International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-1, Issue-6, January 2013

A Survey on Polarization Reconfigurable Patch Antennas

Uma Shankar Modani, Anubhav Kanwaria

Abstract*: Polarization reconfigurability in a microstrip patch antenna system is one of the desired characteristics that have been the focus of research in recent years. Reconfigurable antenna with ability to radiate in more than one polarization state offers several degrees of freedom to antenna designer. The researches on polarization reconfigurable antennas are categorized into simple and complex feed structures. In this paper, several polarization reconfigurable antenna designs with and without loading which have been reported in the literature are discussed.

***Index Terms*: Loading, Microstrip patch antenna, Polarization, Reconfigurable antenna.**

I. INTRODUCTION

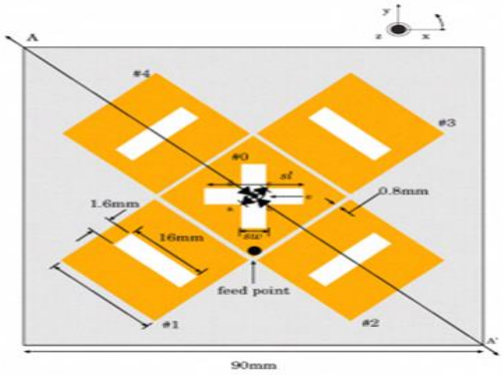
The number of wireless communication systems is constantly increasing, and many applications require integrated multifunctional terminals. Such mobile terminals must operate as antennas providing different polarization as per service requirement. Polarization diversity with switchable polarization is used in order to reduce fading in wireless local area networks (WLANs), as a modulation scheme in radio frequency identification (RFID) systems, and to increase the security complexity in military wireless systems. Fully polarization reconfigurable antenna systems exhibit four states of polarization namely horizontal, polarization, vertical polarization, left hand circular polarization (LHCP) and right hand circular polarization (RHCP). Circularly polarized (CP) microstrip antennas have complex structures because of the direct current (dc) bias circuits and orthogonal feed structures involved. A complicated feeding network is essential to symmetrically excite two orthogonal modes with a 90 degree phase difference [1]. Therefore perturbation effect is used either by simply truncating patch antenna or loading the antenna/ground with slots, stubs, slits, shorting walls [2]. But such loaded antennas have non uniform conical beams in different planes and narrow CP bandwidth. Several techniques have been proposed to enhance the axial ratio bandwidth, such as proximity coupling, stacked CP patches or sequential rotation array [3-14]. Sequential rotation array technique achieves all state of polarization with low VSWR, low cross polarization, and high bandwidth keeping the size and shape of the patch intact. The sequential rotation array technique excites four linearly/circularly polarized elements with 90 degree phase difference with respect to the adjacent ones [15-24]. However, this technique would have the disadvantages of large antenna structure, and complicated to implement in array design. As a result of significance of polarization reconfigurable antennas, in this paper, the latest researches are analyzed and categorized into simple feed structure and complex feed structures in section (ii) and section (iii) respectively followed by conclusions and future work in section (iv).

Revised Manuscript Received on 30 January 2013.
* Correspondence Author
Dr. Uma Shankar Modani*, Electronics & Communication Department, Government Engineering College, Ajmer, Rajasthan, India.
Mr. Anubhav Kanwaria, Electronics & Communication Department, Government Engineering College, Ajmer, Rajasthan, India.

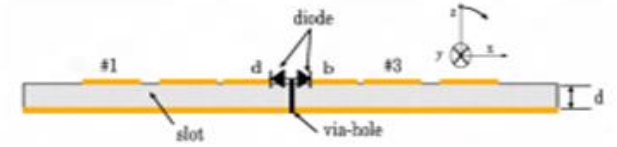
II. SIMPLE FEED STRUCTURES USING PERTURBATION EFFECT

A. Patch or Ground Loaded with Slots/Slits/Stubs/Shorted Wall

1) Switched Slotted Patch Structure: This antenna design consists of a fed patch element (#0) and four parasitic patch elements (#1, #2, #3, #4) as shown in Fig.1 [25]. The fed element has a cross slot at the center of the patch and four switching diodes are embedded in a star form across the slot. There are four parasitic elements around the fed element for a gain enhancement. Changing the applied voltage to the fed element (#0) with respect to the diode junction "e", the design can be made polarization reconfigurable with good gain and power. Another cross slotted polarization reconfigurable patch resonating at 3.92MHz has been presented in [26] which is having comparatively better impedance bandwidth of 250MHz and CP bandwidth of 78.4MHz due to stacked structure but have poor gain and power.



(a) Top view



(b) Side view

Fig. 1 Center fed patch having switchable diodes for CP reconfigurability and coupled patch for gain enhancement.

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2) Switched Slotted Ground Structure: The CP waves are excited by two perturbation elements of loop slots in the ground plane as shown in Fig. 2 [27]. A PIN diode is placed on every slot to alter the current direction, which determines the polarization state (linear polarization (LP), left-hand (LH) and right-hand (RH) circular polarizations (CP). The experimental bandwidths of the 10-dB reflection coefficient for LHCP and RHCP are about 60 MHz, while for LP is about 30 MHz. The bandwidth of the 3dB axial ratio for both CP states is 20 MHz.

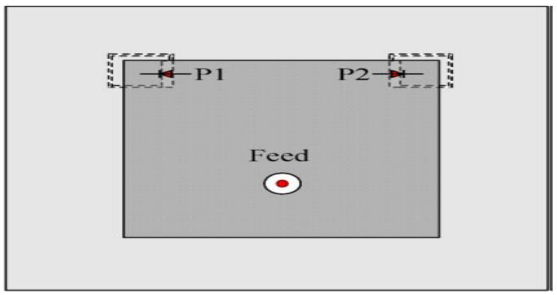
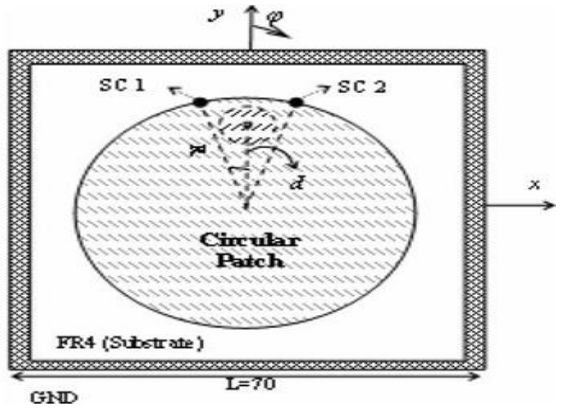


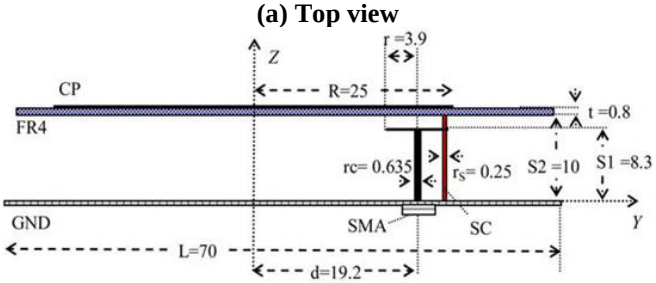
Fig. 2 Geometry of a reconfigurable polarization patch antenna with loop slots on the ground.

Other slotted ground antenna has complex design and complicated feed structures although improved results are observed for them [28] - [30].

3) Switched shorted wall/pin: The antenna presented in [31] has radiating circular patch, printed on a thin substrate, supported by non conductive posts on a conducting ground plane and is excited with a capacitive coupled feed as shown in Fig. 3. Two pins fixed at SC1 and SC2 optimized at the angles of ±22.5 degrees are symmetrically selected and connect the circular patch to the ground plane via two switch elements. By controlling the states of the switches, polarization reconfigurability is obtained. The patterns are applied for diversity reception in multipath channels. The experimental result shows wide impedance bandwidth of 400MHz resonating at 2450MHz and the 3dB axial ratio bandwidth is 150MHz with the center frequency at 2400MHz.



(a) Top view



(b) Side view (All dimensions are in mm)

Fig. 3 Circular patch excited by capacitevly coupled.

B. Unloaded Corner Truncated Patch

The antenna design presented in [32] and shown in Fig. 4 consists of truncated square patch and microstrip feed line both on the same plane. A 50 ohm microstrip line of width 320mm is electromagnetically coupled to patch through a gap '*Wg*'. Diode D1 and D2 are connected to tunable stubs to provide improved input characteristics while biasing of diode D3 decides state of circular polarization. The design has good minimum axial ratio of .6dB and 1.5 dB for LHCP and RHCP respectively with high 3dB beam width of 75 degree.

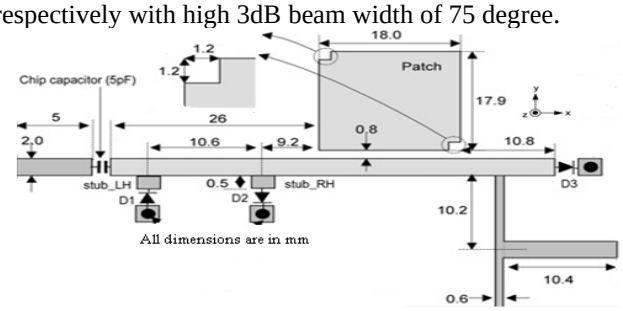


Fig. 4 Circular polarized –proximity coupled microstrip patch antenna with tunable stubs.

III. COMPLEX FEED STRUCTURES

A. Tunable Quasi Lumped Quadrature Coupler (Qlqc)

QLQC coupler behaves as 3dB coupler can works in two modes: Hybrid mode for CP (90 degree phase difference between the direct and the coupled port) and uncoupled line mode (very low coupling between direct and the coupled port) for LP as shown in Fig. 5.

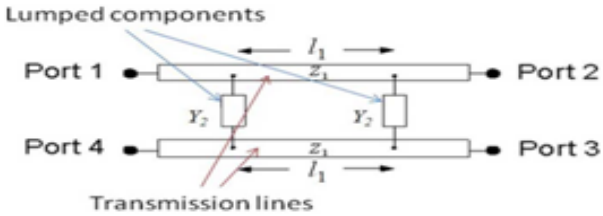


Fig. 5 Design of QLQC coupler.

QLQC can be made tunable by replacing admittance (capacitor) by varactor diode and the capacitance of varactor diode is a function of DC bias. The dc bias conditions are such that for capacitance lower than 0.2pF (*Vr* >11V), four-port network acts as two parallel uncoupled transmission lines and for a capacitance of 0.920pF (*Vr* =0.96V), the system operates like a 3-dB hybrid coupler [33]. The paper reports a QLQC coupler properly attached to feed line, which is shown in Fig.6.

All polarization modes are achieved with CP bandwidth of 106MHz and impedance bandwidth of 134 MHz and 315 MHz for circularly polarized and linearly polarized modes respectively. The design is good for devices embedded in a multi-path propagation environment.

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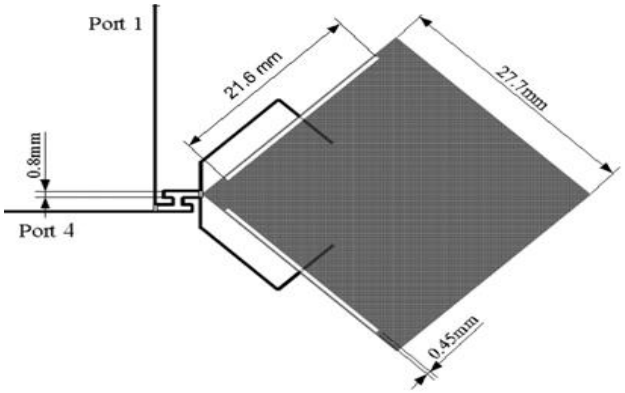

Fig. 6 QLQC coupler attached to feed line of patch.

B. Sequential Rotation Technique for Improved Polarization Characteristics

The principle of sequential rotation of radiating elements to improve the circular polarization bandwidth was introduced in 1985 by Teshirogi et al [34].

In [35], the novel club-shaped microstrip feed line excites the fundamental TM11 mode of the three ring radiating elements through proximity coupling along the semi-annular section of the line as shown in Fig. 7. The phase differences between elements are about 120 degree. The induced rotating surface currents on the ring radiators contribute to the circular polarization characteristic of the antennas. The magnitude of the induced current on the annular ring is at its maximum when current on the feed line under the annular ring is having the maximum rate of change. Reconfigurability is achieved by switching feed positions at two ports. The impedance bandwidth and 3dB axial ratio bandwidth are about 120 MHz and 48 MHz respectively at 2.4GHz and the maximum gain at 2.35 GHz is 10dBic, which is about 3dBic higher than that of U-shaped single element case has reported in [36].

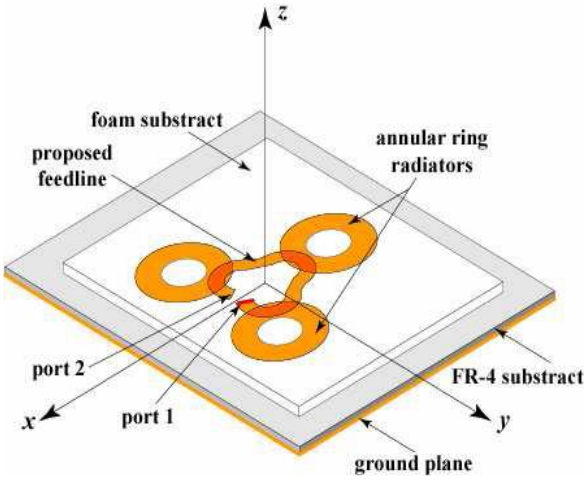

Fig. 7 Club-shaped microstrip feed line.

IV. CONCLUSIONS AND FUTURE WORKS

Corner truncation and slot technique are two common and simple design techniques for generating circular polarization having narrow bandwidth. Much research has been done on polarization reconfigurable designs based on these two techniques. Switched shorted wall technique provides larger bandwidth polarization reconfigurable patch antenna. Compromising the designs simplicity offered by the techniques discussed above and using dual feed by 3dB hybrid coupler, CP can easily be generated. Although this technique is complex due to its feed structure but alleviates the use of capacitor, frequency offset problem caused during polarization switching, and insulating layer required for independent bias separation. Latest research employs array of LP elements properly phased, which when sequentially rotated gives CP. This technique could be a complete package to solve polarization, narrow bandwidth and higher VSWR characteristics but still there is huge further scope of research in this technique. Feed circuit required in this technique such as club shaped microstrip feed line and other mentioned in literature are highly complex. Simple feed circuit compatible with sequential rotation technique needs serious attention and can make patch antenna highly commercial.

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AUTHOR PROFILE

Uma Shankar Modani has received B.E. and M.E. in Electronics and Communication Engineering from M.B.M Engineering College, Jodhpur, Rajasthan, India and PhD from Bhagwant University, Ajmer. He has industrial as well as teaching experience of about 17 years in total. Presently, he is Associate Professor in Department of Electronics and Communication Engineering, Government Engineering College, Ajmer, Rajasthan. He has published many research papers at national and international level. His primary research interest includes antenna and microwave, wireless communication and mobile communication.

Anubhav Kanwaria has received B. Tech. in Electronics and Communication from M.N.I.T, Jaipur. Currently he is pursuing M. Tech. in Digital communication from Government Engineering College, Ajmer. His primary research interest includes polarization and frequency reconfigurable microstrip patch antennas.

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