IJournals: International Journal of Software & Hardware Research in Engineering
ISSN-2347-4890
Volume 4 Issue 8 August, 2016

The Design Study of Circularly Polarized Microstrip Patch Single Layer Reader Antenna for UHF RFID Application

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ABSTRACT

Design of a circularly polarized microstrip patch single layer reader antenna for UHF RFID (Radio Frequency Identification) applications is proposed, in which the design of circular polarized antenna realized by loading two truncated at the corner of the ordinary rectangular patch antenna. The physical parameters of the novel structure are simulated and optimized by using commercial computer simulation technology (CST) simulation packages. The simulation results show the high gain antenna is achieved which is 5.325 dB. The measured results of the return losses and the radiation pattern achieved a good agreement with the simulated results.

Keywords: Mirostrip Patch Antenna, RFID Reader Antenna, computer simulation technology (CST), return loss, high gain.

1. INTRODUCTION

Radio frequency identification (RFID) is a technology that provides wireless identification and tracking capability and is more robust than a bar code. Now RFIDsystem in the ultra high-frequency (UHF) bands (860-960 MHz) finds many applications in various areas such as electronic toll collection, asset identification, retail item management, access control, animal tracking, and vehicle security [1-5]. This is because the UHF band can provide high data transfer rate and broad readable range.

RFID system generally consists of a reader, a tag and a data processing system. A reader (now more typically referred to as an RFID interrogator) is basically a radio frequency (RF) transmitter and receiver, controlled by a microprocessor or digital signal processor. An RFID reader emits electromagnetic signals where an RFID tag draws power from it. This power is then used to energize the microchip's circuits. The chip then modulates the waves and sends back this modulated wave to the reader. This process is called backscattering where the reader sees the tag. The reader antenna must have high gain and directivity [6].Every additional 3 dB of reader antenna gain increase the tag range approximately by 40% [2, 7].

In RFID system, the role of antennas (for reader and tag) is very important.The antenna allows the chip to transmit the information that is used for identification. Commonly, the UHF tag antennas are linearly polarized. Therefore, reader antenna should have circular polarization (CP) characteristic since the tag antenna can be arbitrary positioned on the target. The size reduction and gain enhancement of UHF RFID reader antenna have been key issues to the system developer [8, 9].

An antenna has circular polarization if the field vector (electric or magnetic) for the transmitted wave of the antenna has two orthogonal linear components with the same magnitude and the time-phase difference between this is odd multiples of

90 [10]. Figure 1 below shows how the circular polarized wave propagates.

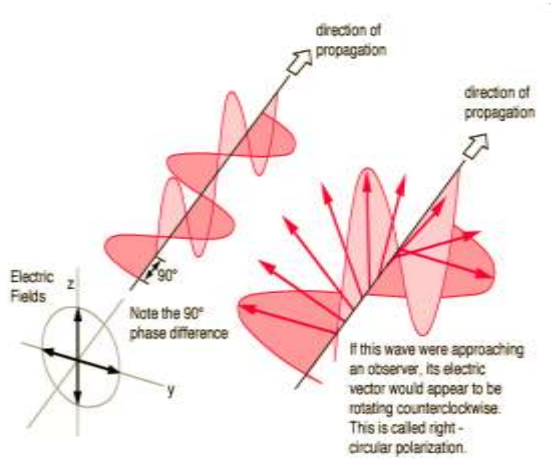
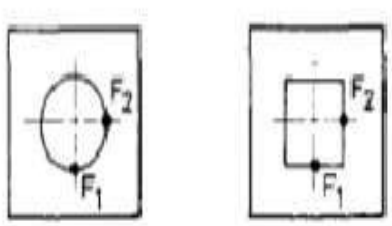
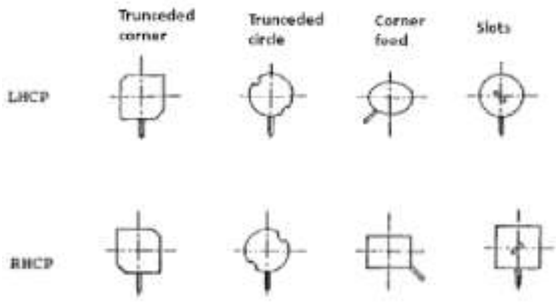


Fig 1: Circular polarization

There are two types of circular polarization. If the field rotation is clockwise then righthand circular polarized (RHCP) or if the field rotation is counterclockwise then left hand circular polarized (LHCP) [11]. Figure 2 below shows some common ways to get left and right handed circular polarization. They can be divided into two groups, Figure 2(a) dual feed and Figure 2(b) single feed patches. The dual feed patch antennas feeds with equal amplitude but on 90 phase difference. The single feed patch antennas using truncated corner, truncated circle, corner feed or slots into the patch [12, 13].



(a)



(b)

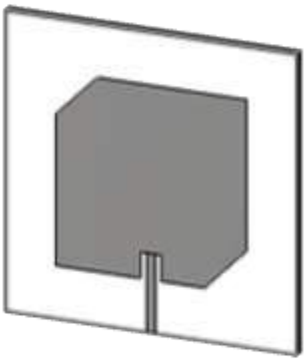
Fig 2: Techniques for circular polarization: (a) dual feed; (b) single feed

In telecommunications, microstrip patch antenna is widely used because of their several advantages such as light weight, low volume, low fabrication cost and capability of dual or triple frequencies operations. However microstrip antenna suffers from numbers of disadvantages. Narrow bandwidth is a serious limitation of these microstrip patch antenna [14].

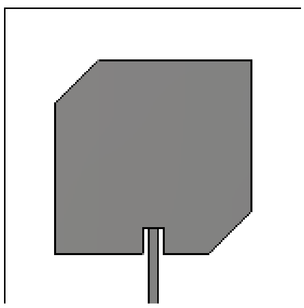
Therefore, the aim of this paper of design circularly polarized microstrip patch antenna for RFID reader and resonate on the Ultra High Frequency (UHF) RFID bands of 860MHz – 960Mhz is presented. The theoretical simulations are performed using CST software.

2. ANTENNA CONFIGURATION AND DESIGN PROCEDURE

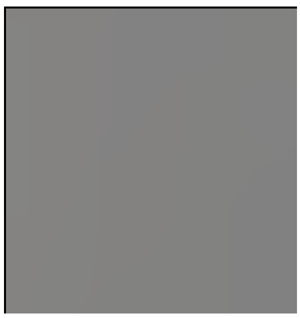
Figure 3(a) shows the geometry of the proposed antenna in 3D view. The antenna is composed of one layer FR4 (loss free) as a substrate with dielectric constant, $\varepsilon r = 4.7$, tangent loss, $\delta = 0.019$, and the thickness, $h = 1.6$ mm. Thetwo truncated at the corner of the ordinary rectangular patch antenna are perform to have a circular polarized antenna. The dimension of the proposed antenna is illustrated in Figure 3(b). The frontview shows the radiating element that has been etched. From the theory, the truncated side of the rectangular patch perform whether the antenna is RHCP or LHCP. The proposed antenna was truncated by left sided so that the proposed antenna is LHCP. Next, the ground is located on the back view of the FR4. The explanation of the proposed antenna working principles to achieve the LHCP is explained in section 3.



(a)



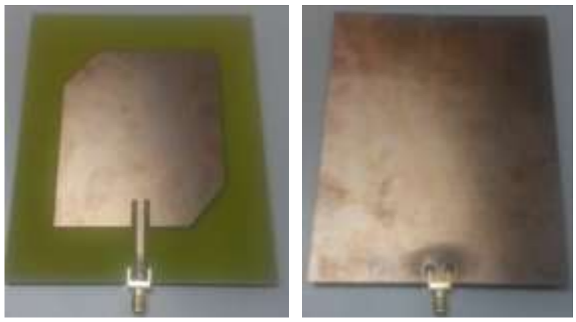
Front View: Truncated Patch



Back View: Ground

(b)

Fig 3: The geometry of the proposed antenna in (a) 3D view, (b) view of front and back view with dimensions (mm)



(a) (b)

Fig 4: Photograph of the fabricated antenna: (a) front view antenna on a 132 mm × 114 mm; (b) back view: ground plane

3. SIMULATION AND MEASUREMENT RESULT

3.1 Axial Ratio for 921MHz

The simulated results of the 3dB axial ratio forproposed microstrip antenna are shown in Figure 5. The length of the square patch was 75.1mm and truncation of 16.5mm × 16.5mm at two opposite corners of the patch. Then, the simulation analysis has been carried out to study the results of the operating frequency. Figure 5 clearly shows that the axial ratio is 0.9395 dB for 921MHz. Therefore, the result proved the proposed antenna is circular polarization based on the theory.

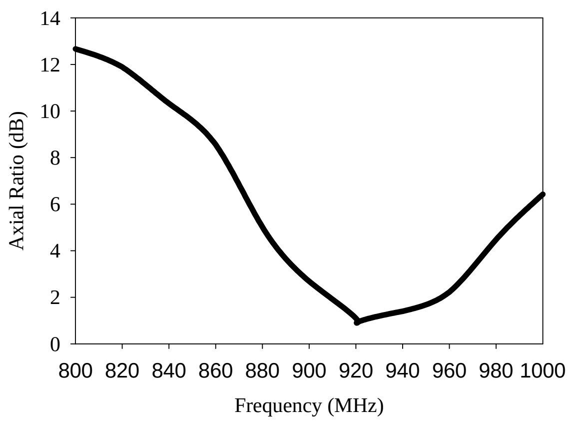


Fig 5: Axial Ratio for 921 MHz

3.2 Impedance Bandwidth and Return Losses

To validate the antenna's performance, the impedance bandwidth (S_{11} < -10 dB) and the experimental return losses between simulation and measurement have been analysed. The CST Microwave Studio software is used to test the

ISSN-2347-4890
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proposed antenna. Figure 6 shows that the proposed antenna is capable to operate at 921 MHz with the bandwidth of 6 MHz and 30 MHz for the simulation and measurement results. As for return losses results, the measured results show a shift to 924 MHz with -16.021 dB, compared to the simulated result with -14.887 dB. Meanwhile, the return losses show better agreement between simulation and measurement. The results prove that the antenna has good performance.

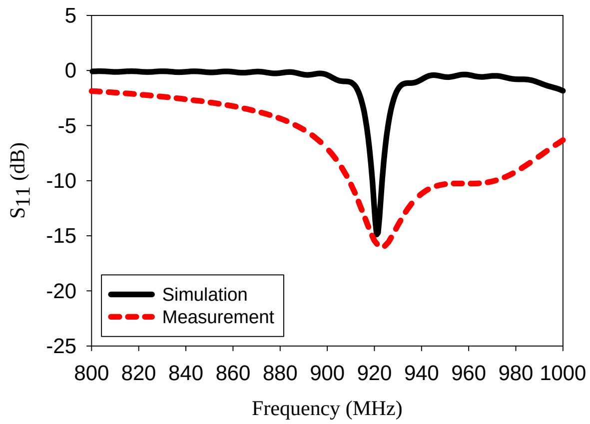


Fig 6: Return losses of the proposed antenna

3.3 Current Distributions

The simulated current distribution of the proposed antenna is shown in Figure 8. The current distribution radiate equally on the radiating element. The current are strongly radiate and focuses on two truncated edge of the ordinary rectangular patch antenna rather than untruncated edge. This is due to effect of the cutting radiating element at the left side to perform circular polarization. Therefore, the LHCP can be obtained based on the circular polarization technique.

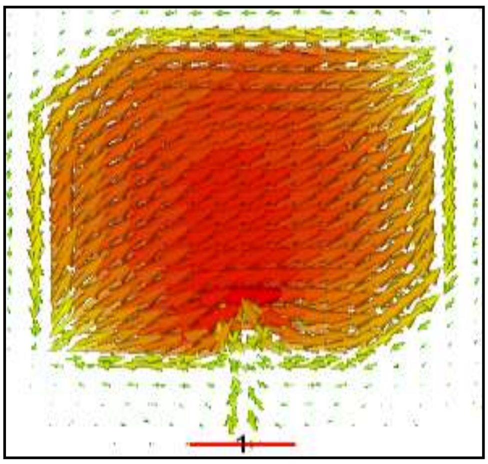
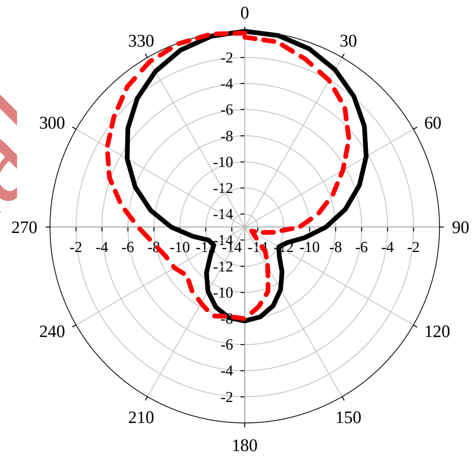
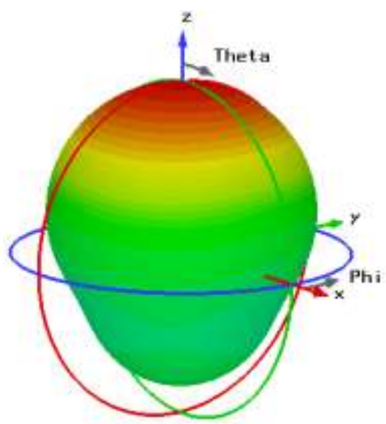


Fig 8: Simulated current distributions

3.4 E-plane and H-plane Radiation Patterns

As illustrated in Figure 9, the radiation patterns of the proposed antenna are measured and simulated in two planes –either in H-plane (*x-z* direction) with phi = 0° and E-plane (*y-z* direction) with phi = 90°. Figure 9 shows the simulated and measured the radiation patterns. Based on the results, there is a good agreement between the simulation and measurement results. However, some minor discrepancies occurred during the measured results are due to a few factors such as the effects during the fabrication. Besides that, the HPBW is 1°. Moreover, the gain is equal to 5.325 dB.





(a)

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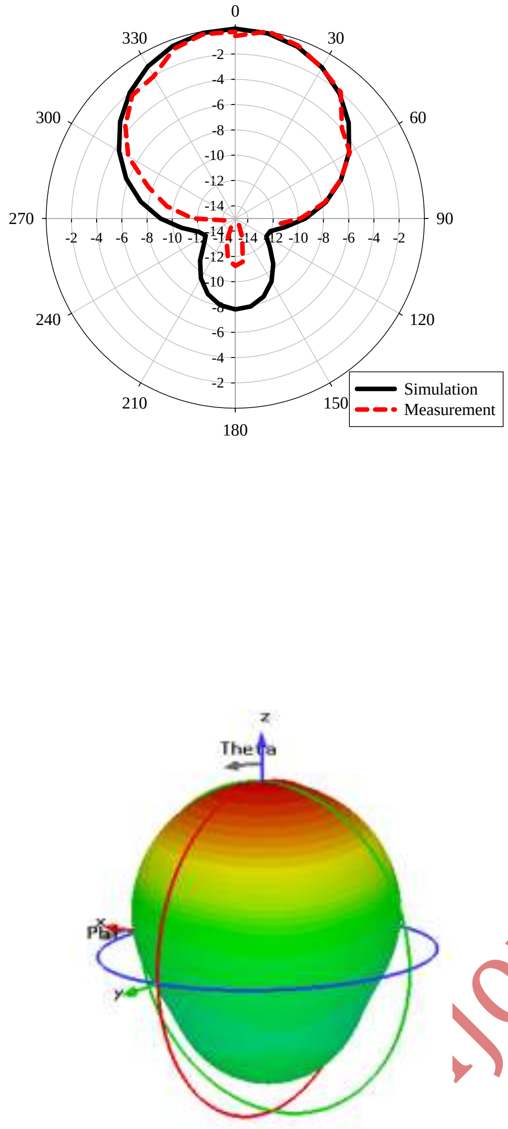

(b)

Fig 9: Radiation patterns of the proposed antenna in polar plot and 3D view during (a) E-plane (phi=90°) and (b) H-plane (phi=0°).

3.5 Practical Outdoor Antenna Measurement

The proposed antenna, known as an Antenna Under Test (AUT), acts as a transmitter (T_x) antenna to test the capability of the antenna to transmit the signal to the receiver (R_x) and to verify the distance based on the power transmit (P_t) signal. Therefore, the power received (P_r) signal measurement is carried out at the R_x side when the distances between the T_x and R_x vary from 1 m to 7 m. In this work, the measurement was conducted at FKE Lab Corridor (see Figure 10). The practical outdoor propagation was carried out with the minimum P_t of 0 dBm supplied to the AUT. However, at the distance of 7 m, no power received (P_r) signal was detected at the R_x side. This finding proves that with the minimum of P_t at 0 dBm, the AUT has the capability to transmit the signal to the R_x side with maximum distance of 6 m at the FKE Lab Corridor.

Fig 10: The FKE Lab Corridor, where the PL and P_r were carried out

The outdoor practical antenna measurement setup is shown in Figure 11. Both AUT and R_x positions at a height of 1 m must be placed face-to-face and aligned towards each other to obtain a line-of-sight (LOS) condition. At the T_x side, the signal generator with Wiltron 6647B model (10 MHz to 20 GHz) was used to inject the RF signal to the AUT, while the equipment at the R_x side was a receiving antenna (Horn antenna with ED200C model) connected to the spectrum analyser (Advantest U3751).

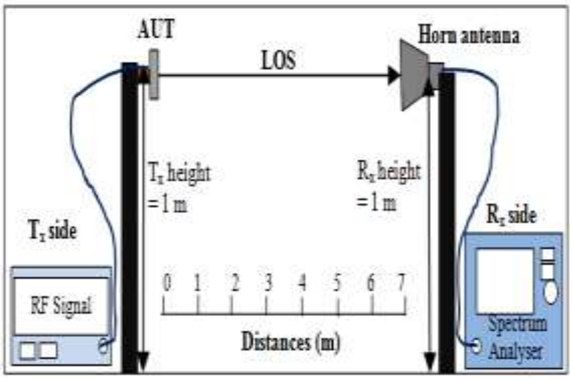

Fig 11: The practical antenna measurement setup

Theoretically, the path loss (PL) versus the distance between the T_x and R_x is described in the Ground Reflection (Two-Ray) propagation model [15], as formula shown in Equation (1).

$$PL = 32.44 + [20 \log d] + [20 \log f] - G_T - G_R + [T_{other\ losses}] \quad (1)$$

where the d is distance (km), f is the frequency (MHz), $G_T$is the transmitter (AUT) gain (dBi), G_R is the receiver gain (dBi), and $T_{Other\ losses}$ includes the floor, wall and glass coefficient, which are defined as T_{floor}= 13 dB,T_{wall}= 2.2 dB and T_{glass}= 0.25 dB, respectively[15]. The G_T gain value refers to the AUT during the simulation and the $G_R$gain value refers to the Horn antenna (R_x) with 10 dBi gain. In this work, during the measurement at the FKE Lab Corridor, only the floor loss (13 dB) was considered.

Next, the P_r is determined following Equation (2) and the theoretical results will be compared with the measurement results at FKE Lab Corridor.

$$PL = 10 \log [P_t / P_r] \quad (2)$$

Figure 12 show the power received signal comparison between theoretical and measurement results at FKE Lab Corridor. The P_r values between the theoretical and measurement are rather similar. As shown in figure, when the distance between T_x and R_x increases, the P_r signal decrease. The figure also show that when the same powers are used to transmit a signal between rooms, the received signal is lower compared to the received signal in an empty room. From the experimental results in this work, it is proven that the antenna can perform as a transmitter as the signal can be transmitted to the receiver side. The AUT can cover a minimum distance of 6 m with minimum P_t of equal to 0 dBm or 0.001 Watt. However, if the P_t is supplied with more than 0 dBm power signal, the AUT has a capability to transmit the signal further.

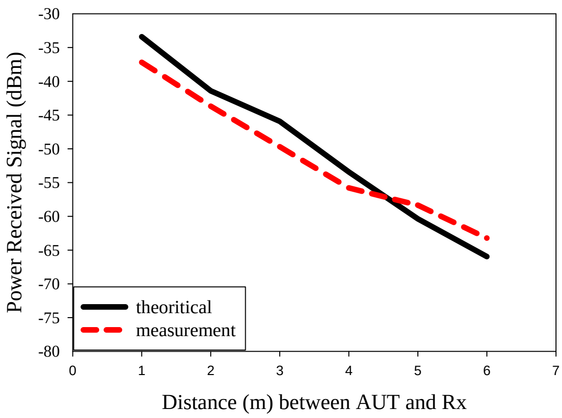

Fig 12: Comparison between theoretical andmeasurement results of the distance between AUT and R_x (unit: m) at FKE Lab Corridor.

4. CONCLUSION

In summary, the proposed antenna with a circular polarized that resonate on the Ultra High Frequency (UHF) RFID bands of 860MHz-960Mhz for RFID reader has been presented. The return loss and radiation pattern measurements and simulations are also presented in this paper. It is confirmed that the antenna achieves a good agreement with the simulation. The results from this research have a great potential in wireless communication and can be used in UHF RFID system applications, especially in Malaysia.

5. ACKNOWLEDGMENTS

This work was supported by the Faculty of Electrical Engineering, UiTM, and the Ministry of Higher Education (MOHE), Malaysia. The authors also wish to thank the Research Intensive Grant (RIF) 600-RMI/DANA 5/3/RIF (362/2012) for the financial aid for this project.

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