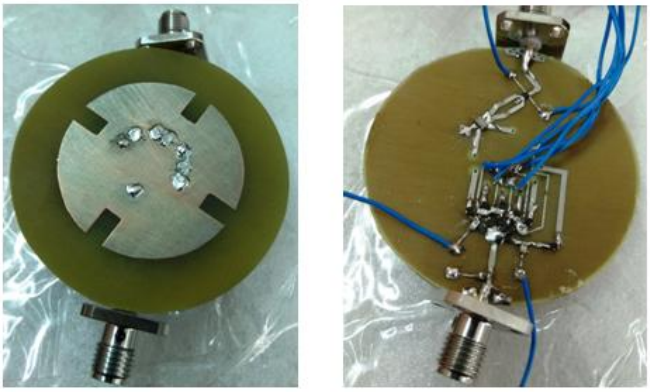


(b)

Figure 2. Proposed antenna-Feed network. Antenna parameters are D= 3mm, W1 = 1mm, W2 = 1mm, S = 0.6mm.

The direction of polarization of the antenna proposed is chosen by keeping any one pair of the switches in ON state and other pairs of switches in OFF state. The different states of polarization of designed antenna are listed in Table 1. Two series PIN diodes are used for better cross-polarization efficiency in the proposed design



(a) (b)

Figure 3.Designed antenna. (a) top view (b) bottom view.

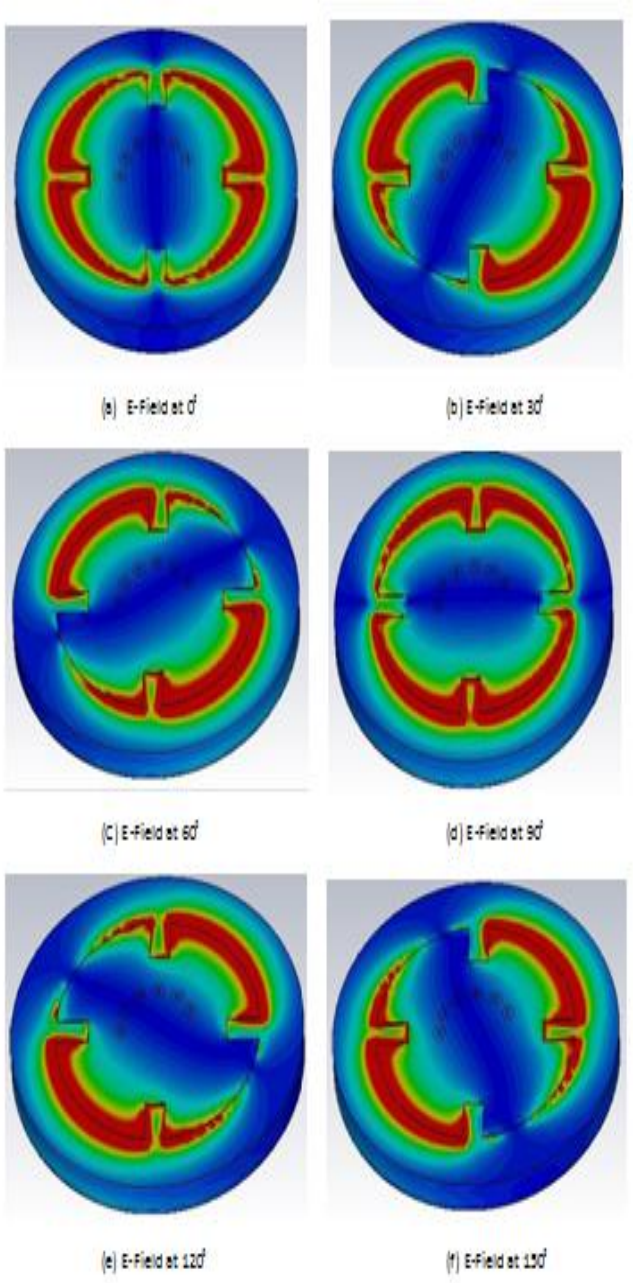


Figure 4.Field current distribution for different linear polarization states.

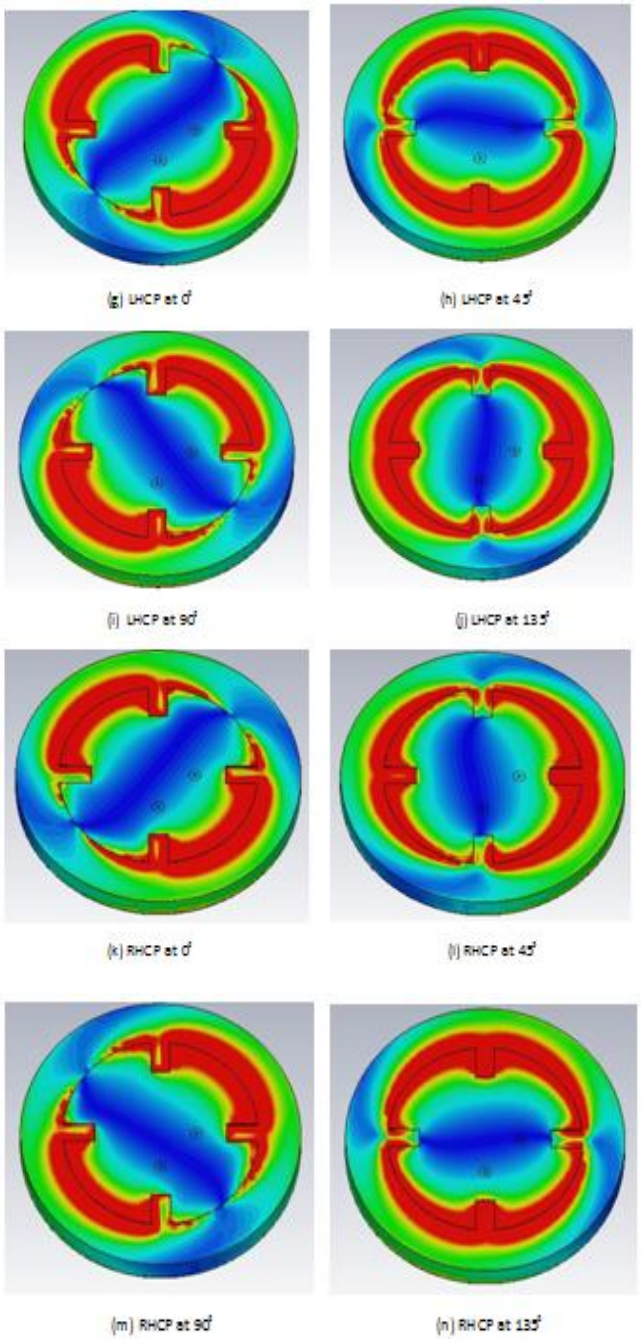


Figure 5.Field current distribution for different circular polarization states.

III. RESULTS AND DISCUSSION

CST Microwave Studio was used to simulate the antenna, verified by fabricating and testing the prototype of the same. Figure 3 displays the manufactured antenna prototype. The field current distributions of octa polarization (six linear and two circular polarization) states are shown in Figures 4 and 5.

Figure 6 shows the stable radiation patterns at 2.4GHz, 2.45GHz and 2.5 GHz for different circular states of polarization. Calculated VSWR of fabricated antenna for different polarization states is presented in Figure 7. The results indicate that VSWR < 1.5 dB is obtained for various polarization states at 2.45 GHz frequency. Measured radiation patterns of all six linear polarization states are stable at $\phi=0^{\circ}$ and $\phi=90^{\circ}$ as shown in Figure 8.

TABLE 1. PROPOSED ANTENNA- DIFFERENT POLARIZATION STATES

	State	Selected feed point	Polarization direction
V1	State 1	Point 1	150°
V2	State 2	Point 2	120°
V3	State 3	Point 3	90°
V4	State 4	Point 4	60°
V5	State 5	Point 5	30°
V6	State 6	Point 6	0°
A	State 7	Point 7	LHCP
B	State 8	Point 8	RHCP

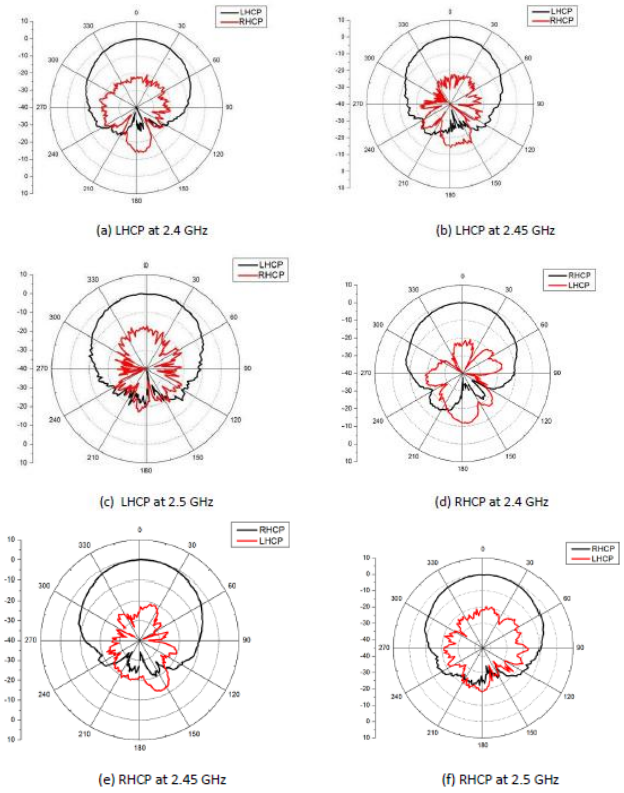


Figure 6.Measured radiation patterns at 2.4GHz, 2.45GHz and 2.5GHz for different circular polarization states.

Axial ratio < 3 dB is achieved for the different circular states of polarization as shown in Figure 9. Also the results indicate that gain of 5dB is obtained for all the different polarization states. Table 2 gives the comparison of different parameters for some existing antennas with the proposed antenna. The results indicate that the patch size is small when compared with other antennas in the proposed design. In this design, a return loss of about -22 dB is achieved which is similar to other existing antennas. A reasonable gain of about 5dBi is attained for the proposed design and also it works in 8 different polarization states, where as other antennas operates only in 3 or 4 different polarization states.

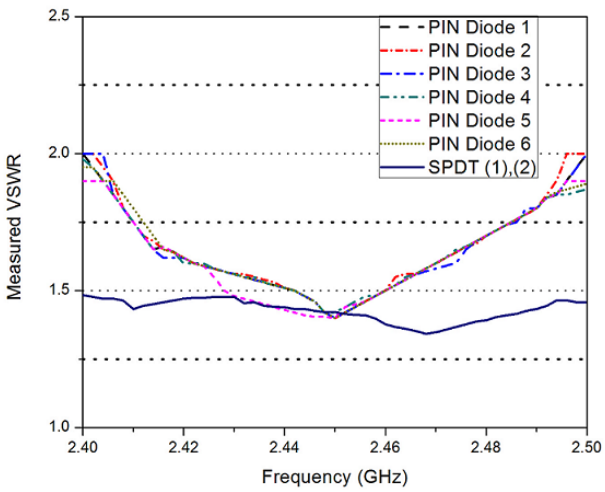


Figure 7.Measured VSWR for different polarization states.

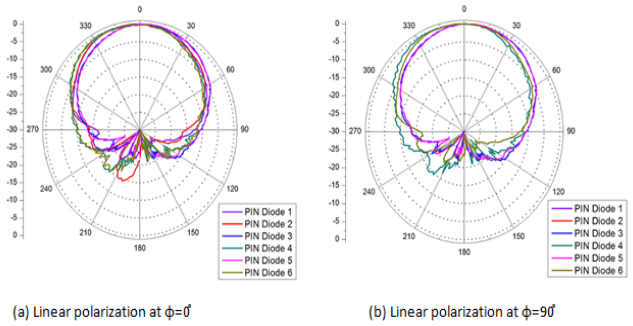
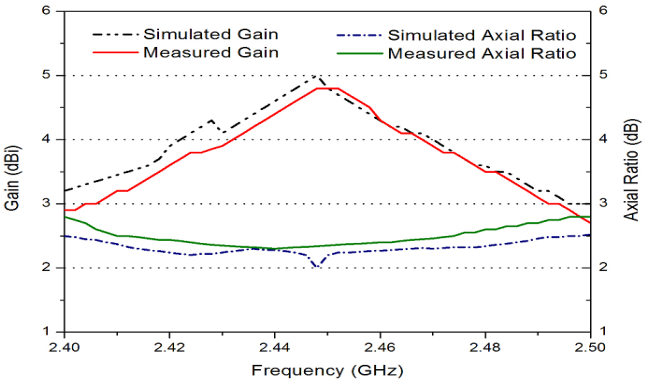
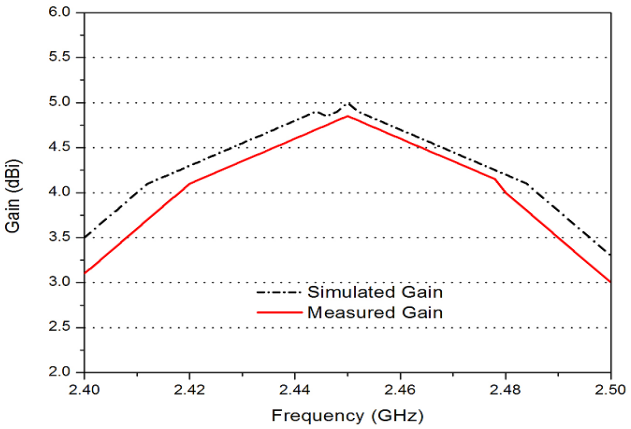


Figure 8.Measured radiation patterns at different linear polarization states.



(a)



(b)

Figure 9.Comparison of (a) gain and axial ratio calculated and simulated results for circular polarization (b) calculated and simulated gain for linear polarization.

IV. CONCLUSION

A new diminutive octa polarization, reconfigurable circular patch antenna is proposed , designed, simulated, manufactured and tested in this work. Operating states of six PIN diode switch pairs and RF switches are changed to achieve various linear and circular polarization states. Optimum performance outcomes are obtained on the same operating frequency for various states of polarization. In future the antenna can be modified further by using a single feed to produce different polarization states with increase in design complexity which is useful in wireless communication systems.

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Table 2.Comparison between some existing antennas and proposed antenna.

Reference	Antenna Type	Size of the patch (mm)	Return Loss (dB)	Measured Gain (dBi)	No.of polarization states	No. of Diodes
[1]	Etched Ring Patch	34	-18	8	4	4
[6]	Center fed Circular patch	18	-22	5.9	4	4
[7]	Probe fed Patch	28	-18	6.9	4	8
[15]	Square Patch with T-shaped Feed	22	-23	7	3	2
This Work	Miniaturized Circular Patch	15	-22	5	8	12

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