Read Range Performance of Microstrip Patch Reader Antenna for UHF RFID Applications

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Abstract: This study conducted to compare a read range performance of microstrip patch reader antenna for UHF Radio Frequency Identification (RFID) applications. The circularly polarized reader antenna described in this study are designed to be affixed the polarization mismatch problem between reader antenna and tag antenna. Two truncated at the corner of the ordinary rectangular patch antenna is designed for UHF band (919-923 MHz) which destined for Malaysian systems. Measured results show that the antenna with size of 115*115*1.6 mm have gain antenna of 5.3 dBi, satisfactory 3-dB axial-ratio and reading range of 2m. Read range measurement results of the reader antenna design and tags antenna with the reader are observed and analysed to validate the practical performance. The reader antenna design delivered in this study areappropriate to UHF RFID applications.

Keywords:Microstrip Patch Reader Antenna, Circularly Polarized, UHF RFID Reader, Read Range Performance, Gain

I. INTRODUCTION

Nowadays, Radio Frequency Identification (RFID) technology is highly demanded in various applications such as asset identification, vehicle security, animal tracking and access control requiring a rapid development in the RFID technology[1][2]. RFID introduces wireless identification and tracking proficiency and is more vigorous compared to barcode. RFID system has an ability in transferring the data-carrying device and the reader using radio waves wirelessly[3][4].

Electromagnetic waveswere usedin passive UHF RFID systems for coupling and communication between tag and reader[5].To activate its microchip, the reader driveswave signal to the tag and then modulate the signal. The tag reacts with its identification code using backscattering of modulated electromagnetic wave. No inner source of energy in the tag's microchip found, hence all the energy needed for operational from the electromagnetic wave radiated by the reader[6][7].

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In the RFID system, read range distance plays an important role to achieve applications success. In order to apply the RFID technology for various applications, the gain value of the reader antenna may vary. The gain of the antenna effects the read range distance which in general, the increase in gain will increase the read range distance of the antenna and vice-versa[3][8]. Generally, the size of high gain antennas is bigger than the antenna that has low gain. Therefore, the microstrip antenna was used to design reader antenna due to their attractive features such as light weight, inexpensive and easy to fabricate[9][8].

This study conducted to compare a read range performance of reader antenna and tags for UHF RFID applications. The antenna should be compressed but still efficient to afford the desired performance. Section II describesthe structure of reader antennas for this study. Section III discussesthe analysis and parameters via computational modelling of reflection coefficient (S_{11}) and gain measurements. The read range performance testing and analysis was presented and verified in Section VI. Finally, Section V provides the conclusion of the study.

II. ANTENNA DESIGN CONFIGURATION

Computer Simulation Technology (CST) structured and optimized the antenna design by simulations. The reflection coefficient (S_{11}) and the – 10 dB bandwidth of the antenna design was then quantified with vector network analyser. Commonly, there was a decent agreement with the measurement and simulation results.

A basic structure of the antenna started with the rectangular shape as a patch and etched on top of the substrate. Then, the implementation of truncated corner at the left side at the top of patch and at the right side at the bottom of patch is to achieve circular polarization radiation pattern of the antenna. The dimension of the truncated corner has been optimized to achieve axial ratio value near to 0 dB. The operating frequency of the antenna is 921 MHz and the layout of the antenna is displayed in Fig. 1 and Fig.2.

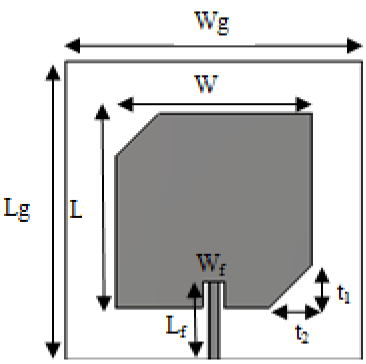

Fig.1Front view of the microstrip patch antenna

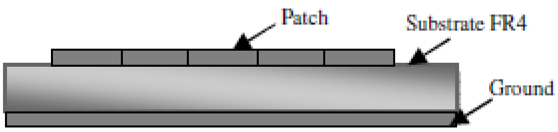

Fig.2 Side view of themicrostrip patch antenna

Structure of microstrip patch antenna consist of antenna width (W), antenna length (L), substrate width (Wg), substrate length (Lg), and a feed line which have impedance of 50 ohm where feed width (W_f) and feed length (L_f) are hostedproportionally to the probe position. The design of microstrip patch antenna used dielectric substrate materials which is FR4 (loss-free). The FR4 (loss free) has a criteria with dielectric constant (Ɛr) of 4.7, thickness (h) of 1.6 mm and tangent loss (δ) of 0.019. Patch and ground of the antenna used PEC material with the thickness of 0.035mm. There are equations to calculate L_g, W_g, L, W, W_f and L_f which are given by equations (1)-(7) below[3]:-

Patch width,

$$W = \frac{c}{2fo}\sqrt{\frac{\varepsilon r + 1}{2}} \quad (1)$$

where*fo* is the operating frequency, *Ɛr* is thedielectric constant and *c*is thespeed of light ($3x10^8$) m/s

Effective dielectric constant,

$$\varepsilon reff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\sqrt{1 + 12\frac{h}{W}} \quad (2)$$

Effective length,

$$Leff = \frac{c}{2\, fo\sqrt{\varepsilon reff}} \quad (3)$$

Length extension,

$$\Delta L = 0.412h\frac{(\varepsilon reff + 0.3)(W/h + 0.264)}{(\varepsilon reff + 0.258)(W/h + 0.8)} \quad (4)$$

where his the substrate thickness

Actual patch length,

$$L = Leff - 2\Delta L \quad (5)$$

Ground plane extension Lg≠Wg,

$$Lg = 6h + L \quad (6)$$
$$Wg = 6h + W \quad (7)$$

where h is the substrate thickness

In order to determine patch antenna to be nurtured by 50 ohm, microstrip feed line was used for line impedance (Zo). Microstrip feed line such as length (L_f) and width (W_f) are calculated using equations[3] (8) and (9):-

Feed length,

$$Lf = \frac{L}{2\sqrt{\varepsilon reff}} \quad (8)$$

Feed width,

$$Zo = \frac{60}{\sqrt{\varepsilon reff}}\ \ln\left[\frac{8h}{Wf} + \frac{Wf}{4h}\right] \quad (9)$$

where his the substrate thickness and *Zo* is the line impedance

Table I shows the optimization result of microstrip patch reader antenna operating at921 MHz.

Table. 1Dimension of The Microstrip Patch Antenna After Optimization

Parameters	Width (mm)	Label	Length (mm)	Label
Patch	75	W_p	75	L_p
Truncated Corner	16.5	t_1	16.5	t_2
Feed line	3.156	W_f	30	L_f
Substrate and Ground	115	W_g	115	L_g
Substrate Material	**Dielectric constant, ε_r**	**Tangent loss, δ**	**Thickness (mm)**	
FR-4	4.7	0.019	1.6	

Fig.3 shows the prototype of reader antenna with substrate size of 115 mm x 115 mm x 1.6 mm.

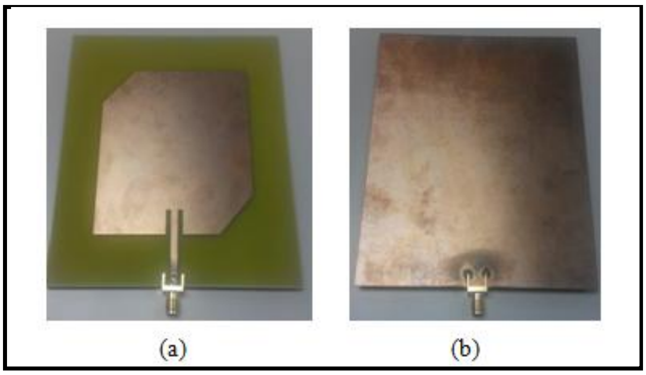

Fig.3 Fabricated of reader antenna (a) Front view and (b) Back view (ground plane)

III. RESULT AND DISCUSSION

Reflection Coefficient Measurement

The impedance bandwidth (S_{11}<-10dB) and the experimental reflection coefficient between measurement and simulation have been analysed in order to verify the reader antenna performance. The CST Microwave Studio software is used to simulate the reader antenna. Fig. 4 shows that the reader 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 reflection coefficient results, the measured results show a shift to924 MHz with -16.021 dB, compared to the simulated result with -14.887 dB. Meanwhile, the reflection coefficient showedwell agreement between measurement and simulation. The results prove that the reader antenna has virtuous performance.

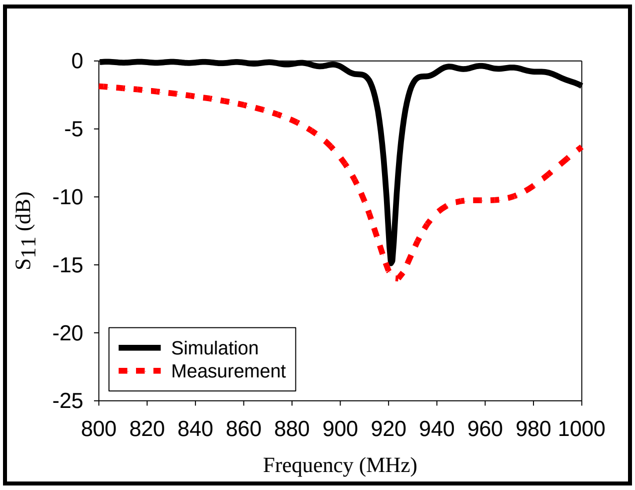

Fig.4Comparison of reflection coefficient, S_{11} value between simulated and measured result

Gain

For this antenna structure, the gain equal to 5.32 dBi as shown in Fig.5 below.

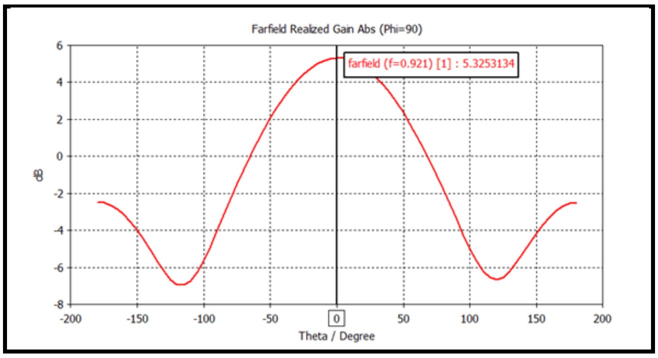

Fig. 5 The simulated gain in Cartesian plot of the reader antenna

IV. PERFORMANCE TESTING AND ANALYSIS

The measurement setup is shown in Fig.6 (a) and the maximum read range distance was recorded. The reader antenna and tag was placed at the same height of 1 m and place face-to-face as shown in Fig.6(b) in order to obtain a line-of-sight (LOS) condition. Ultra High Frequency (UHF) RFID reader and UHF tags were used in this measurement test. The RFID reader as shown in Fig.7 is from RF-iDentSdn. Bhd. company of the type EVO-UHF2200 and can be operated in the frequency range of 902 – 928 MHz with the maximum output power of 32 dBm[10]. The reader was connected to the reader antenna through coaxial cable and to the laptop or computer host through RS 232 cable as well as connected to the power source.

(a)

(b)

Fig.6 (a) Read range measurement setup (b) Both reader antenna and tag positioned facing towards each other

Fig.7RFID reader connected to the laptop through RS 232

The reader 2300 software was used to activate the detectionamong the reader antenna and UHF-tags in measurement test. To measure the reader antenna read range distance, firstly, the tag was positioned closer to the reader antenna. The application software called "reader2300Demo" installed in the laptop will send a command to the reader to detect the tag. The reader will then send the received data from the tag to the computer host if the reader antenna receive a backscattered signal from the tag and beep sound will be heard. Fig. 8 shows the data collected from the different tags. The tag was then gradually moved away from the reader antenna until no detection signal has detected which also no beep sound can be heard. No detection signal means the reader antenna cannot receive a backscattered signal from the tag antenna any longer. The maximum distance that the reader antenna can detect the signal from the tag antenna was then obtained using a measuring tape.

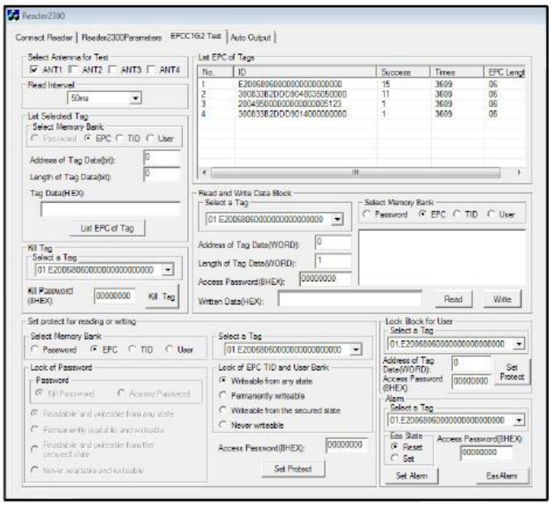

Fig. 8 "Reader2300Demo" Application Software

The study of reader antennaread range performance used five different tag types named Cross, Short Dipole, Frog 3D, Contidex, Alien. The best UHF-tag antenna that give the maximum read range distance is finalized. Fig.9 to Fig.13 shows the type of UHF-tag antennas used in the experiment.

Fig.9Cross Tag

Fig.10 Short Dipole Tag

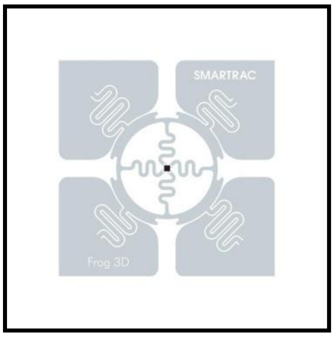

Fig.11 Frog 3D Tag

Fig.12Contidex Tag

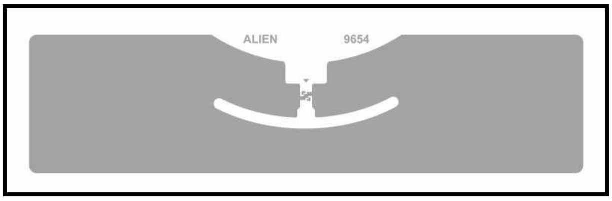

Fig.13 Alien Tag

Table 2 shows the read range distance in meter (m) of reader antenna. Therefore, the best performance of UHF-tag and reader antenna can be obtained. From the verification and validation of the antenna performance using five tags, the UHF Frog 3D tag has been identified to give the furthest read range distance compared to all other tags with the reading of 2.0 m. Meanwhile, the UHF Contidex tag gives the shortest read range distance.

Table. 2 Read Range of Antenna of Five UHF-tags

Type of UHF-Tags	Antenna (m)
Cross	1.0
Short dipole	1.5
Frog 3D	**2.0**
Contidex	0.8
Alien	1.0

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V. CONCLUSIONS

This study describes a read range performance of reader antenna and UHF-tagsfor a UHF RFID applications. The reflection coefficient and gain of the antenna design are analyzed with CST simulations and measurements using a vector network analyzer. The performance of the reader antenna is verified with read range measurement using five different UHF-tags. The attained read ranges are suitable for UHF RFID applications.

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