

Review of Circularly Polarized Microstrip Antennas for RFID Application

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ABSTRACT: The following paper intends to review technical publications related to the design and development of broadband, circularly polarized microstrip patch antenna for UHF RFID (Ultra high frequency radio frequency-identification-detector) application. Circular Polarization has caught the attention of several researchers due to its feature of working independently of the orientation of the transmitter and receiver antennas in wireless communication systems. Circular polarization is also useful for lowering cross talk due to reflected waves and for lowering multipath effects of wireless transmission systems which is necessary for RFID application. In this paper, we review some of the different techniques in published technical papers to achieve wideband, circular polarized radiation for RFID applications.

KEYWORDS: Circular polarization (CP), RFID readers, microstrip antenna, slotted patch, stack, single feed.

I. INTRODUCTION

Microstrip patch antennas have many practical advantages, for instance being low profile and light weight among others. They also allow both linear and circular polarization, but they suffer from low gain and narrow bandwidth, typically 1–5%, which is the major limiting factor for the widespread application of these antennas. To overcome these shortcomings, a microstrip antenna with different techniques such as slotted antennas, stacking, different feed techniques, slits, truncation have been reviewed in this paper. By overcoming these limitations microstrip antennas can be used in a large number of applications with RFID readers being one of the major application.

RFID is a technology that provides wireless identification and tracking capabilities. In recent years, RFID technology has been rapidly developed and applied to many service industries, distribution logistics, manufacturing companies. In an ultra-high-frequency (UHF) RFID system, the reader emits signals through reader antennas. An RFID tag, located at the client consists of an antenna and an application-specific integrated circuit (ASIC). The tag is activated and interrogated for its content information by the reader. The querying signal from the reader must have enough power to activate the tag ASIC to perform data processing, and transmit back a modulated string over a required reading distance. Since the RFID tags are always arbitrarily oriented in practical usage and the tag antennas are normally linearly polarized, circularly polarized (CP) reader antennas have been used in UHF RFID systems for ensuring the reliability of communications between readers and tags [1,2].Circularly polarized microstrip antennas can reduce the loss caused by the multipath effects between the reader and the tag antenna. Circularly polarized (CP) radiation is advantageous because it works independently of the orientation of the transmitter and receiver antennas in wireless communication systems.

The total frequency span of the UHF band for worldwide RFID systems is within the frequency range from 850 MHz to 960 MHz. The RFID system operates in the bands from (902 MHz to 928 MHz in America, from 865 MHz to 867 MHz in Europe, and from 840 MHz to 955 MHz in the Asia-Pacific region. In the Asia-Pacific region, the UHF RFID frequency range is different in different countries, such as in China (920.5 MHz to 924.5 MHz), Japan (952 MHz to 955 MHz), India (865 MHz to 867 MHz), Hong Kong (865 MHz to 868 MHz and 920 MHz to 925 MHz), Taiwan (920 MHz to 928 MHz), Korea (908.5 MHz to 910 MHz and 910 MHz to 914 MHz), Singapore (866 MHz to 869 MHz and

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923 MHz to 925 MHz), and Australia (920 MHz to 926 MHz). Thus, a circularly polarized reader antenna needs to cover the full UHF band (850 MHz to 960 MHz) for worldwide RFID applications [3].

This paper consists of different types of techniques and geometries which are designed and used by different authors to increase bandwidth, achieve good quality circularly polarized radiations. One of the techniques is single feed, stacked, slotted circularly polarized microstrip antenna in which circular polarization is achieved with using two circular slots [3]. A wideband circularly polarized antenna using three stacked patches and fed by a hybrid coupler [4] was designed for UHF RFID applications. Recently, asymmetric-slotted microstrip square patches were also designed for size reduction of circularly polarized microstrip antennas. But, demerits of these antennas have a narrow circularly polarized radiation bandwidth and low gain, and are designed for hand held or portable RFID readers [5]. A wideband circularly polarized RFID antenna with high gain for a fixed reader has a longer reading range compared to a narrowband small circularly polarized antenna (low gain) used in a handheld or portable reader. A stacked ring over the radiating patch [6] is also used to improve the circularly polarized antenna's performance. A wideband circularly polarized stacked antenna is also designed using the main patch fed by four probes, which are sequentially connected to the suspended microstrip feed line [7].

Paper is organized as follows, Literature review is described in Section II. Experimental result is described in Section III. Section IV presents Conclusion.

II. LITERATURE REVIEW

Many technical papers related to microstrip patch antenna are studied based on circular polarization, bandwidth and other antenna parameters.

1] A Wideband Circularly Polarized Stacked Slotted Microstrip Patch Antenna (Nasimuddin, Z. N. Chen, and X. Qing)

A wideband, single-feed, circularly polarized, stacked, square, slotted microstrip patch antenna is designed for radio frequency-identification-reader applications. As shown in figure1(a), the designed antenna consists of an upper square asymmetric slotted patch, stacked over a lower square asymmetric slotted radiating patch and a microstrip stub, along with a coaxial feed. The wideband circularly polarized radiation is achieved using a microstrip stub in the lower patch and a stacked slotted square patch. The antenna is designed using a combination of low-cost FR4 substrate and foam. The measured 10 dB return-loss bandwidth of the antenna was around 21% (833 MHz to 1033 MHz), and the 3 dB axial-ratio bandwidth of the antenna was around 13.4% (835 MHz to 955 MHz). The gain was around 7.0 dBi over the 3 dB axial-ratio bandwidth. The overall antenna volume was $0.601\lambda_0 \times 0.601\lambda_0 \times 0.895\lambda_0$ (where λ_0 is the free-space wavelength at 900 MHz). In figure 1(b) normalized radiation pattern at 900MHz for both principal axes are plotted and it seems that patterns are symmetric in both planes xz and yz.

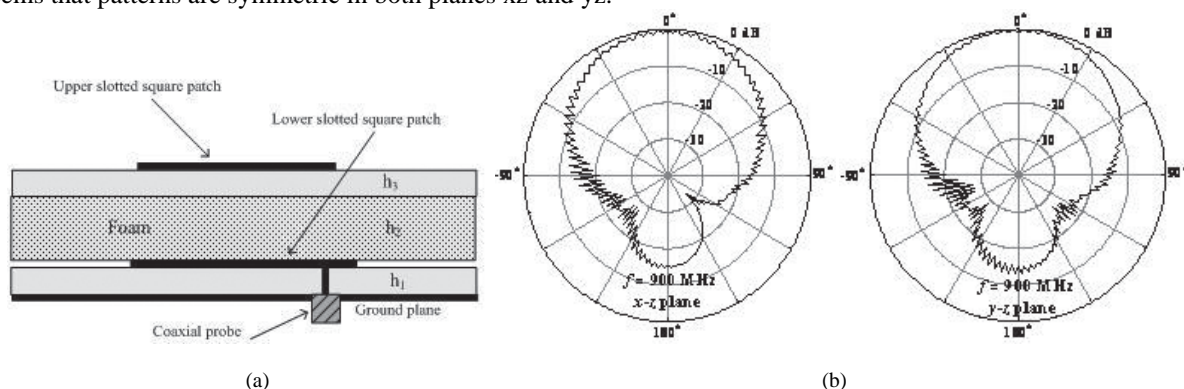


Fig. 1. CP stacked, circular slotted microstrip antenna (a) Cross-sectional view (b) The normalized measured radiation patterns in both planes (xz and yz) at 900MHz.

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2] A Broadband Circularly Polarized Stacked Probe-fed Patch Antenna for UHF RFID Applications (H. L. Chung, X. Qing, and Z. N. Chen)

Designed antenna is fed by two probes which are connected to a hybrid coupler. Two parasitic patches are stacked above a primary probe-fed patch to enhance the bandwidth of the antenna. The antenna is composed of a branch line hybrid coupler which is etched on an FR4 substrate ($\epsilon_r = 4.4$, $\tan \delta = 0.02$, thickness = 0.8128 mm), and three radiators which are made up of brass. The hybrid coupler has four ports. Port 1 is fed by RF signal, port 2 is loaded by a 50Ω resistor, and port 3 and port 4 are used to excite the primary patch radiator. Such a feeding network features the high isolation between two feed ports and less reflection to the RF signal port because the power reflected from a mismatched antenna is absorbed by the resistive load. The primary radiator (patch 1, 150mm × 150 mm, 0.5mm thick) is fed by two feeding probes which are connected to the output ports of the hybrid coupler, that is, port 3 and port 4, respectively. The feed points are positioned symmetrically with the square patches with a distance d of 18.5mm away from the edge of the primary patch. The height of the feeding probes is 10mm and the diameter is 2.2 mm.

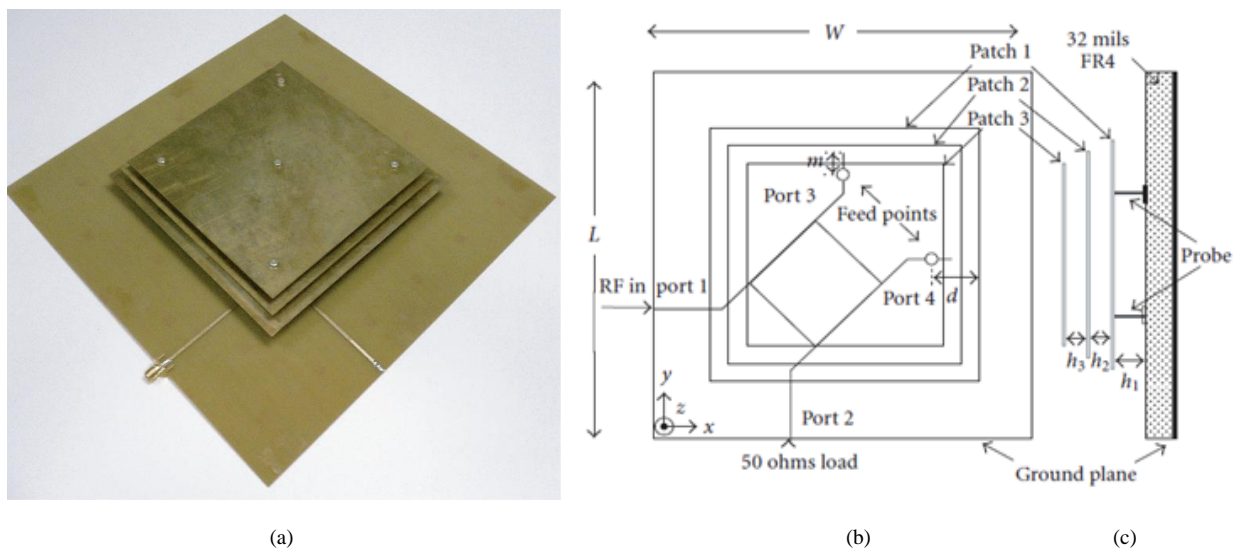


Fig. 2. Geometry of the stacked patch antenna (a) snapshot of designed antenna (b) schematic top view (c) schematic side view

In figure 2(a),(b) and (c), the configuration of designed antenna is shown, 3 patches are stacked using FR4 substrates and hybrid coupler is also placed. The measured 3 dB axial ratio shown in figure 3(a) covers the range of 820–1000MHz and the axial ratio is lower than 2.6 dB across 860–960 MHz and measured gain is shown in figure 3(b) is more than 6.5dBic over 800-980MHz range.

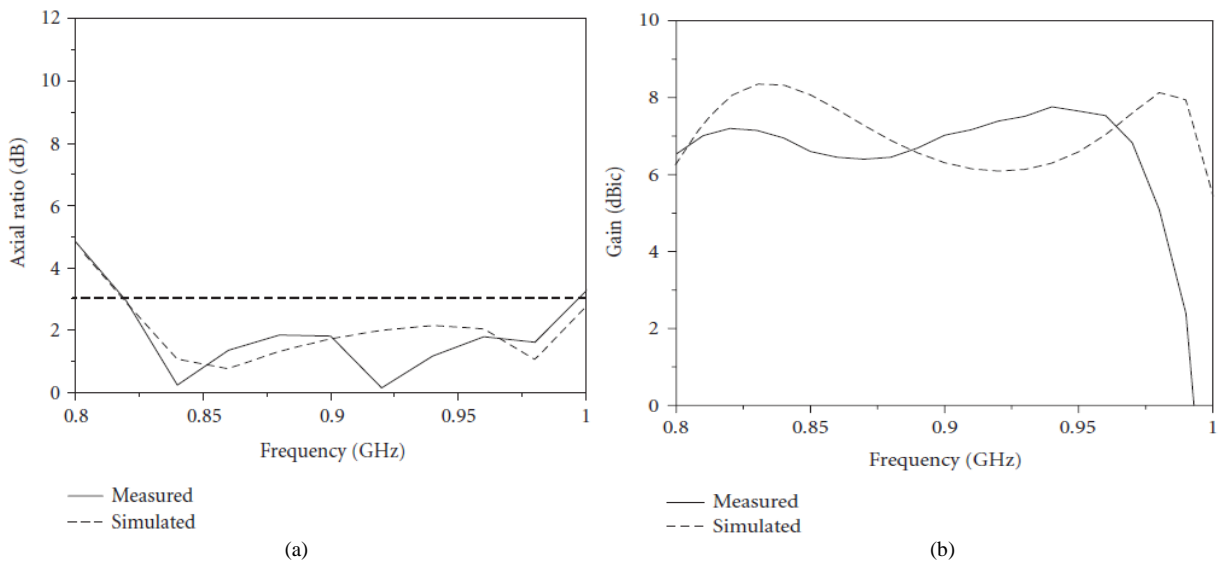


Fig. 3. Results of the stacked , probe fed patch antenna (a) Measured and simulated axial ratios of the antenna (b) Measured and simulated gains of the antenna

3] Asymmetric-Circular Shaped Slotted Microstrip Antennas for Circular Polarization and RFID Applications
(Nasimuddin, Z. N. Chen, and X. Qing)

Designed asymmetric-circular shaped slotted microstrip patch antennas with slits for circularly polarized (CP) radiation and radio frequency identification (RFID) reader applications. In figure 4(a) cross sectional view of this designed antenna is shown. A single-feed configuration based asymmetric-circular shaped slotted square microstrip patches are adopted to realize the compact circularly polarized microstrip antennas. Figure 4(b) shows, the unequal-circular shaped slots along the diagonal directions are embedded symmetrically onto a square microstrip patch for CP radiation and small antenna size. The coaxial feed-location is on the x axis and it is 45° from the asymmetries by the circular slots on the patch radiator.

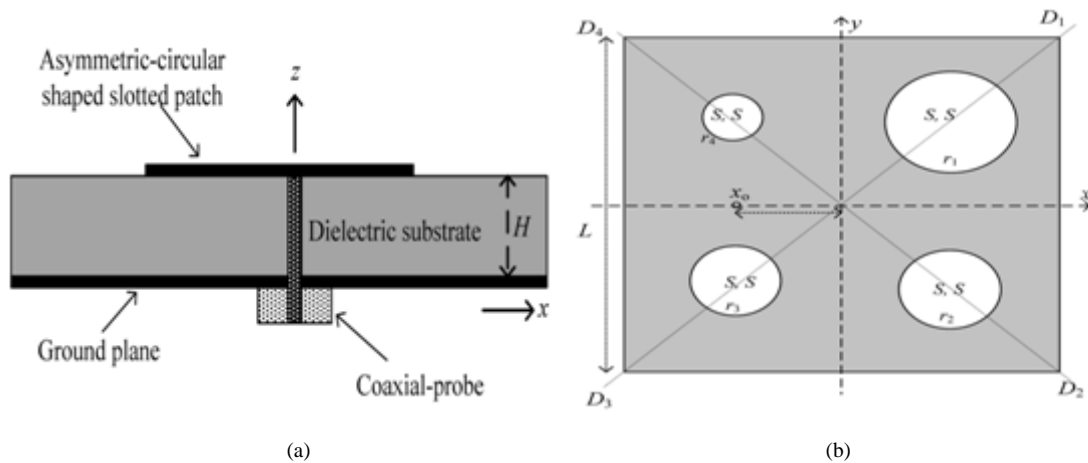


Fig. 4 Asymmetric-circular shaped slotted microstrip antenna (a) Cross-section view of the designed antenna (b) Asymmetric-circular shaped slotted microstrip patch.

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In figure 5(a) and (b), simulated return loss boresight AR of the four examples are plotted that is result for only one slot, then only for two, for three and for four slots. The operating frequency and minimum AR frequency also decreases with increase number of circular slots on the patch.

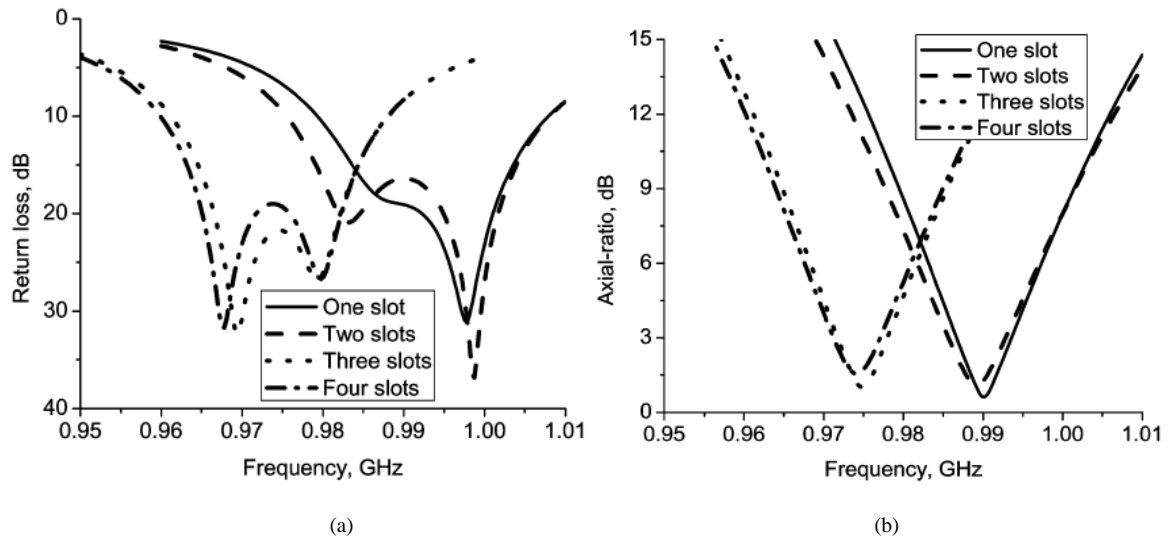


Fig. 5. Simulated results of the ACSSMP antennas (a) return loss (b) axial ratio at the boresight.

Author also illustrated comparison of CP microstrip patch antennas and design and results of ACSSMP antennas with slit variations to enhance Return loss bandwidth, AR bandwidth and gain.

4] Circularly Polarized Ring-Patch Antenna (The-Nan Chang and Jyun-Ming Lin)

The top and the cross-sectional views of the probe-fed rectangular patch antenna with a stacked ring are shown in figure 6(a). The inner and the outer contours of the ring are Ai-Bi-Ci-Di-Ai and Ao-Bo-Co-Do-Ao, respectively. The contour of the patch is A-B-C-D-A, where $AB=CD=84\text{mm}$ and $AD=BC=77\text{mm}$. The rectangular patch is etched on the top of 3.2-mm thick FR4 substrate ($\tan \delta=0.02$), under which there is a ground plane dimensioned with $160 \times 160\text{mm}^2$. According to geometry and centre of patch, the patch is fed at (34.4 mm, 24.1 mm, 0 mm) by a coaxial cable. The contour of the patch is kept to be in the middle of the inner and outer contours of the ring when the ring and the patch are projected to the xy-plane. It is arranged that both the inner contour and the outer contour of the ring are squares in shape. The spacing d is considered between any of the following pairs of lines: AD and AoDo; AD and AiDi; BC and BoCo; BC and BiCi; AB and AoBo; AB and AiBi; CD and CoDo; and CD and CiDi.

By varying the offset parameter 'd' cp radiation and bandwidth are optimized. The stacked ring can effectively be coupled in that way to have a rotation current distribution and thus the CP radiations. The spacing distance is found crucial to simultaneously optimizing the return-loss, the axial-ratio, and the flat-gain bandwidths of the proposed CP antenna. The optimized spacing used by author is 0.09λ in free space.

The antenna is designed in the ultrahigh frequency band so useful in radio frequency identification (RFID) system. According to design simulation, measured 10-dB return-loss bandwidth is 16.4% (835–975MHz), and the 3-dB axial-ratio bandwidth is 7.7% (870–940 MHz). The gain is about 7 dBic within the overlapped.

In figure 6(b) simulated axial ratio responses of the designed antenna by varying the offset parameter d are shown. It shows that antenna has a narrow AR bandwidth for $d=0.1$ while AR bandwidth is enhanced with larger value of d , $d=20$ (can cover 870-940MHz).

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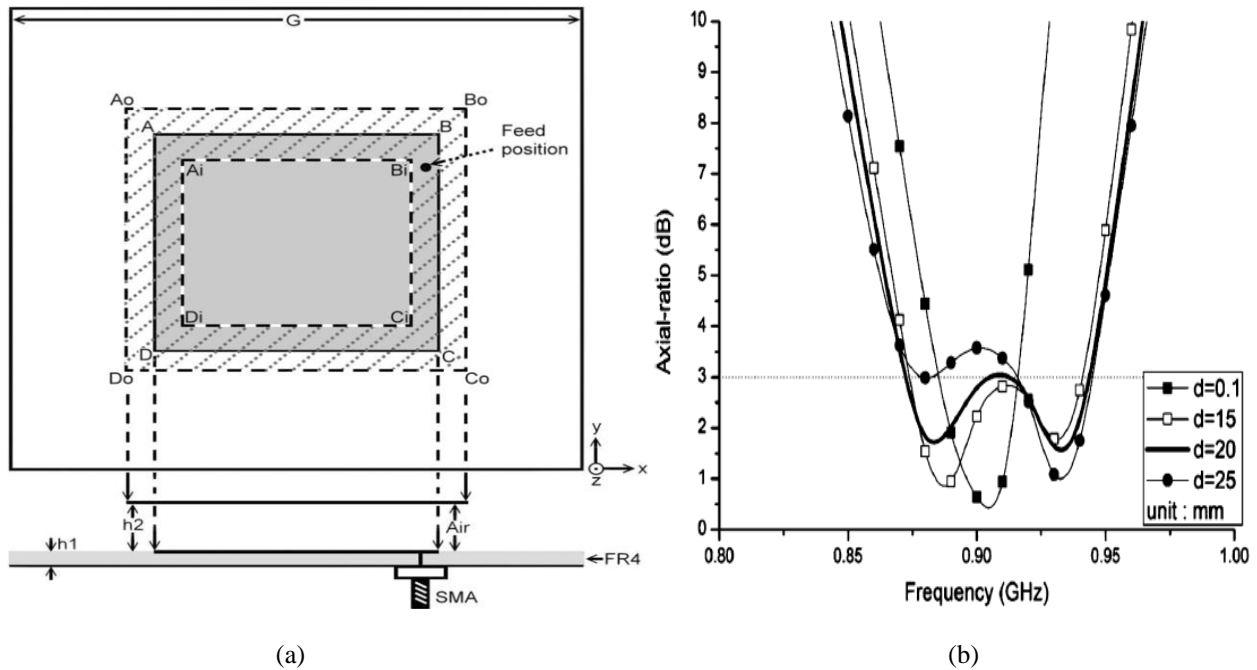


Fig. 6. Circularly polarized ring-patch antenna (a) Structure of the antenna (b) Effect of the shifting distance on axial ratio.

5] A Universal UHF RFID Reader Antenna (Z. N. Chen, X. Qing, And H. L. Chung)

This broadband circularly polarized patch antenna is designed and developed by author for universal ultra-high-frequency (UHF) RF identification (RFID) applications. As shown in figure 7(a) and (b) this antenna consists of four layers of conductor, which include two suspended radiating patches, a suspended microstrip feed line, and a finite-size ground plane. Air is used as a substrate to achieve higher gain, broader bandwidth, and lower cost. The microstrip feed line of a width of 24 mm is suspended above the ground plane (250 mm \times 250 mm) at a height of (5 mm). One end of the feed line is connected to an RF input and other end is open circuited, so antenna structure simplifies. The main radiating patch of 156 mm \times 156 mm is truncated at both corners of a diagonal with dimension 24.5 mm and is placed above the feed line at spacing of mm. The main patch is fed by four probes which are sequentially connected to the suspended microstrip feed line. The probes are of diameter of 2.2 mm and positioned along the microstrip feed line with adequate distance to create the 90° phase lag between the probes and brings into sequential rotation of current on the radiation patch for CP radiation. Also, to enhance the bandwidth, a parasitic patch with a dimension of 139 mm \times 139 mm is truncated with dimension of 17 mm at both corners of a diagonal (same as main radiating patch but with different dimension) is placed right above the main patch with the spacing of $h_3=10$ mm. These truncated patches produce additional degenerating modes necessary for widening the AR bandwidth.

The measurement shows that the antenna achieves a return loss of 15 dB, gain of 8.3 dBic, axial ratio (AR) of 3 dB, and 3-dB AR beamwidth of 75 over the UHF band of 818–964 MHz or 16.4%.

Author has also done parametric study according to simulation provide more detailed information about the antenna design and optimization.

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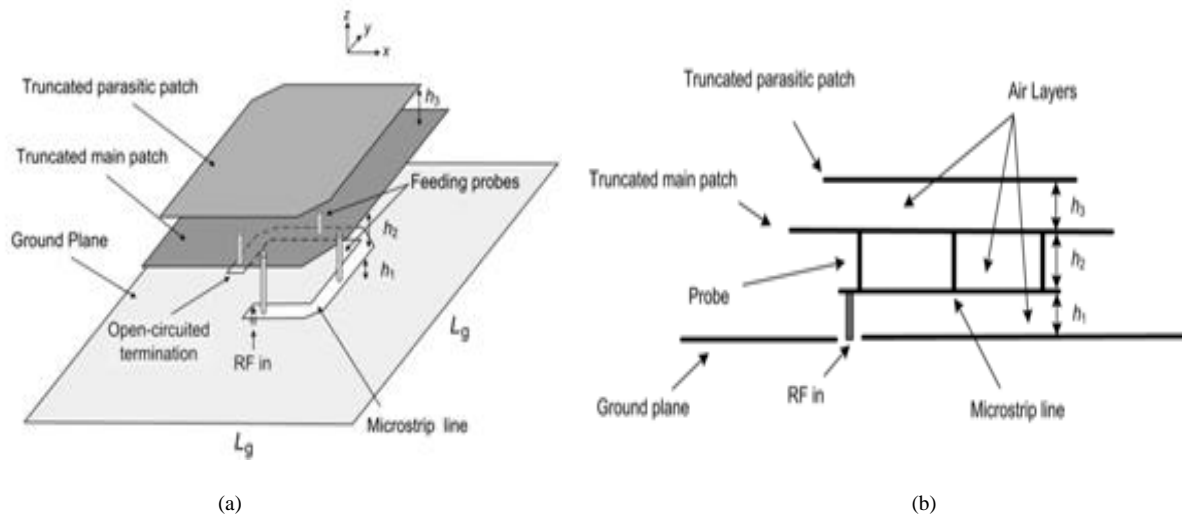


Fig. 7. Configuration of antenna (a) Expanded view

(b) Side view

III. EXPERIMENTAL RESULTS

The results achieved by the respective authors using the different design configurations are summarized in the following table:

Table 1
Reviewed circularly polarized microstrip antenna comparison

Reviewed paper No.	Frequency Range (MHz)	AR Bandwidth	Impedance Bandwidth	Gain	Size (L*W*H, in mm)
[1]	835-955	13.40%	21%	~ 7 dBic	200 * 200 *29.8
[2]	940-960	17.70%	n.a.	> 6.5 dBic	250 * 250 * 33.5
[3]	903-909	n.a.	n.a.	3.8 dBic	90 * 90 * 4.6
[4]	870 - 940	7.70%	16.40%	~ 7 dBic	160 * 160 * 33.2
[5]	818 -964	16.40%	n.a.	8.3 dBic	250 * 250 * 37

In table 1, a comparison of measured results of different technical papers reviewed in this paper are shown. Asymmetric circularly shaped slotted microstrip antenna provides good axial ratio bandwidth and gain but its large size is a drawback while circularly polarized ring-patch antenna volume is comparatively compact but provides low axial ratio bandwidth. Broadband circularly polarized stacked probe-fed patch antenna geometry is large in size and gives higher axial ratio bandwidth but low gain. Wideband circularly polarized stacked slotted microstrip patch antenna design is showing good axial ratio bandwidth and impedance bandwidth with optimal gain and size.

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IV. CONCLUSION

This paper presents a review of various technical papers related to circularly polarized microstrip patch antennas designed and developed by different authors. Most of the papers that reviewed are implemented for Ultra-high-frequency Radio Frequency Identification (RFID). According to RFID requirement all papers aim to enhance circular polarization, axial ratio bandwidth, return loss bandwidth and gain. To achieve these requirements different techniques such as truncated patches, slots, slits, feeding techniques were used. For future exploration, above antenna designs can be reworked with an aim to reduce polarization losses, as well as to achieve good circular polarized radiation (high AR bandwidth), enhanced return-loss bandwidth and gain. Also there is scope to make the antenna compact (by keeping other antenna parameters in required range) so that the resonating frequency can be increased. With this and some other modifications, the same compact geometry can also be used for other wireless application such as GPS, WiFi etc.

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