Study on Polarization Reconfigurable Patch Antennas

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Abstract

When we consider a microstrip patch antenna, the main important feature that is been emphasized in recent years is about polarization reconfigurability. These reconfigurable antennas are providing multiple degrees of freedom to the antenna designers because they are able to radiate in one or more polarization states. The detailed study made on polarization antennas are broadly classified into two types: simple feed structure and complex feed structure. Multiple polarizations reconfigurable designs of antenna consisting of load and without load are reported in this literature are discussed in this paper.

Keywords: load, microstrip patch antenna, polarization, reconfigurable antenna

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INTRODUCTION

In recent years, large number of wireless communication systems is increasing constantly and a wide variety of applications need multifunctional integrated terminals. As per the service it is providing, mobile terminals should function as antennas and also should provide different polarizations. In order to overcome fading in WLANs, modulation scheme in RFID systems and to maximize the security complexity in wireless military systems, polarization diversity with exchangeable polarization is used. Completely polarized reconfigurable antenna systems exhibit 4 states of polarization. They are horizontal polarization, vertical polarization, left hand circular polarization, and right hand circular polarization. Circularly polarized microstrip antennas usually have complex structures as it involves direct current bias circuits and perpendicular feed structures. There is a complicated feeding network that is essential to excite symmetrically two perpendicular modes having 90° phase shift.[1] So, perturbation effect is used normally by truncating the patch antennas or by loading the antenna with stubs, slots, shorting walls, and slits.[2] But these loaded antennas will have uneven conical beams in different planes and narrow circularly polarized bandwidth. For this, many techniques have been suggested to strengthen the axial ratio bandwidth, like proximity coupling and sequential rotation array.[3–14]

Sequential rotation array technique brings about all states of polarization having low VSWR, less cross polarization, and maximum bandwidth by maintaining the size and shape of the patch undisturbed. This technique that is referred to as a sequential rotation array excites 4 linear or circular polarized elements having 90° phase difference with respect to the nearby elements.[15–24] However, the technique has a disadvantage if we consider large antennas and also there will be a complication in the implementation of array design. In this paper, main importance is given for polarization reconfigurable antennas. Latest studies are observed and then categorized into simple and complex feed structures, which are explained in proceeding sections and then followed by conclusion and future work

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SIMPLE FEED STRUCTURES BY MEANS OF PERTURBATION EFFECT

Patch or Ground Being Loaded With Slits/Stubs/Slots/Shorted Wall

Exchangeable Slotted Patch Structure

The antenna design comprises of a 4 parasitic patch elements such as (1, 2, 3, and 4) and feeding patch element (0) as shown in Figure 1.[25] The feeding patch element has a cross slot at the center of the patch and also 4 switching diodes that are embedded in the shape of a star over the slot. The feeding patch elements are present to improve the gain. By changing the voltage that is been given to the feeding element (0) with the diode junction "e," we can make the design made polarized reconfigurable with a better gain and power. There is also another cross-slotted polarization reconfigurable patch having resonating frequency at 3.92 MHz is been presented in ref.[26] and it consists of better impedance bandwidth of 250 MHz and circularly polarized bandwidth of 78.4 MHz because it consists of stacked structure and has a poor gain and less power.

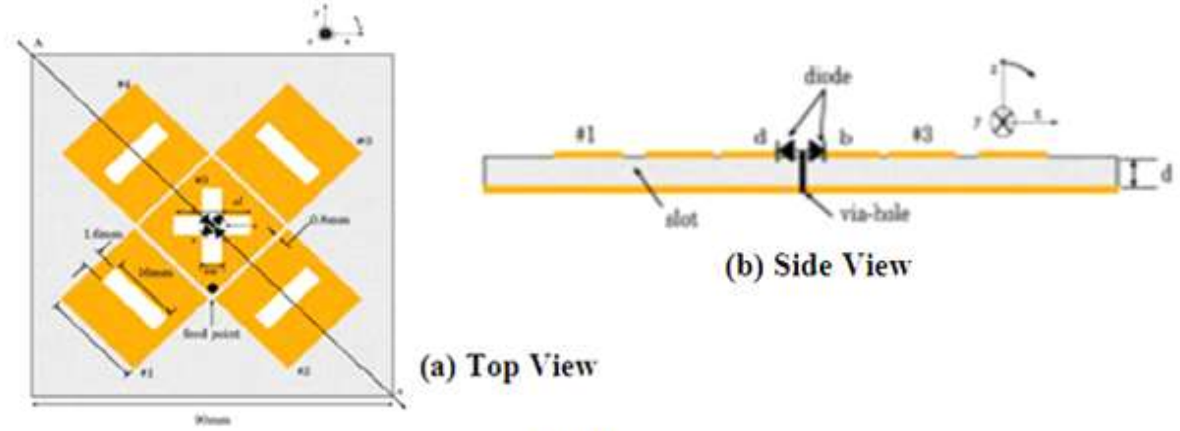

Fig.1

Fig. 1. *The Center Feeding Patch Consisting of Exchangeable Diodes for Circularly Polarized Reconfigurability and Also Matching Couple to Enhance the Gain.*

Switched Slotted Ground Structure

Here, the circularly polarized waves are excited by the two perturbation elements consisting of loop slots that are present in ground plane as shown in Figure 2.[27] There is a PIN diode which is placed on each slot to alter the direction of current which mainly determines the polarization states. Experimental bandwidths of 10 dB reflection coefficient for left and right hand circular polarization is about 60 MHz, for linear polarization it is 30 MHz and the bandwidth of 3 dB axial ratio for both left and right hand circular polarization states is 20 MHz.

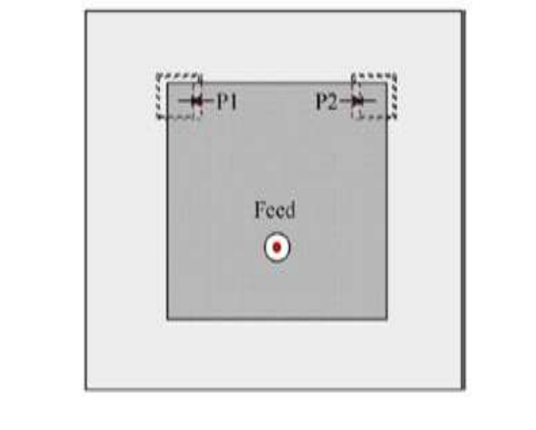

Fig. 2. *Geometry of a Reconfigurable Polarization Patch Antenna With Loop Slots on the Ground.*

There is another slotted ground antenna that has composite design and intricate feeding structures even though healthier outcomes are detected for it.[28–30]

Switched Shorted Pin

The antenna represented in ref.[31] consists of a radiating circular patch is printed on a thin substrate. It is supported by non-conducting posts placed on a conducting ground plane and it is excited by a capacitive feeding couple as shown in Figure 3. Two pins namely SC1 and SC2 are fixed at an optimized angle of +22.5° are selected symmetrically and is then connected to the circular patch on the ground plane by 2 switching elements. Hence, polarization reconfigurability is obtained by managing the states of these switches. These patterns are generally applied for various multipath channels. Experimentally the result shows a wide impedance bandwidth of around 400 MHz having a resonating frequency of 2450 MHz with the 3 dB axial ratio bandwidth of 150 MHz having center frequency at 2400 MHz.

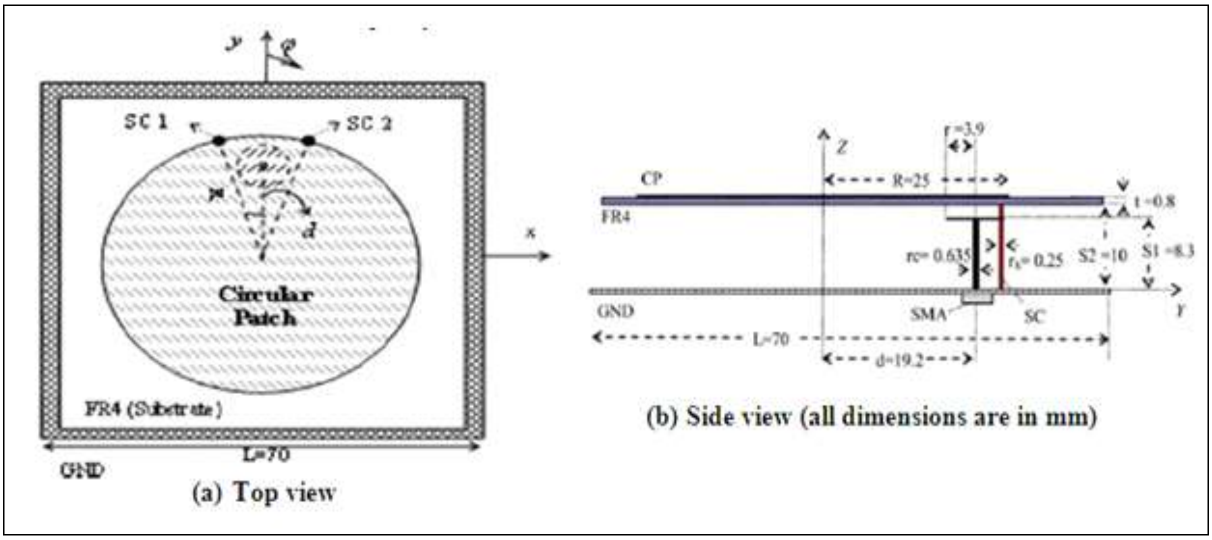

Fig. 3. *Circularly Patch Excited With Capacitive Coupled.*

Corner Truncated Patch without Any Load

Design of the antenna that is presented in ref.[32] and which is also shown in Figure 4 mainly consists of a truncated square patch and also a microstrip feed line. These both are placed on the same plane. Now a 50 Ohm microstrip line of width 320 mm is considered and it is coupled electromagnetically to patch having a gap of Wg″.

To the tunable stubs diodes D1 and D2 are connected so as to provide better input characteristics by biasing the diode D3. This diode D3 mainly decides the state of circular polarization. This design of the antenna has a minimum axial ratio of 0.6 and 1.5 dB for left and right hand circular polarization with a greater 3 dB beam width of 75°.

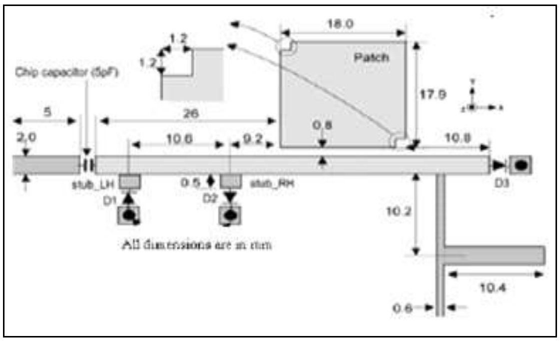

Fig. 4. *Circularly Polarized-Proximity Coupled Microstrip Patch Antenna Consisting of Tunable Stubs.*

COMPLEX FEEDING STRUCTURES

Tuned Quasi Lumped Quadrature Coupler (QLQC)

QLQC coupler generally acts as a 3 dB coupler and basically it operates in two modes: hybrid mode for circularly polarized (it has 90° phase shift between the direct port and the coupled port) and uncoupled linear mode (and has very less coupling between the direct port and the coupled port) linearly polarized (Figure 5).

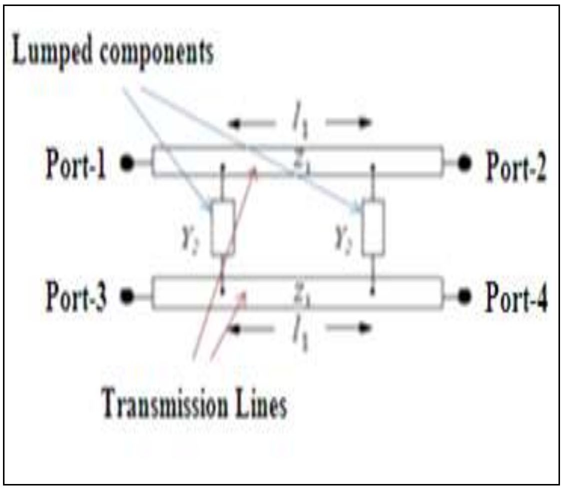

Fig. 5. *QLQC Coupler Design.*

A QLQC coupler can be made tuned by exchanging the capacitor (admittance) by the varactor diode. Here, the capacitance value of the varactor diode is a function of direct current bias. These bias conditions are only used for the capacitance value that is less than 0.2 pF (Vr > 11 V). A 4 port network will behave as a 2 parallel uncoupled transmission lines for the capacitance value of 0.92 pF (Vr = 0.96 V) and so the system operates as a 3 dB hybrid coupler.[33]

Here, the paper discussed gives a detailed report of QLQC coupler attached to the feed line as shown in Figure 6. Hence, all the polarization modes are having a circularly polarized bandwidth of 106 MHz. For circularly polarized and linearly polarized modes we have impedance bandwidth 134 and 315 MHz. The design is better for the devices embedded in a poly-path propagation environment.

Sequential Rotation Technique for Improved Polarization Characteristics

In 1985, Teshirogi et al[34] introduced the principle of sequential rotation for radiating elements to have an improvised circular polarization bandwidth. In ref.,[35] The novel club-shaped microstrip feed line, that is described in ref.,[35] describes the fundamental TM11 mode of the 3 ring radiating elements by proximity coupling along with a semiring-shaped section line as shown in Figure 6. There is 120° phase difference between the elements. On the ring there are radiators that induce rotating surface currents which contribute for characteristics of the circular polarization antennas.

On the annular ring, magnitude of induced current attains a peak value when the current on the feed line that is beneath the annular ring is attains the highest rate of change. Reconfigurability is attained by exchanging the feed positions at both the ports. The impedance bandwidth is 120 MHz, and 3 dB axial ratio bandwidth is 48 MHz. At frequencies of 2.4 and 2.35 GHz maximum gain is 10 dBic and is about 3 dB greater than that of U-shaped single element as discussed in ref.[36]

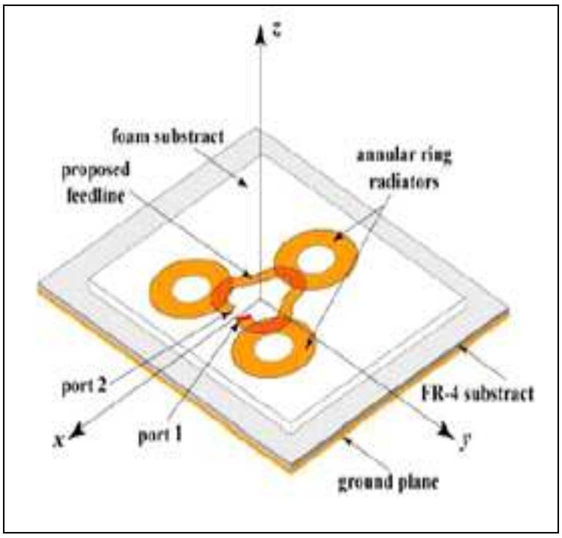

Fig. 6. *Club Shaped Microstrip Feed Line.*

CONCLUSION AND FUTURE SCOPE

The two common and normal design techniques that are used for the generation of circular polarization consisting of narrow bandwidth are corner truncation and slot technique. Many studies have been done based on polarization reconfigurable designs on these two techniques. Switched shorted wall is one of the techniques that provide a greater bandwidth polarization reconfigurable patch antenna.

The designs normally offer the techniques that are discussed above and by using dual feed 3 dB hybrid coupler, circular polarization can be easily generated. This technique is usually complex because of its feeding structure, but neglects the usage of capacitor and frequency offset problems occurred during the polarization switching process and also nonconducting layer required for bias separation independently.

Current research introduces the array of linearly polarized elements that are properly phased, but when rotated sequentially it should be circularly polarized. This technique can be a total package to address the polarization, narrow bandwidth, and high VSWR characteristics.

Further there is a great further scope of study in this technique. Feed circuit that is required in the club-shaped microstrip feed line technique and also other mentioned in literature are really complex. Normal feed circuit compatible along with sequential rotation technique requires a serious attention and also can make the patch antenna highly commercial.

REFERENCES

1. Wei W.B., Liu Q.Z., Yin Y.Z., et al. Reconfigurable microstrip patch antenna with switchable polarization. *IEEE Trans Antenn Propag.* 2010; 28(11): 2010.
2. Tang C.L., Lu J.H., Wong K-L. Circularly polarized equilateral-triangular microstrip antenna with truncated tip. *Electron Lett.* 1998; 34(13).
3. Fathy A.E., Napoli L.S., Denlinger E., et al. Novel planar polarizer feed for dual circular polarization. *Electron Lett.* 2005; 38(25).
4. Lo W.K., Chan C.H., Luk K.M. Circularly polarised patch antenna array using proximity-coupled L-strip line feed. *Electron Lett.* 2006; 3(1).
5. Lo W.K., Chan C.H., Luk K.M. Circularly polarised microstrip antenna array using proximity coupled feed. *Electron Lett.* 2005; 3(2).
6. Tong K.F., Lacotte G. Novel Single feed proximity coupled wideband circularly polarized slot antenna. *Asia-Pacific Microwave Conference*. APMC 2008.
7. Zawadzki M. A multi-layer circularly polarized microstrip patch antenna with proximity coupling and increased gain. *IEEE Antenn Propag Soc Int Symp*. 2001; 3.
8. Tong K.-F., Huang J. New proximity coupled feeding method for reconfigurable circularly polarized microstrip ring antennas. *IEEE Trans Antenn Propag.* 2006; 56(7).
9. Nishiyama E., Egashira S., Sakitani A. Stacked circular polarized Microstrip antenna with wide band and high gain. *Antenn Propag Soc Int Symp*. 1992.
10. Assailly S., Terret C., Daniel J.P., et al. Low cost stacked circular polarized microstrip antenna. *Antenn Propag Soc Int Symp.* 1989.
11. Falade O.P., Rehman M.U., Gao Y., et al. Single feed stacked patch circular polarized antenna for triple band GPS receivers. *IEEE Trans Antenn Propag.* 1998; 60(10).
12. Shekhawat S., Sekra P., Bhatnagar D., et al. Stacked arrangement of rectangular microstrip patches for circularly polarized broadband

performance. *IEEE Antenn Wireless Propag Lett.* 2001; 9.
13. Kaffash S., Kamyab M. A sequentially rotated RHCP stacked patch antenna array for INMARSAT-M land applications. *6th European Conference on Antennas and Propagation (EUCAP)*. 2012.
14. Hu D.-c., Wang J., Gao J.-r. Design a wide-scan angle phased-array antenna with circular polarization using a new cross-dipole. *Microwave and Millimeter Wave Circuits and System Technology (MMWCST), 2012 International Workshop*. 2012.
15. Soliman A., Brebels S., Beyne E., et al. Sequential-rotation arrays of circularly polarized CPW-fed aperture antennas in the MCM-D technology. *Microelectronics*. ICM, 1999.
16. Lin S.-K., Lin Y.-C. A compact sequential-phase feed using uniform transmission lines for circularly polarized sequential-rotation arrays. *IEEE Trans Antenn Propag*. 59(7).
17. Chen A., Zhang Y., Chen Z., et al. Development of a -band wideband circularly polarized 64-element microstrip antenna array with double application of the sequential rotation feeding technique. *IEEE Antenn Wireless Propag Lett.* 2001; 10.
18. Thiel M., Dreher A. Sequential rotation in a smart antenna terminal for broadband communication. *IEEE*. 1.
19. Tong K.-F., Du J., Huang J. Novel sequential rotation technique for broadband circularly polarized microstrip ring antennas. *Loughborough Antennas and Propagation Conference*. 2008.
20. Palmer K.D., Cloete J.H., van Tonder J.J. Bandwidth improvement of circularly polarized arrays using sequential rotation. *Antennas and Propagation Society International Symposium*. 1992.
21. Kraft U.R. Main-beam polarization properties of four-element sequential-rotation arrays with arbitrary radiators. *IEEE Trans Antenn Propag.* 2006; 44(4).
22. Smolders A.B., Johannsen U. Axial ratio enhancement for circularly-polarized millimeter-wave phased-arrays using a sequential rotation technique. *IEEE Trans Antenn Propag*. 2005; 59(9).
23. Hing K.K. Waterhouse R.B. A small CP-printed antenna using 120° sequential rotation. *IEEE Trans Antenn Propag.* 50(3).
24. Smolders A.B., Johannsen U. The effect of phase and amplitude quantization on the axial ratio quality of mm-wave phased-arrays with sequential rotation. *IEEE Antenn Propag (APSURSI).* 2011.
25. Ushijima Y., Nishiyama E., Aikawa M. Linear polarization switchable patch array antenna. *IEEE*. 978-1-4244-3647-7/09/ ©2009.
26. Nishiyama E., Aikawa M. Circular polarization controllable microstrip antenna. *IEEE*. 1-4244-0878-4/07/ ©2007.
27. Yang X.-X., Shao B.C., Elsherbeni F.Y., et al. A polarization reconfigurable patch antenna with loop slots on the ground plane. *IEEE Antenn Wireless Propag Lett.* 2012; 11.
28. Yoon W.-S., Baik J.-W., Lee H.-S., et al. A reconfigurable circularly polarized microstrip antenna with a slotted ground plane. *IEEE Antenn Wireless Propag Lett*. 2010; 9.
29. Yoon W.-S., Han S.-M., Baik J.-W., et al. A compact microstrip antenna on a cross-shape slotted ground with switchable circular polarization. *IEEE Trans Antenn Propag*. 2009; 30(7).
30. Yoon W.-S., Lee D.-H., Lee K.-J., et al. Circular patch antenna for a switchable circular polarization sense with a slotted ground structure. *Loughborough Antennas & Propagation Conference*. 2009.

31. Khaleghi A., Kamyab M. Reconfigurable single port antennas with circular polarization diversity. *IEEE Trans Antenn Propag*. 2009; 57(2).
32. Simba A.Y., Yamamoto M., Watanabe S., et al. Improving the input characteristics of a circularly polarized proximity-fed microstrip antenna with polarization switching ability. *IEEE*. 1-4244-0123-2/06/©2006.
33. Ferrero F., Luxey C., Staraj R., et al. A novel quad-polarization agile patch antenna. *IEEE Trans Antenn Propag*. 2009; 57(5).
34. Teshirogi T., Tanaka M., Chujo W. Wideband circularly polarized array antenna with sequential rotations and phase shift of elements. *Proceedings ISAP*. 1985; 117–20p.
35. Tong K.-F., Du J., Huang J. Novel sequential rotation technique for broadband circularly polarized microstrip ring antennas. *IEEE Trans Antenn Propag*. 2010; 26(13).
36. Tong K.-F. A new single-feed proximity coupled circularly polarized square ring antenna. *Proceeding of APMC Yokohama*. Japan; 2006 December 12–15: 69–72p.