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Polarization Reconfigurable Antenna: A brief Review

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Abstract—The main motive of this paper is to understand the different techniques which have been adopted in recent years in the design of polarization reconfigurable antenna. It is a solitary antenna that is used for different polarization diversities like horizontal linear polarization (HLP), vertical linear polarization (VLP), right-hand circular polarization (RHCP), and left-hand circular polarization (LHCP) with the help of a switching. This antenna increases the diversity gain by reducing the interference and multipath fading effects which generally occurs due to the presence of other antennas for the same purpose. Hence, these antennas can be easily used for terrestrial and aerospace applications, i.e. adaptive beam scanning and multiple inputs and multiple-output (MIMO) systems.

Keywords—polarization antenna, reconfigurable antenna, Linear polarization, Circular polarization.

INTRODUCTION

The antenna is a device that translates the electric signals into electromagnetic waves or vice versa. The conventional antennas can work in single-polarization only. However, when the system requirement varies then we need to reconfigure the antenna. But it is difficult and increases the cost and size of the antenna. The main resolution to this problem is to use the reconfigurable antenna in which only a single antenna is used for various frequencies, for a different pattern and different polarization states. The hardware complexity in the design, inflexibility in hardware and the number of components in the design can be easily reduced with the help of technology of reconfigurability. So, change in the reconfiguration of an antenna will provide a number of benefits to the future generations of the wireless system. By switching the location of the feed of antenna or switching the radiating path or ground structure of the antenna, the operative resonating length

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of the antenna is altered so this brings the reconfigurability in the antenna. So basically, for the switching purpose, we prefer mostly PIN diodes, optical switches, varactor diodes, and MEMS to connect or disconnect any part of the antenna. Reconfigurable antenna improves the spectrum efficiency and power utilization and also increases the capabilities of the wireless system, expands its functionality or broadens its bandwidths. Reconfigurable antennas are of three types as frequency reconfigurable antennas, pattern reconfigurable antennas, and polarization reconfigurable antennas. Patten and polarization reconfigurable antennas play a significant role in diversity schemes.

The main motive of this paper is to put lights on the polarization reconfigurable antenna. It can be utilized to enhance system security and satisfy system requirements. One of its vital applications is in the terrestrial and aerospace wireless communication system. Polarization antenna is classified into linear polarization (LP) and circular polarization (CP). LP antenna is further classified into horizontal polarization (HP), vertical polarization (VP) and ± 45°slant polarization [1-3] as depicted in fig 1. The circular polarization antenna [4-5] again has two categories like RHCP and LHCP.

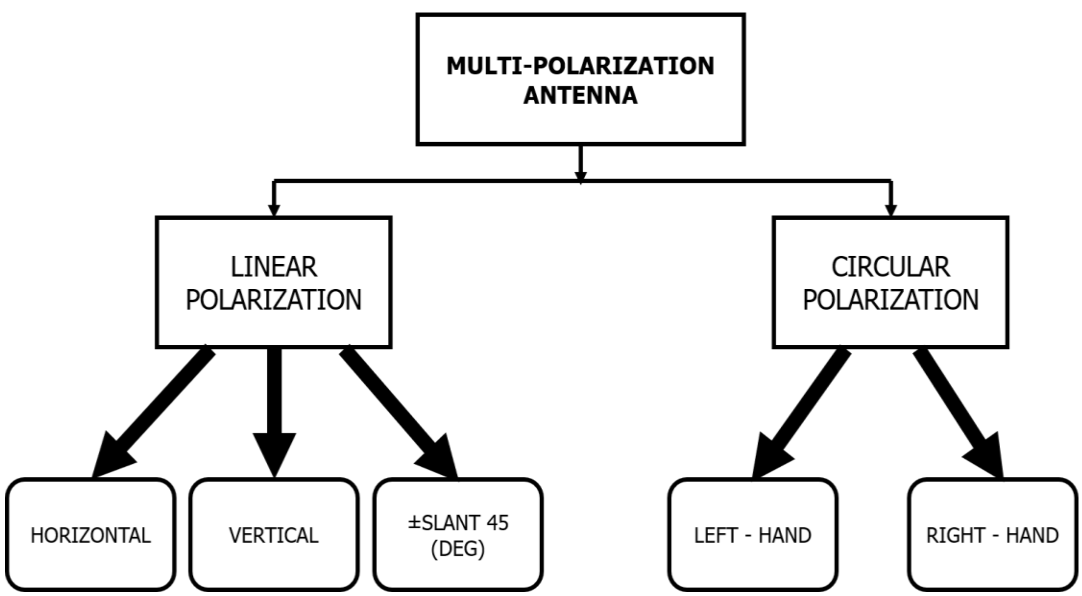

Fig 1: Classification of polarization reconfigurable antenna

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Due to frequency reuse applications, polarization reconfigurable antennas becoming more popular day by day. Microstrip antennas are generally LP because they generally designed for single-mode operation. But in some applications like satellite communications, CP antennas are mostly used due to their insensitivity toward transmitter and receiver orientations. Mainly PIN diode switches are used for the switching between LHCP and RHCP. Sometimes radiation performance of the antenna can also be affected by the biasing circuit of the design.

EMERGING TECHNIQUES

This paper reviews various kinds of emerging technologies in the fields of polarization reconfigurable antennas. Both linear and circular polarized reconfigurable antenna structures have been implemented yet are discussed in this paper below.

Most of the polarization reconfigurable antennas that have been developed so far are unidirectional antennas. So, for the omnidirectional pattern mostly 45°slant polarized and circularly polarized antennas are used [1]. Equality of the received signal level can be improved by slanting the antenna elements to 45 degrees left and 45 degrees right. By using these types of the cross-polarized antenna the interference occurs due to multiple antennas can be reduced. ±45°slant polarization antennas have more symmetric propagation characteristics than vertical and horizontal polarization antennas so in mobile communication these antennas are basically used at base stations. To attain the radiation pattern of these antennas at 360 degrees, an omnidirectional radiation pattern is required. For a ±45 degree slant polarized antenna, to achieve an omnidirectional radiation pattern, vertical and horizontal components should be the same with equal magnitude and equal phase.

An approach of ±45-degree slant polarization omnidirectional antenna is discussed in [2]. Four cross-dipole elements and a feeding element are used to design a 45-degree slant polarized antenna as visualized in fig 2. A flexible dielectric substrate is used to print the four cross-dipole elements and then they rolled up on a hollow cylinder to achieve the required radiation pattern. Each cross-dipole consists of a vertical dipole and a horizontal dipole. By adjusting the length of horizontal (L_h) and vertical dipoles (L_v), 45-degree slant polarization is achieved. A feed network excites the

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multiple crossed dipole elements which further comprise an impedance matching circuit. After simulation bandwidth of 22% (15 dB) return loss is achieved.

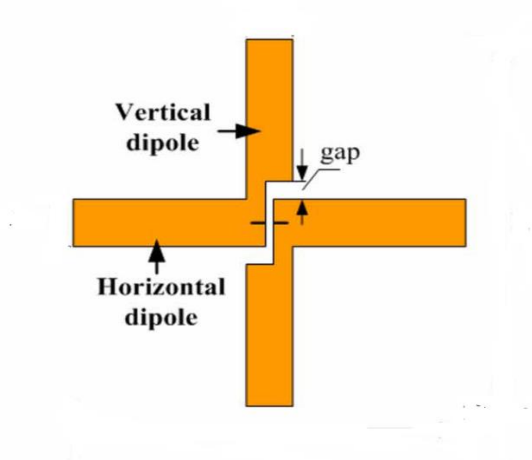

Fig 2: Cross-dipole elements [2]

Another approach of the design of omnidirectional antenna with ±45degree slant polarization is discussed in [3] in which an antenna is capable to radiate in two dipoles like patterns one is +45 degree slant polarized and other is - 45-degree slant polarized pattern. One is covering 360 degrees in the elevation plane and the other is in the horizontal plane. In this technique, the rectangular patches are fed to the two lower corners by the microstrip lines. This antenna includes two back to back coupled radiating elements which share a joint ground structure. Patches operate on a resonant frequency of 2.56 GHz. To achieve dual ± 45 degrees slanted polarization two feeds for each patch are required. For pattern reconfigurability, all four edges of each patch must be excited by the electric field. Each patch should be fed at the corner to achieve this. As the length and width of the radiator are equal so it realizes as a linear slant polarization, otherwise this technique was applied for the circularly polarized antenna. The excessive input impedance at the corner is a significant problem. With the help of phase difference amongst the ports pattern, reconfigurability is observed and polarization is found out by port selection. Only two ports out of four ports can be excited at a time by each configuration. The change of exciting ports determines the polarization. The excited ports may be in phase or out of phase. This antenna has a high degree of polarization as well pattern reconfigurability. It is highly convenient for MIMO applications because it can allow two configurations at the same time.

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A design approach of low-profile wideband CP antenna is discussed in [4]. It consists of vertically polarized microstrip patches which let it work in TM_{01}/TM_{02} mode and in sequence bent slots cut into the ground plane which provides horizontal polarization field. Circularly polarized radiation field achieved with the combination of both radiation fields of microstrip patch and slots. PIN diodes, which can be controlled electronically, provide the polarization reconfigurability to the structure. The alignment of the slots on the ground structure can be dynamically transformed and polarization state could be switched from RHCP to LHCP. In the end, the operational bandwidth occurred is 19.8% (2.09GHz-2.55GHz) having an axial ratio underneath 3dB and return loss above -10 dB in any RHCP or LHCP waves. It provides compact size, low thickness and has a stable CP omnidirectional radiation pattern inside the whole operational band.

A new approach is discussed in [5] in which polarization reconfiguration is achieved with the help of PIN diodes and microelectromechanical (MEMS) switches. In the earlier time, metasurface material was used for polarization reconfigurability of antennas to achieve they should be rotated mechanically. This would need extra motor facilities, which increase the cost.

Usually, microelectromechanical (MEMS) switches and PIN diodes are used to achieve reconfiguration and often used to regulate radiation from the antennas. Antennas were usually intended to yield CP and LP signals. In polarization reconfiguration, DC biasing is used to regulate the PIN diode switches. Capacitor, inductor, and resistors are used to design the DC biasing circuits. For the soldering of the components onto the substrate, DC pads are used and with the help of microstrip lines components are joined together. With the help of simple wires, DC voltages are given to the biasing circuit. If DC wires, microstrip lines, and electronic components are not well designed then it will affect the antenna performance. If the DC biasing circuits are designed on the ground surface then affects the antenna performance can be reduced. A new polarization reconfigurable slot antenna is proposed at a frequency of 5.80 GHz for wireless local area networks (WLAN). It contains four slots in X-shape. To provide polarization reconfiguration four PIN-diodes are utilized which regulates the radiation from the slots. The switching of the

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antenna from LHCP to RHCP is done by doing ON/OFF operation of the PIN-diodes. The results show that antenna has a return loss of less than -10 dB and has wider bandwidth 5.11- 6.21 GHz.

A wideband polarization reconfigurable partially reflecting surface (PRS) antenna in [6] is proposed for the polarization switching among LHCP, RHCP and LP which employs a Wilkinson power divider network and a shorted annular patch (SAP). The reconfigurable feed network attains a phase difference of 0º or ±90 between the dual output ports within a broad range by proposing two-phase shifter and eight PIN-diodes in the power divider. The circuit does not need any frequency matching networks due to its highly integrated nature; it also provides a compact structure. We achieve a 10-dB overlapped impedance bandwidth and 3dB AR bandwidth of 13%.

In paper [7], as displayed in fig 3 a reconfigurable patch antenna array with aperture feeding is designed for ±45-degree polarization. First, a novel method for reconfigurable ±45-degree polarization antenna is discussed. For two orthogonal polarizations, controllable RF switches are designed on a cross aperture to feed the square radiating part. Two sets of DC biases are used to control the RF switches which select the polarization. By controlling the DC voltage ±45-degree linear polarizations are switched. Second, based on cross aperture feeding two patch antennas are discussed. With the help of four switches primary structure uses a fragmented ground plane, on the other hand, the other one uses eight switches and employs a united ground plane. As a single element, both antennas work well. But, for designing a dual-polarized reconfigurable antenna array only the antenna with the joint ground plane is suitable. This antenna also provides a reconfigurable controlling network and simple DC biasing lines. The -10dB impedance bandwidth of this array covers 2.4 GHz WLAN band and is 9.3%. The maximum gain of the antenna is 13.5 dB. This antenna also provides stable gain and insignificant cross-polarization throughout the operational bandwidth.

A new approach is discussed in [8] where a multi-polarization reconfigurable antenna with the help of four dipole radiating elements used in body-centric wireless communication (BWCS) for biomedical applications in. To overcome the polarization mismatch and multipath distortion in the complex wireless channel the multi-dipole antenna is used which is switchable at 0°, +45°, 90°,

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and −45° linear polarization. For all the dipoles with 45° rotated sequential arrangement are assembled together to realize the reconfiguration feature among all these antenna designs. By providing a ground tapered balun, the same feeding source is applied to excite all these dipoles. To generate broadside radiation, a metallic reflector is used which is located beneath the dipoles. Eight PIN-diodes are used as RF switches amongst four dipoles and excitation source to control a specific dipole as a result of that 0°, +45°, 90°, and −45° linear polarizations could be converted to different operating diodes. The investigational results show a wider impedance bandwidth of 34% and peak gain is 5.2 dB.

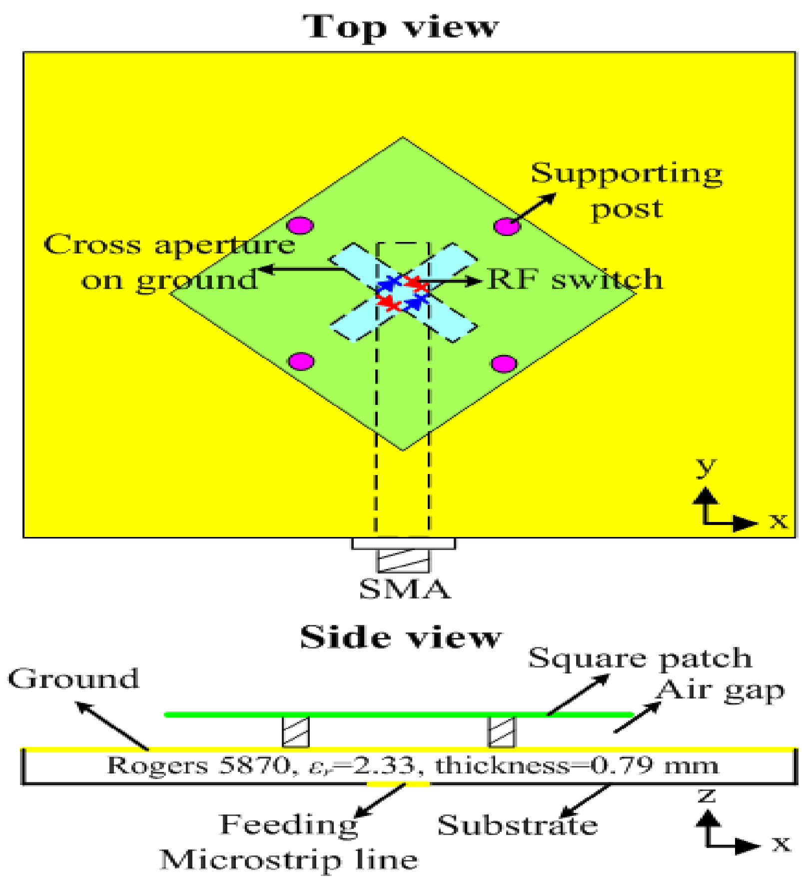

Fig 3. Single element antenna configuration [7]

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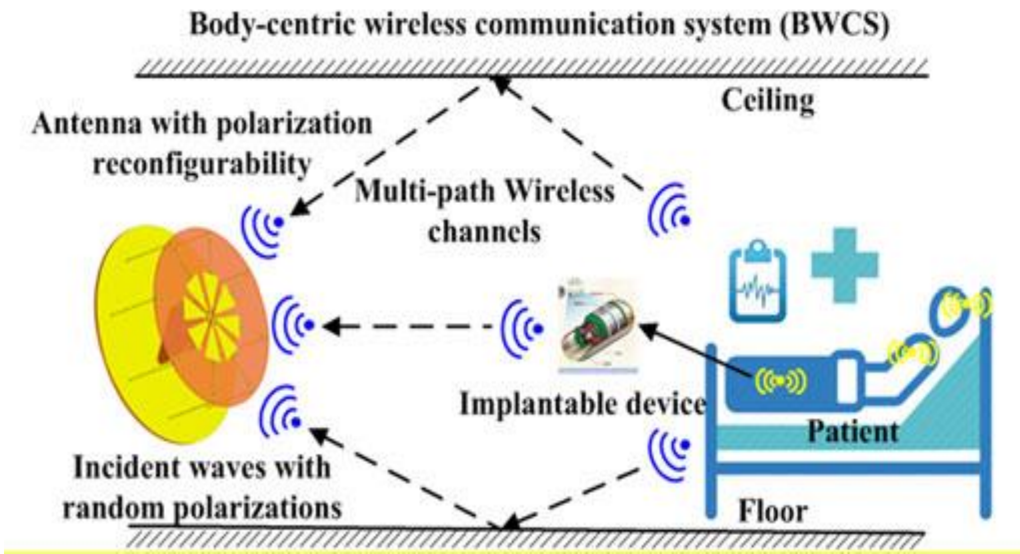

Fig 4. A body-centric wireless communication system (BWCS) [8]

In this approach [9] a new planer polarization reconfigurable antenna with switching technology is discussed. Substrate integrating waveguide (SIW) cavity with dual resonating-mode behavior is utilized in this polarization reconfigurable antenna. To fine-tune the phase distribution of the slots which are engraved on the uppermost surface of the SIW cavity two input ports are adopted. By using proper input ports, the LHCP, RHCP and LP can be realized. For the visualization of array application, a 2x2 array antenna is designed without using any additional switching elements as capacitor, inductor, and PIN-diodes. It provides a relatively high gain and low cost. It also reduces the complexity. It is utilized for polarization diverse applications for the wireless system.

An approach is discussed in [10] which proposed the design of polarization reconfigurable dual-port microstrip patch antenna. With the help, dual-polarization channel capacity and system performance are enhanced. By modifying the feed network reconfigurability is achieved. Two orthogonal polarizations are simultaneously excited by this dual-port antenna. The upper substrate of the design will act as a radiating element which consists of a circular patch on that. The ground plane consists of a coplanar waveguide slotline transmission. By utilizing the CPW feeding structure dual ports are constructed. To vary the current four PIN-diodes are used. PIN-diodes are

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rested on the slotline interjection. Based on the switching configuration, polarization can be altered.

A new approach is discussed in [11] in which a reconfigurable polarization antenna using metasurfaces superstrate is presented. This antenna comprises a planer coupling slot and also consists of an array of metallic rectangular patches that contain PIN-diodes and can be seen as a reconfigurable metasurface superstrate. It also has a DC bias controlling circuitry and rectangular metasurface array comprising of 12-unit cells printed on a dielectric substrate. Electronically the polarization state on the antenna is switched with the help of bias lines, chip inductors and DC bias controlling circuit. consisting of PIN-diodes. The antenna is left hand circularly polarized (LHCP) when the PIN switches are off and linearly polarized (LP) when PIN switches are ON. The simulation results show the impedance bandwidth from 5.1 GHz to 6.4 GHz that is 22.6% with 3 dB AR bandwidth of 1 GHz and average gain of 7 dB while the PIN diodes are off. While the PIN switches are ON the impedance bandwidth is 1.4 GHz with a gain of 6.1 dB.

A wideband polarization reconfigurable antenna is discussed in [12]. For the feeding purpose, a coplanar waveguide (CPW) to slotline transition is utilized. The LHCP, RHCP, and vertical polarization (VP) modes are achieved in CPW mode and horizontal polarization is achieved in slotline mode. With the help of corner perturbation technique, wide circular polarization (CP) bandwidth is achieved. At 2.4 GHz very good performance is obtained with orthogonal circular polarization and at 1.9 GHz an orthogonal linear polarization is achieved. After the simulation results display a 28.8% impedance bandwidth and 3 dB AR bandwidth 14.8% for CP. This antenna architecture is mostly used in WLAN and universal mobile telecommunication system (UMTS).

In another approach [13] a magneto-electric dipole antenna is discussed. A magneto-electric (ME) combines two orthogonally located complementary dipoles, electric and magnetic. This antenna provides four states of polarization regulators like LP in the x-direction and in the y-direction, LHCP, and RHCP. A cross dipole feed is integrated into the cross-gap of an improved ME dipole to provide LP states and CP (left or right) is obtained by adding perturbation to the ME dipole structure. To change all the possible polarization states PIN-diodes are required. After the

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simulation, the operating bandwidth obtained by LPs is 21.5% and the operating frequency range is 1.37-1.7 GHz and operating bandwidth for CPs is 17.8% covering1.38-1.65 GHz. This antenna provides nearly same gain for both linear and circular polarizations, low back radiation level and symmetrical radiation pattern at operating frequencies.

A new approach is discussed in [14] in which a twin-port polarization reconfigurable antenna with the sphere-shaped patch is designed. By modifying the CPW slotline feed network which is positioned on the ground structure the polarization reconfigurability is accomplished. On each of the plotlines, two-phase delays having a quarter wavelength, are interconnected. To deactivate and activate the phase delay slot lines eight switches are positioned on CPW slotline transmission, this modifies the polarization mode of the antenna by monitoring the flow of the current. With the help of even and odd modes of CPW characteristics dual-port feature of the antenna is realized. The simulations results show that the proposed antenna has good impedance matching, port-to-port isolation and the ability to shift the polarization modes. This antenna is used in space-limited MIMO applications which are utilized as an access point for WLAN.

Another approach is discussed in [15] in which a piezoelectric transducer (PET) is used for the switchable circular polarized reconfigurable antenna. The propagation constant, effective permittivity and phase shift of the communication line is changed by a dielectric which is perturbed in the electromagnetic fields of the transmission line. The deflection of PETs is done by two external voltages. So as shown in fig 4, dielectric perturbers which are added to the PETs can either trace the substrate or can append above the substrate. The external dc voltages help to control the switching mechanism. This PET measured switchable CP antenna uses simpler dc biasing circuit for its piezoelectric transducer compared to the reconfigurable antenna using diodes. By lifting up the one PETs and pulling down the other one the RHCP and LHCP can be obtained. This antenna works at 5.8 GHz frequency band shows the same kind of performance including axial ratio, gain, and radiation patterns for both LHCP and RHCP.

For the WLAN system, a dual-port polarization antenna operating at 2.4 GHz and 5.8 GHz frequency is discussed in [16]. This antenna is a single-aperture-fed antenna that switches between

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vertical, horizontal and 45º degree linear polarizations at 2.4 GHz and 5.8 GHz. By considering the TM_{10} and TM_{30} modes of square patch antenna the dual-band operation is achieved. The frequency ratio of these modes is adjusted by inserting the four shorting posts into the patch. PIN diode is used to connect the center of each edge with the ground plane for polarization switching. The measured results on radiation pattern and reflection coefficients suit well with numerical simulations.

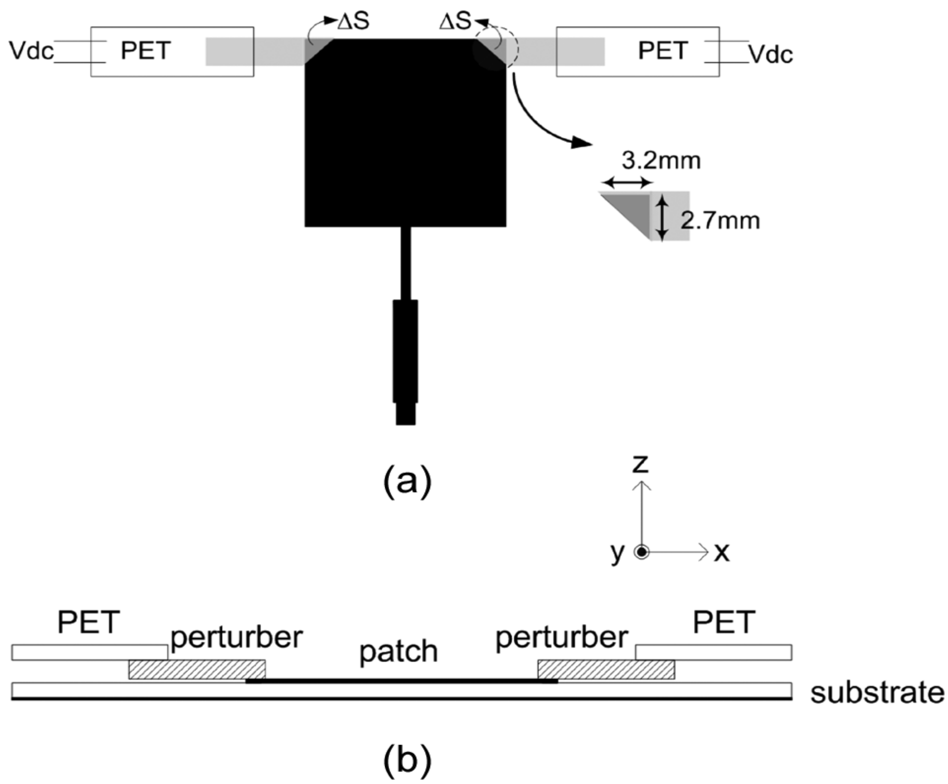

Fig 4. Diagram of the proposed antenna (a) Top view and (b) Side view

A novel approach is discussed in [17] in which a loop antenna having wide bandwidth with reconfigurable circular polarization is designed. Both sides of the dielectric substrate are printed by the loop antenna. A dual gap loaded smaller loop is printed on one side and a dual PIN diode loaded loop is printed on another side. The polarization state of the antenna is switched from RHCP to LHCP by monitoring the ON/OFF state of the PIN diode. The experimental gain is near about 7 dB for RHCP state and 8 dB for LHCP state. This antenna is very suitable in dual-CP wireless communication system due to its wide bandwidth high gain and simple feeding structure.

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An alternative approach is discussed in [18] where a circularly polarized proximity-fed microstrip antenna having polarization switching ability is designed. The four-sided patch with shortened corners and a microstrip feed line are on the same plane. With the help of a conducting post, a pad and PIN diode is connected to the ground plane. The diode is implanted between the pad and end of the feed line controls the switching operation. By switching the diode ON/OFF, the LHCP and RHCP of the antenna can be achieved. Tuning stubs controlled by two diodes are coupled in shunt with the feed to improve the input impedance of the radiator. Simulation results show the 10 dB bandwidths of 2.40 % and 3.60 % and a gain of 7.1 dB.

In [19], the authors contributed to designing a polarization reconfigurable microstrip patch antenna by means of PIN-diodes. This antenna consists of an imprinted ring shape slot on the upper side of the radiating element and a cross-slot in the ring slot for matching the impedance. The PIN diodes are mounted on the ring-slot to switch the polarization state. For the feeding purpose, EM coupling is used. The switching of polarization can take place among the LHCP, RHCP and two linear polarization (LP) for the same frequency. Cross slot is used to boost the impedance matching characteristics.

Researchers discussed the combined effects of a dipole antenna and a loop radiator which develops a polarization reconfigurable omnidirectional antenna in [20]. The circularly polarized omnidirectional radiation pattern is achieved by combining these two radiators. Small loop and dipole are excited by the same current but having a 90-degree phase difference so that an omnidirectional circular polarized radiation pattern is achieved. The left/right-hand circular polarized radiation pattern is achieved by just changing the direction of the current. The microstrip line is utilized to feed the antenna and feeding substrate contains a dc bias network and a transition part in it.

TABLE1 DESIGN TECHNIQUE, ANTENNA PARAMETERS AND APPLICATIONS

Ref.	**Design Technique**	**Parameters**	**Application**

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[2]	Slant polarized antenna using four-cross dipole elements	The frequency used is (1.75-2.18) GHz and (1.90-2.20) GHz	Base stations for mobile communications
[4]	Bended slots are etched on the ground plane and PIN diodes are used	Left/ right-hand circular polarization with (2.09-2.55) GHz	Wideband wireless communication system
[5]	Four PIN diodes are used in an X shape	LHCP/RHCP with a wide bandwidth (5.11-6.21) GHz	Use in WLAN 802.11a standards
[7]	RF switches are imposed on a cross aperture	It covers 2.4 GHz WLAN band	It can be utilized for base station antenna or RFID system
[10]	Four diodes are entrenched on the intersection of the Coplanar-waveguide slotline	LP and CP modes can be excited simultaneously	Utilized in wireless local area network (WLAN)
[12]	CPW to slotline transition is utilized for feeding	Orthogonal CP at 2.4 GHz and orthogonal LP at 1.9 GHz	Used in WLAN and UMTS
[15]	The piezoelectric transducer is used for switching the CP mode	Operating frequency band is 5.8 GHz	Used for polarization diversity
[16]	A square patch is aperture coupled with a microstrip line	Operating frequency is 2.4 GHz and 5.8 GHz	Used in WLAN system for MIMO applications
[19]	The antenna consists of a radiator, ring slot, and a cross slot	40 MHz bandwidth is utilized	Used in radar, wireless, and satellite communication system
[20]	Dipole and loop radiators are combined to get the omnidirectional pattern	Operating frequency is 5.575 GHz	Operating frequency is 5.575 GHz

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TABLE 2. RETURN LOSS, IMPEDANCE BANDWIDTH, AND GAIN

Ref.	**Return loss (s_{11})**	**bandwidth**	**Gain**
[5]	S_{11} < -10 dB; for RHCP	Both RHCP/LHCP (5.5-5.91 GHz)	Maximum gain is 4.3 dB at 5.5 GHz
[6]	S_{11} < -25 dB; for LP S_{11} < -30 dB; For LHCP/RHCP	For LP (4.65-5.33 GHz) For CP (4.63-5.84 GHz)	For LP (7.5-11.3 dB) For CP (7.3 dBic-11.2 dB)
[7]	S_{11} < -15 dB	(2.25-2.47 GHz)	Maximum gain is 13.5 dB
[11]	S_{11} < -25 dB; for LHCP S_{11} < -20 dB; for LP	(5.1-6.4 GHz) for LHCP (5-6.4 GHz) for LP	Average gain is 6 dB
[17]	S_{11} < -20 dB; for RHCP S_{11} < -23 db; for LHCP	32% bandwidth under LHCP 38.8% bandwidth under RHCP	Maximum gain is 9 dB for RHCP
[19]	S_{11} < -15 dB; for LP S_{11} < -30 dB; for CP	(3.06-3.10 GHz) for LP and (3.06-3.14GHz) for CP	Peak gain is 7.74 dB for LP and 8.06 dB for CP
[20]	S_{11} < -25 dB; for both LHCP/RHCP	(1.36-1.63 GHz) for RHCP (1.43-1.64 GHz) for LHCP	0.5 dB for RHCP 0.15 dB for LHCP

CONCLUSION

This paper represents an overview of the polarization reconfigurable antenna. In this paper, we have discussed many techniques which are helpful to provide multi-polarization from a single antenna. For the switching purpose mainly PIN diodes, RF switches, some kind of materials and surfaces are used which provides many types of polarization in different planes. So, polarization

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switching does help to reduce installation space, cost, coupling effects, and multipath fading effects and also increase the system capacity. Polarization reconfigurable antennas widely used in MIMO systems, RADAR, WLAN, satellite communications, 2G, 3G, 4G LTE wireless communications, aerospace and terrestrial wireless communication systems.

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