Dipole Antenna Design With CPS Matching For RFID Application

Bayu Kumoro* and Yulisdin Mukhlis
Electrical Engineering of Technology Industry, Gunadarma University, Jl.Margonda
Raya no. 100 Depok, Indonesia

bayuyakti@student.gunadarma.ac.id

Abstract. Antenna is a media transition between the free space transmission lines that is used
to drive the electromagnetic energy from the source transmitter to the antenna or from the
antenna to the receiver. This study aims to simulate a dipole antenna matching RFID chip
ALN-9338-R by using Matlab 2015b. Matlab is used to find impedance and radiation pattern
of the antenna. The research method is done by designing antenna using PDEtoolbox in Matlab
program, followed by the antenna design is exported to the antenna impedance toolbox for the
results obtained. Antenna matching values obtained 76.5%, backscatter efficient distance of
less than 30 cm. simple dipole antenna can meet the standards of the RFID system.

Keywords: RFID, antenna, CPS, impedansi, PDE tool, radiation pattern

1. Introduction
The Radio Frequency Identification (RFID) system of Ultra High Frequency (UHF) bands from 860
MHz to 960 MHz has increase into the use in industrial automation, business automation,
transportation control management and other fields.1

The advantage of RFID is that it does not require direct contact or line-of-sight scanning. An RFID
system consists of three components: an antenna and transceiver (often combined into one reader) and
a transponder (the tag). The tag antenna is the key factor which determines the read range of the RFID
system.

When activated, the tag transmits data back to the antenna. The data is used to notify a
programmable logic controller that an action should occur. The action could be as simple as raising an
access gate or as complicated as interfacing with a database to carry out a monetary transaction. Low-
frequency RFID systems (30 KHz to 500 KHz) have short transmission ranges (generally less than six
feet).

High-frequency RFID systems (850 MHz to 950 MHz and 2.4 GHz to 2.5 GHz) offer longer
transmission ranges (more than 27 meters). In general, the higher the frequency, the more expensive
the system.8

Therefore, the simulation should be done in advance of the practice. There are a few things why
simulation is important such as: cost of experiment might be too high, experimental behavior might be
obscured by disturbances, reduce risk, retain/improve your talent pool, minimize spending, optimize
use of what you have.1 Parameters are very important when making the antenna. Here are some of the
most important parameters on an antenna. Directivity gain is an antenna parameter that measures an
antenna's capability or how efficiently an antenna is in directing signal radiation and receiving signals
from a particular direction. Radiation pattern is closely related to the power of the antenna in
transmitting radio waves or receiving radio waves at different angles.

Directivity is the ratio between the denticity of power held by the antenna at a certain point
distance relative to an isotropic radiator.
Polarization is the direction of propagation of the electric field or in other words the electric field vector deployment.

This study conducted an analysis of the dipole antennas with the RFID chip using ALN-9338-R with the chip impedance 6.2-j127 / 915MHz. This research will be done using Matlab 2015b (PDETtool and Antenna Toolbox). The aim is to measure the impedance matching at the antenna RFID.

2. Literature Review

A. Impedance Matching

Assume an equivalent lumped circuit RFID tag shown in Figure 1, where $Z_c = R_c + jX_c$ is the impedance Chip and $Z_a = R_a + jX_a$ is the impedance of the antenna. The voltage source is the open circuit voltage developed at terminal RF receiver antenna. Chip impedance includes the effects of package parasitic. Both $Z_a$ and $Z_c$ are depending on the number of frequencies. In addition, the chip impedance $Z_c$ may vary with the power absorbed by the chip. Antenna will usually match the chip level power minimum threshold so that the chips can respond.\(^3\)

![Figure 1. RFID transponder](image)

The amount of power that can be absorbed by the $P_c$ of the chip antenna is given by:

$$P_c = P_a \tau.$$  \hfill (1)

Where $P_a$ is the maximum power that can be generated antenna and $\tau$ is the transmission power coefficient. $P_a$ is the power that can be irregular in chips when $Z_c = Z_a$. $\tau$ is the transmission power formula:

$$\tau = \frac{4R_cR_a}{|Z_c + Z_a|^2}$$  \hfill (2)

Impedance match between the antenna and the chip is the point where $\tau = 1$.

B. Backscattering

Backscattering is a reflection of a wave, a particle or a signal back from the direction in which the waves, particles or the signal is coming from. Figure 2 illustrates the backscattering on RFID.

![Figure 2. Passive RFID use backscattering](image)
Most RFID tag consists of a chip and an antenna. Chip obtains energy from the RF signal transmitted from the RFID reader. RFID tag on the run with a chip that the impedance changes between the two conditions, usually between high and low. RFID tags in paths Radar Cross Section (RCS). RFID tags send information back using backscattering modulation.  

RFID tag RCS can be formulated into:

\[ \sigma = \frac{\lambda^2 G^2 R_a^2}{\pi (Z_a + Z_c)^2} \]  
(3)

Where \( \sigma \) is the RCS, \( \lambda \) is the wavelength, \( G \) is Gain antenna, \( R_a \) is the real value of the antenna impedance, \( Z_a \) is the impedance of the antenna and chip impedance \( Z_c \). Energy backscatter of the tag can be formulated as follows:

\[ P_{\text{backscattered}} = \frac{P_t G_t^2 \lambda^2 \sigma}{(4\pi)^3 r^4} \]  
(4)

Where \( G_t \) is the gain of the antenna, \( P_t \) is the energy from the transmitter. Where \( r \) is the distance to the tag. Return loss is measured after getting power backscatter can be formulated into:

\[ |S_{11}|^2 \approx \frac{P_{\text{backscattered}}}{P_t} = \frac{G_t^2 \lambda^2 \sigma}{(4\pi)^3 r^4} \]  
(5)

C. Path Loss

Depending on the wireless communication system, some of these characteristics allow a more important factor in the design of RFID systems. Thus, the operation of passive UHF RFID systems are based on the modulation of the reflected wave or backscatter of the RF reader, which is different from traditional wireless modulation system, comprising transceiver is active on both sides of the link.  

Passive transponder consists of two parts: the antenna and application-specific integrated circuit (ASIC). All the energy needed to be generated from the chip antenna RF signals. The information required for the identification of objects that carry transponders already written on the chip. Therefore, the modulated RF signal emitted from the reader antenna reached the transponder antenna. Most of this energy is used for transponder operation by changing the input impedance, depending on the modulation information contained in ASIC chip. In return link from the transponder to the reader, incoming RF signals backscattered from the transponder and the little power that goes back to the reader antenna. ASIC changing RF impedance and controlling the amount of area that bounces. In this case, the spread modulation contains identifying information. Transponder is identified as an area that is reflected is received and decoded in the reader unit. Antenna plays an important role in communication systems. Thus, there should be noted for their design.

Here is an example of a chip that can be used:

| Table 1. Input impedance of various ASIC chips |
|---------------------------------------------|
| Chip   | Impedance (Ω)          | Manufacturers |
|--------|------------------------|---------------|
| MM9647 | 73-j113/915 MHz        | NSC           |
| ALL-9238 | 20-j127/900 MHz | Alien Technology |
| ALN-9338-R | 6.2-j127/915 MHz | Alien Technology |
| EPC1.19G2 | 16-j315/914 MHz | Philips |

Dipole with coplanar strip (CPS) analyzed by observing variations in input impedance with physical dimensions, especially of this dipole arm length and line length CPS. The analysis was done using Matlab.
D. Radiation Pattern

In the field of antenna design the term radiation pattern (or antenna pattern or far-field pattern) refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source. A bare dipole is not considered a directional antenna. However like all antennas, its radiation is not uniform in all directions. Its radiation pattern in three dimensions is shaped like a toroid (doughnut) symmetric about the axis of the dipole. The radiation is maximum at right angles to the dipole, dropping off to zero on the antenna's axis. Therefore, a dipole mounted vertically will be omnidirectional in the horizontal plane, with a modest gain, at the expense of radiation in the vertical direction.

![Figure 3](image3.png)

**Figure 3.** Three dimensional radiation pattern of a vertical half-wave dipole antenna.

3. Dipole Antenna Design with CPS Matching

In the transponder antenna there are two antenna parameters that must be considered, i.e. the radiation pattern and input impedance. The radiation pattern must be omnidirectional or hemispherical antenna. Dipole antenna to qualify, the dipole antenna has omnidirectional radiation pattern. In addition, the dipole antenna has a simple structure that is easy to design. Antenna impedance must match the input impedance of the chip so that energy is transmitted from the antenna to the chip can be transmitted efficiently. In the RFID tag, but used for data transmission, the transmitted energy reader as well as a power supply used by the tag.

![Figure 4](image4.png)

**Figure 4.** System-transponder-reader link on passive UHF RFID reader

Input impedance at Chip consists of real numbers and capacitive imaginary. In this simulation, the dipole antenna is designed with additional matching CPS, CPS aims to earn a high inductive impedance antenna. Antenna impedance can be changed and adjusted as needed by changing the size of the dimensions of each part of the antenna, namely L, Ld, Ls, Lp, Wd, h, and g.

![Figure 5](image5.png)

**Figure 5.** Layout dipole antenna with CPS Matching
This simulation was performed using software Matlab 2015b, which is done by designing antenna using PDETool on PDE Toolbox contained in Matlab 2015b.

![Design dipole dipole on PDEtool](image)

**Figure 6.** Design dipole dipole on PDEtool

Then the results are exported to Antenna designing Toolbox. It aims to analyze the results of designing Using Antenna function contained in the toolbox. Radiation pattern can be obtained, impedance of the antenna has been designed.

![Mesh antenna](image)

**Figure 7.** Mesh antenna

4. Experimental Result

Antenna is designed for ASIC Chip ALN-9338-R with impedance input $Z_c = 6.2 + j127$ at a frequency of 915 MHz. From the experimental results, obtained dimensions of the antenna $L_d = 45$ mm, $W_d = 8$ mm, $L = 15$ mm, $L_s = 30$ mm, $h = 1.5$ mm, $L_p = 12$ mm. The width of the feed line 0.5 mm

![Dipole antenna RFID Tag](image)

**Figure 8.** Dipole antenna RFID Tag

Having obtained the antenna design and exported to the antenna toolbox obtained antenna impedance is $Z_a = 5.7053 + j133.4$. Then
\[\tau = \frac{4R_c R_a}{|Z_c + Z_a|^2} = \frac{4 \times 6.2 \times 5.7055}{|(6.2 - j127) + (5.7055 + j133.4)|^2} = 0.765\]

Efficient coefficient is 0.765. This means that the amount of energy that can be accepted by the chip by the antenna that is equal to 76.5% of energy is transmitted from the antenna. While radiation pattern of the antenna has been designed is shown in Figure 4.

\[P_c = P_a \tau\]

\[P_c = 76.5\% P_a\]

![Figure 9. radiation pattern of the antenna](image)

If done counting Power scattering using equation (3) and (4) the antenna impedance and the gain derived from the simulation results. Where in the reader, it is assumed using TH72035 transmitter (3.3V) at a frequency of 915 MHz with power output by 9 dB antenna (Pt.Gt2) and use the UHF ASK receiver which has a sensitivity of -35dB. The obtained results the following calculation:

| No | r(m) | \(\sigma\) | \(P_{\text{Scattering}}\) (dBm) |
|----|------|------|-----------------|
| 1  | 0.03 | \(1.285 \times 10^{-3}\) | 8.026628 |
| 2  | 0.05 | \(1.285 \times 10^{-3}\) | -0.84732 |
| 3  | 0.08 | \(1.285 \times 10^{-3}\) | -9.01212 |
| 4  | 0.1  | \(1.285 \times 10^{-3}\) | -12.8885 |
| 5  | 0.2  | \(1.285 \times 10^{-3}\) | -24.9297 |
| 6  | 0.3  | \(1.285 \times 10^{-3}\) | -31.9734 |
| 7  | 0.5  | \(1.285 \times 10^{-3}\) | -40.8473 |
| 8  | 0.6  | \(1.285 \times 10^{-3}\) | -44.0146 |
| 9  | 0.8  | \(1.285 \times 10^{-3}\) | -49.0121 |
| 10 | 1    | \(1.285 \times 10^{-3}\) | -52.8885 |

5. Conclusion
After simulated, it can be concluded that the antenna with a simple design can meet the standards of the RFID system. By doing MATLAB simulation results can be achieved coefficient of efficiency of 76.5%, which means the amount of energy that can be accepted by the chip antenna not cause much loss of energy. Efficient distance of less than 30 cm, because if it is more than 30 cm smaller than the scattering power reader sensitivity (-35 dBm).
References
[1] K. Jaakkola, “Small on-metal uhf rfid transponder with long read range,” IEEE Transactions on Antennas and Propagation (2016).
[2] Nenad Popovic. UHF RFID Antenna: Printed Dipole Antenna with a CPS Matching Circuit and Inductively Coupled Feed (2011)
[3] Marrocco, G. “The Art of UHF RFID Antenna Design Impedance-Matching and Size-Reduction Techniques”, IEEE Antennas and Propagation (2008)
[4] Imranullah Khan. Performance Analysis of Various Path Loss Models for Wireless Network in Different Environments (2008)
[5] A. T. Kolsrud. Frequency tunable CPW-fed CPS dipole antenna using varactors (1998).
[6] Constantine A. Balanis: “Antenna Theory, Analysis and Design”, John Wiley & Sons, Inc., 2nd ed. (1982)
[7] Pavel V. Nikitin. Measurement Of Backscattering From RFID Tags. Intermec Technologies Corporation (2005)
[8] Pavel V. Nikitin. Simple low cost UHF RFID reader. IEEE international conference (2013)