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Research paper

Design of High Gain Microstrip Patch Reader Array Antenna with Parasitic Elements for UHF RFID Application

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Abstract

Design of a microstrip patch UHF reader parasitic array antenna for RFID (Radio Frequency Identification) applications is proposed, in which the design patches antenna realized by loading two truncated at the corner of the ordinary rectangular patch antenna. The patch was sorted in a 2 x 2 array configuration, meanwhile the feed network was constructed by coaxial feed concept. The parasitic elements are added on the same layer of the substrate and at the right and left side of the every patch. 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 11.15 dBi. The measured results of the return losses and the radiation pattern achieved a good agreement with the simulated results.

Keywords: *Mirostrip patch antenna, UHF RFID reader antenna, array, parasitic elements, computer simulation technology (CST).*

1. Introduction

Recently, Radio Frequency Identification (RFID) technology has grown much attention from all over the world. RFID system in the Ultra High Frequency (UHF) bands which is 860-960 MHz is a fast growing technology for automatic identification and is being exploited in many areas such as healthcare, airport, libraries, military, passport, supply chain etc. [1][2]. The UHF band can deliver wide readable range and high data transfer rate. The worldwide operating frequency for UHF RFID system is between 860 MHz - 960 MHz with some variances in frequency from region to region depending on the radio regulation of that region [3]. In Malaysia, the permitted operating frequency is between 919 MHz – 923 MHz.

RFID is a technology that offers tracking capability and wireless identification and is more robust compared to barcode. Due to its ability to transfer the data-carrying device and the reader wirelessly using radio waves, RFID system is more flexible. Therefore, the amount of time needed to input the data manually can be reduced and also can increase the accuracy and efficiency of the operation [4].

A microstrip (MS) antenna is a popular approach to UHF RFID reader antennas because of their several advantages such as simple fabrication, low profile and adequate directivity [5][6]. A simple MS antenna commonly comprise three layers: Ground plane, substrate, and antenna patch, where the substrate preferably have low loss tangent, but where a low loss tangent unfortunately also comes at a high cost and thus limit its use for very large area applications. Though, several disadvantages disturbed the microstrip antenna. Microstrip patch antenna suffers a serious limitation of narrow bandwidth [7].

In RFID system, the role of antennas (for reader and tag) is quite important. The main function of antennas is to radiate waves carrying information into the air and transmit them over large distances. The microstrip antenna's element can be organized or sorted either in the single element or in an array configuration. Single element antennas were incapable to meet the demands of read range distance requirement in certain applications, especially in terms of low gain. The benefits of array configuration are improved the overall gain, offer diversity reception and has the capability to steer the radiation pattern [8][9]. The reader antenna must have high directivity and gain. Every added 3 dB of reader antenna gain increase the tag range roughly by 40% [3].

The elements of array antenna comes in several geometrical configurations where either arranged in a linear or planar array configuration. Antenna dimension either x-axis or y-axis is a linear array. Antenna array where the elements are organized on a plane in two dimensions is a planar array, which is in x-axis and y-axis [10][11].

In RFID system, gain of the antenna plays the important characteristics in read range distance. The higher the gain is, the higher read range distance of the antenna. The gain performance of the antenna can be increased by using array configuration and adding the parasitic elements. The paper presented in [12] proposed a compact loop antenna for UHF RFID applications. A folded-dipole antenna with parasitic elements are designed by using FR-4 substrate and produced gain of 4.4 dBi. Work by [13] proposed a high gain circularly-polarized dual band antenna array for UHF and microwave band RFID application. A 2 x 2 array formed by sequentially-rotated configuration exhibited 8 dBi gain at UHF band and 10 dBi gain at microwave band. A microstrip antenna array presented in [14] is made up of a 2 x 2 antenna array which adopts coaxial cable as the feeder. A simple impedance matching network is designed which is composed of some T-shaped structure to match with 50 ohm coaxial line. The results of the antenna show that maximum gain of 13.9 dBi. The proposed antenna used the concept of 2 x 2 antenna array configuration and parasitic elements in order to increase the antenna gain.

In this paper, a novel design of microstrip patch array antenna with parasitic elements for RFID reader and resonate on the UHF RFID bands of 860-960 MHz is presented. The UHF reader antenna specification was aimed to have more than 8 dBi gain. The theoretical simulations are achieved by means of CST platform.

2. Antenna Configuration and Design Procedure

Figure 1 (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, εr = 4.7, tangent loss, δ = 0.019, and the thickness, h = 1.6 mm. The structure of the proposed antenna was constructed from 2 x 2 patches with the dimensions of 300 mm x 300 mm x 1.6 mm. The parasitic elements are added on the same layer of the substrate and at the left and right side of the every patches. The dimension of the proposed antenna is illustrated in Figure 1 (b) whereas the front view shows the radiating element that have been etched. To reduce the mutual coupling between them, the maximum distance between these two patches must be λ/2. Moreover, the feed line structure of this 2 x 2 array configuration is assembled as presented below. Next, the ground is located on the back view of the FR4 as shown in Figure 1 (c).

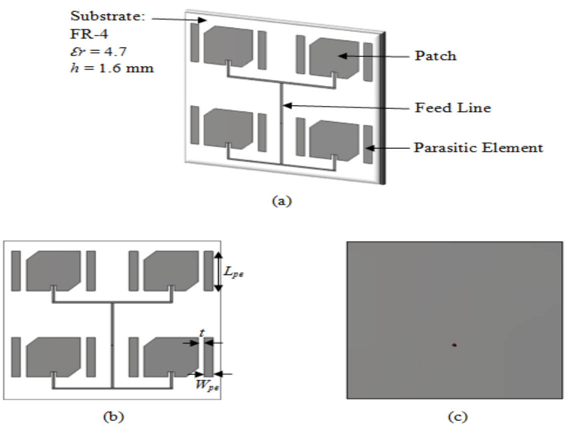


Fig. 1: The geometry of the proposed antenna in (a) 3D view, (b) front view and (c) back view with dimensions (mm)

Figure 2 shows the fabricated proposed antenna. The structure consisted of four truncated patches with parasitic elements at left and right of the patch and integrated with coaxial feed network. To maintain the input impedance of 50 ohms the T-junction power splitter is used in the feed networking. RF signals are injected to the antenna by a standard SMA connector connected at the feed line. The ground plane is placed at the back of the substrate.

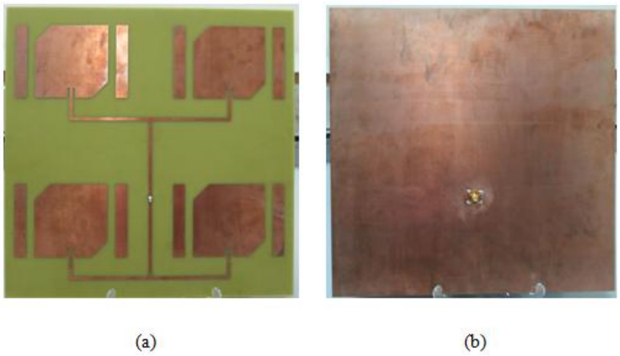


Fig. 2: Photograph of the fabricated antenna: (a) front view antenna on a 300 mm × 300 mm; (b) back view: ground plane

3. Simulation and Measurement Results

The reflection coefficient (S_{11}< -10 dB) and radiation pattern between simulation and measurement have been analysed to validate the performance of the antenna.

3.1. Reflection Coefficient

The reflection coefficient, S_{11} measurement of the suggested antenna configuration was conducted using the Rohde and Schwarz ZVA 40 instruments 10 MHz to 40 MHz Vector Network Analyzer (VNA). Figure 3 shows the reflection coefficient, S_{11} measurement setup for the proposed antenna.

Fig. 3: The reflection coefficient, S_{11} measurement setup

The simulation and measurement reflection coefficient, S_{11} shown in Figure 4. As for reflection coefficient, S_{11} results, the measurement result shows a shift to 918 MHz with -26.99 dB, compared to the simulation result 921 MHz with -31.887 dB. Yet, the shifted frequency is just slightly from the simulation frequency and reached an acceptable return loss with lower than -15 dB. All the discrepancies, which are some imperfections developing from the antenna such as the error during soldier the SMA cable to the coaxial feed line and also minor errors happened throughout the cutting process during antenna fabrication. However, from the measurement results, it is proven that the measurement and simulation results did not differ much. An acceptable agreement between the measurement and simulation reflection coefficient were obtained.

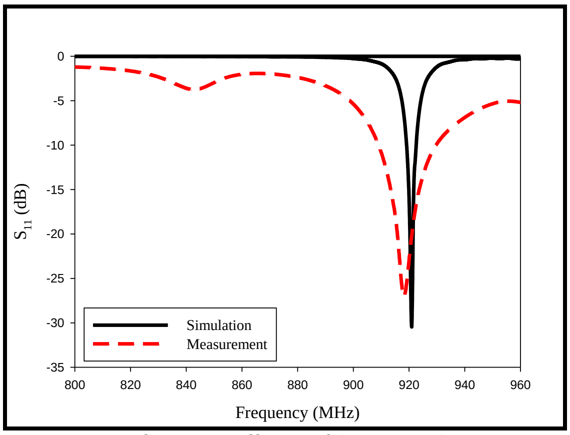


Fig. 4: Reflection Coefficient of the proposed antenna

3.2. E-Plane and H-Plane Radiation Patterns

As shown in Figure 5, the proposed antenna perform as an antenna under test (AUT), which is associated through the vertical position holder. The radiation pattern has been measured in an indoor anechoic chamber by means of a near-field measurement system at operating frequency 921 MHz. The data of AUT was obtained by rotated the antenna that attach on the mechanical rotator.

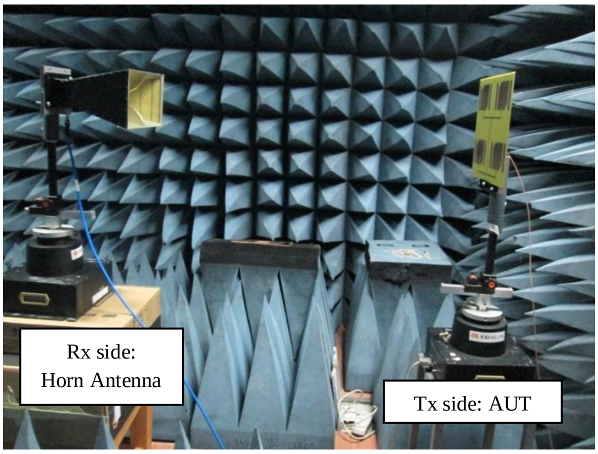
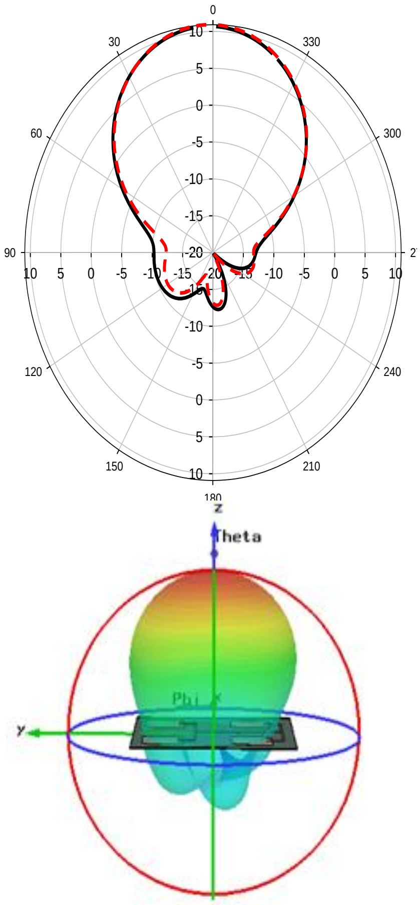
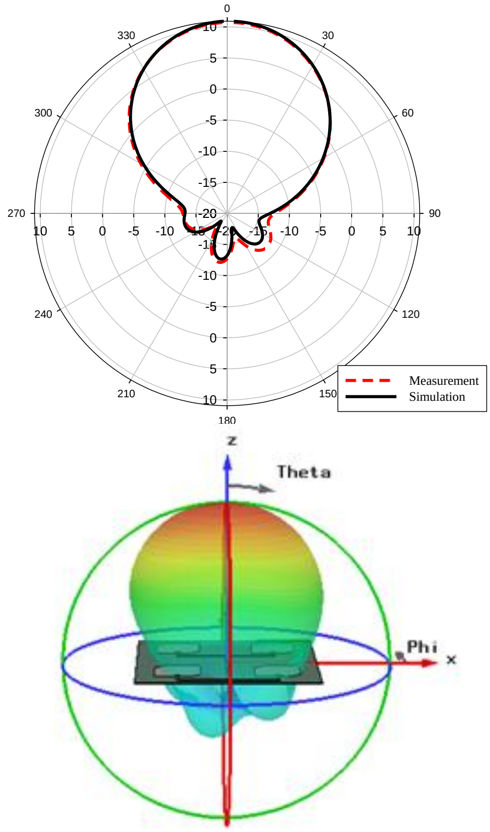


Fig. 5: The measurement setup of radiation pattern in the anechoic chamber

The proposed antenna's simulation and measurement radiation patterns are carried out in two-planes - either in E-plane (y-z direction) with phi = 90º and H-plane (x-z direction) with phi = 0º. The measurement and simulation radiation pattern at 921 MHz is shown in Figure 6. We can consider the measurement radiation pattern as having acceptable agreement, in contrast to the simulation outcomes as illustrated in Figure 6. Nevertheless, several minor discrepancies were shown in the measurement outcomes mostly due to the identical reasons deliberated in reflection coefficient measurement. A satisfactory agreement amid the measurement and simulation design was hence acquired. Besides that, the HPBW is 0°. Moreover, the gain is equal to 11.15 dBi as shown in Figure 7.



(a)



(b)

Fig. 6: Radiation patterns of the proposed antenna in polar plot and 3D view during (a) E-plane (phi = 90°) and (b) H-plane (phi = 0°).

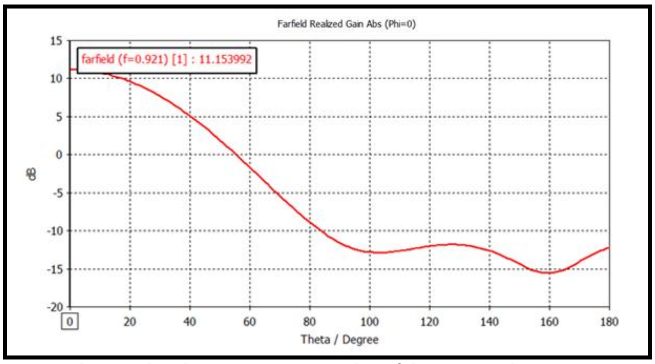


Fig. 7: The simulated gain in Cartesian plot of the proposed antenna at 921 MHz

4. Practical Indoor Antenna Measurement

Antenna's performance can be validated by testing the ability of the antenna in an indoor or outdoor measurement. The proposed antenna, identified as an Antenna Under Test (AUT), acts as a transmitter (Tx) antenna to test the ability of the antenna to transmit the signal to the receiver (Rx) in addition to validate the distance based on the power transmit (Pt) signal. When the distances between the Tx and Rx vary from 1 m to 12 m, the power received (Pr) signal measurement is conducted at the Rx side. In this work, the measurement was conducted at Fakulti Kejuruteraan Elektrik Laboratory Corridor (Figure 8). With the minimum Pt of 0 dBm delivered to the AUT, the practical indoor propagation was carried out. However, power received (Pr) signal has not identified at the Rx side at the distance of 12 m. This finding proves that the AUT has the ability to transfer the signal to the Rx side with maximum distance of 11 m with the minimum of Pt at 0 dBm, at the Fakulti Kejuruteraan Elektrik Laboratory Corridor. Practical Indoor Antenna is to measure the capability of the AUT if the antenna can transfer or receive the signal to verify whether the AUT is working and not a dummy antenna.

Fig. 8: Real practical indoor antenna measurement setup at Fakulti Kejuruteraan Elektrik Laboratory corridor

The practical indoor antenna measurement setup is shown in Figure 9. Rx and AUT both located at a 1m height and advised be positioned face-to-face, in addition to bring them into line towards each other to attain a line-of-sight (LOS) condition. The signal generator which is Wiltron 6647B model (10 MHz to 20 GHz) is implemented to inject the RF signal to the AUT at the Tx side while the receiving antenna which is Horn antenna with ED200C model is the tool at the Rx side is associated with the spectrum analyzer (Advantest U3751).

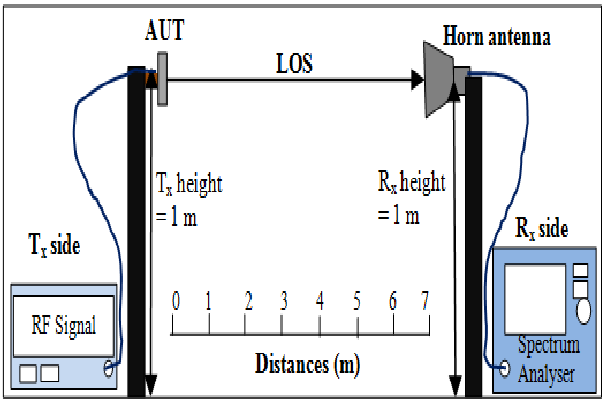


Fig. 9: The practical antenna measurement setup

Theoretically, Ground Reflection (Two-Ray) propagation model defined the path loss (PL) versus the distance between the Tx and Rx [12], as formula shown in Equation (1).

$$PL = 32.44 + [20 \log d] + [20 \log f] - GT - GR + [Tother\ losses] \quad (1)$$

where d is the distance (km), f is the frequency (MHz), GT is the transmitter (AUT) gain (dBi), GR is the receiver gain (dBi), and Tother losses includes the wall, glass and floor coefficient, that are assigned as Twall = 2.2 dB, Tglass = 0.25 dB and Tfloor = 13 dB, respectively [15] . The GT gain value refers to the AUT during the simulation and the GR is gain value of the Horn antenna (Rx) with 10 dBi gain. In this work, only the floor loss (13 dB) was considered during the measurement at the Fakulti Kejuruteraan Elektrik Laboratory Corridor.
Next, the Pr is determined by following Equation (2) and the theoretical results are compared with the measurement results at Fakulti Kejuruteraan Elektrik Laboratory Corridor.

$$PL = 10 \log [Pt / Pr] \quad (2)$$

The comparison of power received signal between theoretical and measurement results at Fakulti Kejuruteraan Elektrik Laboratory Corridor are shown in Figure 10. The Pr values between the theoretical and measurement are slightly parallel. Figure 10 shows that the Pr signal decrease when the distance between Tx and Rx increases. From the experiment, it is proven that the signal can be transferred to the receiver side and the antenna can implement as a transmitter. With minimum Pt of equal to 0 dBm or 0.001 Watt, the AUT can cover a minimum distance of 10 m. However, the AUT has an ability to transmit the signal further if the Pt is supplied with more than 0 dBm power signal.

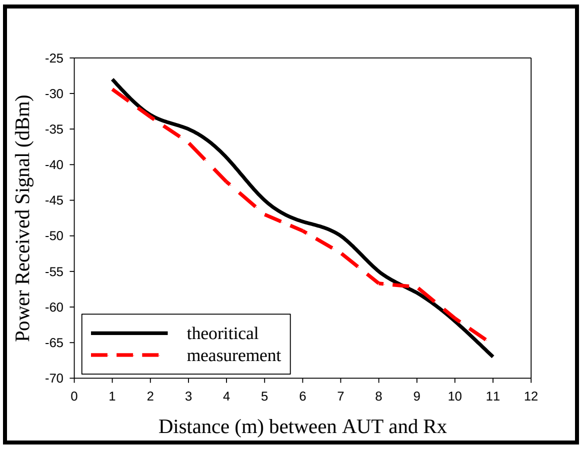


Fig. 10: Comparison of Power Received Signal between theoretical and measurement results at Fakulti Kejuruteraan Elektrik Laboratory Corridor

5. Conclusion

In summary, the proposed array antenna with parasitic elements configured the Ultra High Frequency (UHF) RFID bands of 921 MHz operating frequency for RFID reader. The measured result of the antenna illustrated that the reflection coefficient measurement at the 921 MHz showed that the S_{11} magnitude being lower than -10 dB. The measured radiation pattern of antenna showed that the measured result was similar to the simulated results. It is confirmed that the antenna achieves a good agreement with the simulation. Work by [16] had proposed a 10.17 dBi gain value of RFID reader antenna. The contrast gain among both antennas can be perceived, as the proposed antenna had a gain more than 11.15 dBi. This paper gives a promising ability in the field of wireless communication as it can be implemented in UHF RFID system applications, especially in Malaysia.

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