eISSN: 2477-7986

Journal of Measurements, Electronics, Communications, and Systems *(Vol.05, Pg.01-06, December 2019)*

Microstrip 915 MHz Antenna Design Of RFID Reader for Highway Toll Ticketing

Muhamad Abdul Rahman Suyudi[1], Bambang Setia Nugroho[2], Edwar [3]

School of Telecommunication Engineering, Telkom University, Bandung, 40287, Indonesia

rahmansuyudi@student.telkomuniversity.ac.id[1], bambangsetianugroho@telkomuniversity.ac.id[2], edwarm@telkomuniversity.ac.id[3]

Manuscript received April 19, 2018; revised October 10, 2018; accepted December 2, 2018

Abstract

The use of radio frequency identification (RFID) for gateless highway toll ticketing system is expected to have an excellent accuracy in detecting every passing car. Practically, a RFID reader should be able to precisely read tags installed in cars queuing in a certain lane, while avoiding any reading of car tags in other queuing lanes or outside the reader's reading range. Therefore, a microstrip antenna for the reader is required to have a proper configuration. In this work, an RFID reader antenna microstrip, has been proposed, operating at 915 MHz and deployable at highway gates. The proposed beam width is intentionally configured to cover the width of one gate lanes, avoiding excessive coverages on other lanes. Besides, the antenna is intended to have a circular polarization, hence avoiding any reading problem despite potential tilting of RFID tag in a passing car. The resulting gain is 1.77 dB, which is expected to affect the amount of transmitting power required by an RFID transmitter. Looking at the result of this study, the proposed antenna is stated to be applicable for RFID readers at gateless highway system.

Keywords: RFID, Microstrip, Radiation Pattern, Polarization, Gain, VSWR, S-parameter

doi: 10.25124/jmecs.v5i1.1954

1. Introduction

The use of private transportation vehicles in Indonesia, especially cars, has been consistently increasing at an annual average of 1.336.756 cars [1]. Hence, the number of highway users is expected to continuously increase. It would then affect the density of queuing cars within highway gates, causing heavy traffic jams. To overcome the problem, RFID system offers an advantage in accelerating the service time for ticketing processes.

In fact, RFID based highway gates have been used in Indonesia however, car drivers are still required to tap their RFID tags to RFID readers at the gates. A tapping system as such requires a close distance between a RFID tag to a reader reducing the efficiency of RFID-based gates due to additional actions by car drivers in doing ticketing procedures. The tapping action particularly produces an added holding time for each queuing car at the highway gate. To reduce the holding time, therefore, RFID systems with a wider reading range is urgently required.

To produce a good performance of long-distance RFID system, a properly configured antenna is required for applications at specific highway gates. Practically, the antenna must effectively perform and work at ultra high frequency (UHF) to transmit within a greater range. According to ITU-R SM2255 the frequency of 915 MHz is preferred for RFID communication usages at highway gates [2] . This work proposed a microstrip antenna that works at 915 MHz frequency. Besides, a circular polarization was applied for RFID UHF due to its advantage in a controlled long-range reading [3] [4] . Then the proposed antenna will have an unidirectional radiation pattern covering a limited width of highway gate (2.9 meter) [5].

Furthermore, previous researches on UHF RFID antennas, [6] , [7] , had proposed different design of circular microstrip UHF antenna. In the work by Zhi Ning Chen, Xianming Qing, and Hang Leong Chung [6] , a proposed antenna was intentionally designed to work at UHF 818 - 964 MHz bands using the truncate method to obtain the CP antenna. On the other hand, Xi Chen, Guang Fu, Ya-Li Yan, and Wei Zhao [7] applied the slot method throughout ring antenna body and parasitic additions to increase its bandwidth and gain. Besides, the research [7] proposed a suitable radiation pattern for RFID application at 915 MHz.

2. Antenna Design

2.1 System Model

As the first assumption, the antenna being designed is to be placed at the 5.1 m standard-height ceiling of highway gate [5] . Besides, the perpendicular distance between the antenna and a passing car is as far as 2 m in between a gate lane. In other words, the antenna must have a minimum transmission radius of 7.14 m. On the other hand, RFID tags are assumed to be installed on the dashboard of every passing car. Fig. 1 provides the description of antenna placement.

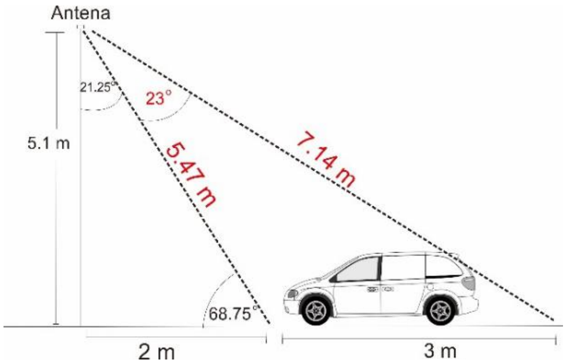

Figure. 1. Antenna Model

Based on above-mentioned system model, the antenna being designed should have a required half power beam width (HPBW) angle of 23° to cover the width of one gate lane.

Looking at assumption and placement model, table 1 provides the technical requirement of the toll gate antenna.

Table 1. Technical Requirements Antenna

Frequency	915 MHz
Beam width	23°
Polarization	Circular

2.2 *Patch Design*

The patch antenna was intentionally formed as a square and the substrate used was FR4 with a relative permitivity, (ε_r) of 4.6. The dimension of patch antenna is calculated by using Equation (1) [4].

$$L = 0.49\frac{\lambda}{\sqrt{\varepsilon_r}} \quad (1)$$

To obtain a circular polarization, the patch antenna is modified by applying slot and truncated methods. These methods are intended to decrease the value of axial ratio (AR) to 0 dB < AR < 3 dB. Equations (2) and (3) are used to get the slot dimension, while the slot angle is determined to get the minimum AR. Furthermore, truncated value is obtained by conducting an optimization in the end of design process. Fig. 2 provides the dimension of antenna patch [8].

$$\text{Slot length} = \frac{patch\ length}{2{,}72} \quad (2)$$

$$Slot\ Width = \frac{slot\ length}{10} \quad (3)$$

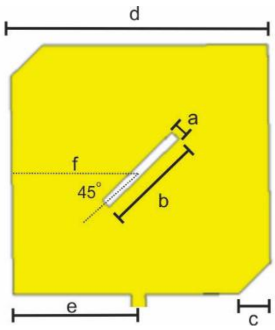

Figure. 2. Patch Design

a = 2,78 mm	d = 71,8 mm
b = 27,87 mm	e = (d/2) + 1 = 36,9 mm
c = 8,97 mm	f = d/2 = 35,9 mm

2.3 *Array Design*

Next, array method is applied to obtain narrow beam width of the microstrip antenna. In this case, the antenna beam width is set at 23°. Four patch elements are arranged as a microstrip antenna array with λ/4 transformer as a feeding network or power divider. The dimension of λ/4 transformer is obtained by using Equations (4), (5), and (6). Fig. 4 provides data of the microstrip antenna array [9]

$$Z_1 = \sqrt{R_{in}\, Z_0} \quad (4)$$

$$R_{in} = \frac{1}{2G_e} \quad (5)$$

$$G_e = 0{,}00836\ \frac{w}{\lambda} \quad (6)$$

Besides, Equations (7), and (8) are applied to determine the width of the feed path [10]

$$\text{Wf} = \frac{2h}{\pi}\left\{B - 1 - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln(B-1) + 0{,}39 - \frac{0{,}61}{\varepsilon_r}\right]\right\} \quad (7)$$

$$B = \frac{60\,\pi^2}{Z_0\sqrt{\varepsilon_r}} \quad (8)$$

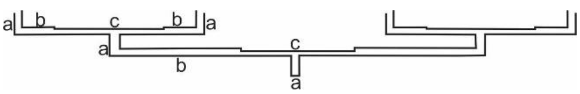

Figure. 3. Feeding Network Design

Then, calculation results of feeding network calculation are provided in Fig. 3. Having three different impedance (value a, b, and c), these impedances are expected to produce a matching impedance of 50 Ω, which is required in reducing power attenuation when power is transferred to the antenna. Table 2 provides the value of each impedance.

Table.2. Dimension of Feeding Network

Variable	Impedance (Ω)	Line Width (mm)
a	50	5,5
b	76,4	3,6
c	116,83	2,4

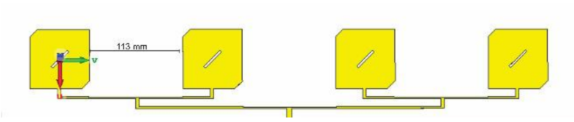

Figure. 4. Design of Antenna Array

3. Result and Analysis

3.1 VSWR

Fig. 5 sums VSWR results of the antenna. Looking at these measurement results, the print antenna parameters shift towards higher values, which should perform the best at -16 dB based on the simulation at 915 MHz. In fact, applying 935 MHz frequency in the printed antenna parameters, produces a 20 MHz larger shift.

After being analyzed using an antenna simulation software, parameter shifts occur due to differences in printed antenna material and simulation. Particularly, Fig. 6 provides the results of a simulation applying FR4 (ε_r) at 4.4

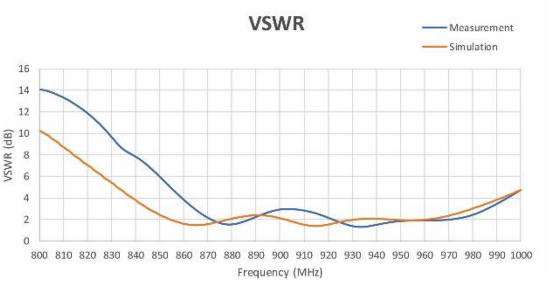

Figure 5. VSWR Result

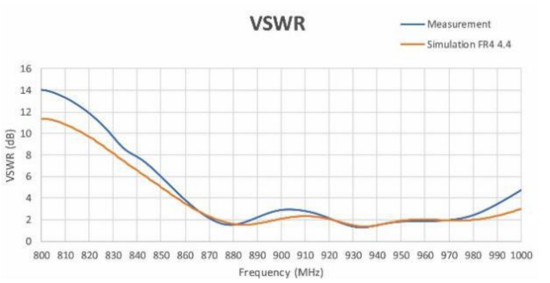

Figure 6. VSWR εr 4.4

3.2 Radiation Pattern

Fig. 7 and 8 show radiation patterns of the antenna, by which resulting beam width appears to not precisely performing at 23°. Meanwhile, there are differences in the values between simulation results and actual performances of the antenna.

In fact, these differences occur due to different antenna materials applied for simulation and during field trials. Besides, differences may occur due to the setting during trials, including imperfect resonance conditions in which there is a non-resistive impedance.

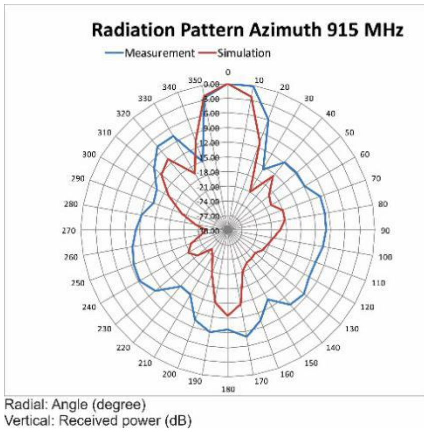

Figure 7. Radiation Pattern Azimuth

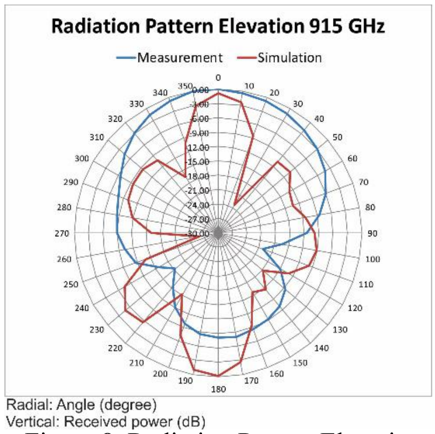

Figure 8. Radiation Pattern Elevation

Table 2. HPBW Result

	Azimuth		Elevation	
	HPBW Range	Angle Value	HPBW Range	Angle Value
Simulation	350°-10°	20°	350°-12°	22°
Measurement	350°-15°	25°	320°-50°	90°

Looking at all results, the actual antenna must be placed azimuthally to set the HPBW antenna radiation on the width of one gate lane with no radiation to other lanes.

3.3 Polarization

Fig. 9 shows polarization results of the antenna.

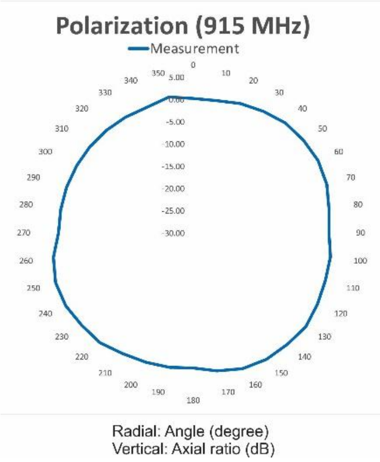

Figure 9. Polarization Result

Looking at the results, the average axial ratio of the printed antenna appears at 1.39 dB. Besides, antenna with an axial ratio <3 dB perform a circular polarization [8] , hence fulfilling required circular polarization parameter. The CP antenna would ensure a seamless reading process when RFID tags rotate in various phi (ϕ) angles. In fact, no power attenuation occurs when power from a tag is received.

3.4 Gain

On the other hand, antenna gain is achieved at 1.77 dB. The gain is 0.41 dB smaller than the result of antenna simulation at 2.18 dB. Practically, the gain achieved will affect the calculation of planned link budget. As a result, power required by a transmitter to obtain a minimum receiving power of -96.96 dBm is at -41.68 dBm [11] . Improvement needed to increase antenna efficiency which is cause achieved low antenna gain.

4. Conclusions

Looking at all simulation and field results, the antenna being design is stated as being applicable but not optimal yet. Intentionally, the antenna beam width includes the width of one highway gate lane to prevent undesirable reading of RFID tags in other lanes. Besides, the antenna is designed to have a circular polarization, hence any potential tilting of RFID tags on car dashboard will not affect reading performances.

Practically, under-optimum parameter occurs in terms of inner parameter antenna due to an incompatibility between simulation and actual materials, making the antenna VSWR to shift inappropriately at 915 MHz working frequency. It will then produce a reduced power transferred from the transmitter to the antenna. The resulting gain is revealed at 1.77 dB which is not the expected value. It makes the link budget calculation, especially the transmitting power to be greater than planned. Improvement needed to increase the antenna efficiency

Acknowledgment

This work was financially supported by the Telkom University, Indonesia.

Reference

[1] Korlantas Polri, "Perkembangan Jumlah Kendaraan Bermotor Menurut Jenis," Traffic Corps Indonesian National Police, Indonesia, 2015.

[2] ITU-R, "ITU-R SM 2255-0," ITU-R, Switzerland, 2012.

[3] J. Uddin, M. B. I. Reaz, M. A. Hasan, A. N. Nordin, M. I. Ibrahimy and M. A. M. Ali, "UHF RFID Antenna Architectures and Aplication," p. 7, 2010.

[4] W. L. Stutzman and G. A. Thiele, "Antenna Theory and Design," Hoboken, Wiley, 2013, pp. 466 - 478.

[5] Departemen Pekerjaan Umum Direktorat Jenderal Bina Marga, "Standar Kontruksi dan Bangunan," in *Geometri Jalan Bebas Hambatan Untuk Jalan Tol*, Indonesia, Departemen Pekerjaan Umum Direktorat Jenderal Bina Marga, 2009, p. 74.

[6] Z. N. Chen , X. Qing and H. L. Chung, "A Universal UHF RFID Antenna," p. 1, 2009.

[7] X. Chen, G. Fu, S.-X. Gong, Y.-L. Yan and W. Zhao, "Ciculary Polaryzed Stacked Annular Ring Microstrip Antenna With Integrated Feeding Network For UHF RFID Reader," vol. 9, pp. 1-4, 2010.

[8] C. A. Balanis, "Antenna," in *Antenna Theory Analysis And Design*, Canada, Wiley, 1997, pp. 772-775.

[9] A. Hashim, 2007. [Online]. Available: dspace.unimap.edu.my/dspace/bitstream/123456789/2860/4/Methodology.pdf. [Accessed 29 Januari 2019].

[10] K. J. A.S., L. O. Nur and B. Syihabuddin, "Perancangan Antena Array 1x2 Rectangular Patch Dengan U-Slot Untuk Aplikasi 5G," p. 3, 2017.

[11] DIMULTI, "Aplicable Standard for RFID Indonesia," Kepdirjen, Indonesia, 2014.

Muhamad Abdul Rahman Suyudi, S.T. was born on 8 January 1996. He studied telecommunication engineering at SMKN 1 (State Technical High School 1) in Cimahi, Indonesia majoring in transmission engineering. He pursued a Bachelor in Telecommunication Engineering at Telkom University, Indonesia, and graduated in 2019 with a final project on transmission design. During 2017-2018 he worked as an Assistant in the Laboratory of Electrical Circuit Telkom University.

Dr. Bambang Setia Nugroho, S.T., M.T. obtained a bachelor's degree in 1999 and master's degree in 2004, both of which were from the Bandung Institute of Technology (institute Teknologi Bandung – ITB), Indonesia. In 2015, he obtained a PhD in Electrical Engineering from the University of Indonesia. Currently, he works as a lecturer in the School of Electrical Engineering, Telkom University, Indonesia, in which he serves as the Head of Antenna Laboratory. His research interest includes microwave technology, antenna engineering, electromagnetics, by which he has been publishing journal articles in various international proceedings and national journals. Besides, he is an active reviewer at international telecommunication conferences

Edwar, S.T., M.T. obtained a bachelor's degree from Telkom University, and a master's degree from ITB, Indonesia. Currently, he is a lecturer at the School of Electrical Engineering, Telkom University, Indonesia, in which he serves as the Head of Telecommunication Electronics Laboratory. Besides, he is a member of Nanosatellite Laboratory in the university. His research interests include nanosatellite subsystem, payloads, RF devices, and their applications especially in remote sensing. He has been actively publishing in various international proceedings and national journals.

.