

DUAL BAND ANTENNA FOR RADIO FREQUENCY IDENTIFICATION  
APPLICATIONS

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To my beloved mother, **HAJJAH SABIAH AB RAHMAN**  
and father, **HAJI SABRAN REMALI**

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## ABSTRACT

Radio Frequency Identification (RFID) has the highest growth of applications system and is the most interesting field of research in communication technology. RFID systems have been implemented in various applications such as Electronic Toll Collection (ETC) and monitoring systems for railway stations. One of the ETC applications is the *Touch & GO* system that uses the Short Range RFID (SRRFID) technology. This technology benefits users as they are able to pay their toll automatically by passing through the toll gate without queuing for a long time. On the other hand, the monitoring system for railway stations uses the Long Range RFID (LRRFID) technology. Railway employees use this technology to monitor locations and automatically control the speed of trains from the railway station. Applications of LRRFID technology are meant for high-end users thus this technology has a higher marketability value as compared to SRRFID. Generally, LRRFID uses: (i) Ultra High Frequency (UHF) band and (ii) Industrial, Scientific and Medical (ISM) band. Both these bands can be applied using a single RFID multipurpose application reader. For this application, a multiband antenna is needed to fulfill the dual application. The aim of this research project is to develop a dual band antenna design operating the UHF and ISM bands having linear and circular polarization capabilities. A square patch antenna is selected as the basic design and modifications on the radiating patch were conducted using Computer System Technology (CST). The simulation from the CST resulted in development of dual band diamond shaped linear polarized antenna. The newly developed antenna has good return loss for frequencies in both bands. To enhance the quality of propagation of this antenna, a pair of slots was introduced to the radiating patch which transformed the proposed antenna to become a circular polarization antenna. Both antennas had air gap introduced between dielectric substrate layer and ground plane to boost the gain and efficiency of the antennas. The developed antennas have good gains, approximately 7~9 dBi and antenna efficiency is about 85~95%.

## ABSTRAK

Pengenalan Frekuensi Radio (RFID) mempunyai pertumbuhan yang paling pesat dalam pelbagai sistem aplikasi dan merupakan bidang penyelidikan dalam teknologi komunikasi yang menarik. Sistem RFID boleh dilaksanakan dalam pelbagai aplikasi seperti sistem Kutipan Tol Elektronik (ETC) dan sistem pemantauan di stesen keretapi. Salah satu daripada sistem ETC adalah sistem *Touch & GO* yang menggunakan teknologi komunikasi jarak dekat RFID (SRRFID). Teknologi ini memberi faedah kepada pengguna jalan raya untuk menjelaskan bayaran tol secara automatik tanpa perlu beratur untuk tempoh masa yang lama. Selain itu, contoh lain untuk teknologi RFID ialah sistem pemantauan di stesen keretapi menggunakan komunikasi jarak jauh RFID (LRRFID). Pekerja keretapi menggunakan teknologi ini untuk memantau lokasi dan mengawal kelajuan secara automatik dari stesen keretapi. Sistem LRRFID merupakan teknologi kompleks untuk pengguna sasaran dan mempunyai nilai komersial yang lebih baik jika dibandingkan dengan sistem SRRFID. Secara umumnya, teknologi LRRFID menggunakan; (i) jalur Frekuensi Ultra Tinggi (UHF) dan (ii) jalur Perindustrian, Sains dan Perubatan (ISM). Kedua-dua jalur ini boleh digunapakai dalam satu pembias RFID pelbagai aplikasi. Antena pelbagai jalur diperlukan bagi memenuhi kehendak kedua-dua aplikasi. Matlamat utama kajian penyelidikan ini adalah membangunkan reka bentuk antena dua jalur dengan keupayaan polarisasi linear dan bulat yang beroperasi pada jalur UHF dan ISM. Antena tampalan segi empat sama dipilih sebagai reka bentuk asas dan pengubahsuaian pada unsur tampalan telah dijalankan menggunakan perisian "*Computer System Technology*" (CST). Simulasi daripada CST menghasilkan antena dua jalur linear polarisasi berbentuk berlian. Antena yang dibangunkan mempunyai refleksi rugi yang baik bagi kedua-dua jalur. Untuk meningkatkan kualiti perambatan antena, sepasang slot diperkenalkan pada unsur tampalan untuk mengubah antena yang dibangunkan itu menjadi antena polarisasi bulat. Kedua-dua antena mempunyai sela udara antara lapisan substrat dan sata bumi bagi meningkatkan gandaan dan kecekapan antena. Ia juga mempunyai gandaan yang baik, kira-kira 7~9dBi dan kecekapan antena kira-kira 85~95%.

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**LIST OF ABBREVIATIONS**

AR	-	Axial Ratio
BW	-	Bandwidth
CP	-	Circular Polarization
CST	-	Computer Simulation Technology
DCS	-	Digital Communication System
dB	-	Decibel
EIRP	-	Equivalent Isotropic Radiated Power
EM	-	Electromagnetic
ETC	-	Electronic Toll Collection
EU	-	European United
FCC	-	Federal Communication Consumer
FR4	-	Flame Resistant 4
GSM	-	Global System Mobile
GPS	-	Global Position System
LHCP	-	Left Hand Circular Polarization
LRRFID	-	Long Range RFID

LP	-	Linear Polarization
MCMC	-	Malaysia Communication and Multimedia Commission
ISM	-	Industrial Sciences Medical
SRRFID	-	Short Range RFID
ITS	-	Intelligent Transportation Systems
MPA	-	Microstrip Patch Antenna
PCB	-	Printed Circuit Board
PLUS	-	Project Lebuhraya Utara Selatan
RF	-	Radio Frequency
RFID	-	Radio Frequency Identification
RHCP	-	Right Hand Circular Polarization
RL	-	Return Loss
SDMB	-	Satellite Digital Multimedia Broadcasting
SMA	-	Sub Miniature version A
TEM	-	Transverse Electromagnetic
UHF	-	Ultra High Frequency
UV	-	Ultra Violet
VSWR	-	Voltage Standing Wave Ratio

**LIST OF SYMBOLS**

$\%BW$	-	Bandwidth Percentage
$c$	-	Speed of light
$D$	-	Outer Probe feed diameter
$d$	-	Inner probe feed diameter
$\epsilon_r$	-	permittivity
$\epsilon_e$	-	Effective permittivity
$e_0$	-	Total efficiency
$e_r$	-	Reflection (mismatch)
$e_c$	-	Conduction efficiency
$e_d$	-	Dielectric efficiency
$\lambda_0$	-	Free Space wavelength
$f_c$	-	Center frequency
$f_H$	-	High frequency
$f_L$	-	Low frequency
$h$	-	Height of substrate
$L$	-	Length of patch
$L_{eff}$	-	Effective length
$\Delta L$	-	Delta Length

$Q$	-	Material's quality factor
$S$	-	Area of patch
$\Delta S$	-	Delta area of patch
$\Gamma$	-	Reflection coefficient
$t$	-	Thin Metallic Strip
$V_o^-$	-	Reflected voltage
$V_o^+$	-	Incident voltage
$W$	-	Width of patch
$W_{\text{eff}}$	-	Effective width
$Z_L$	-	Load impedance
$\leq$	-	Less than
$Z_0$	-	Characteristic impedance
$\Omega$	-	Ohm

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Introduction

RFID technology has undergone a rapid growth since decades ago. RFID technology is well known and extensively applied in many home and industry appliances such as for logistic distribution, manufacturing process, security and monitoring purposes [1]. In Malaysia, RFID technology is applied in the Intelligent Transportation Systems (ITS) for a safer, effective, efficient, reliable, and environmentally friendly system [2]. Electronic Toll Collection (ETC) is one of the ITS application. The users do not need to line up and waiting to pay their toll payment when they used “*Touch N Go*” system. ETC is developed by the Malaysia Government to reduce traffic congestion at toll booths in highways all around Malaysia. Therefore, this Short Range RFID (SRRFID) technology is an excellent example of how this communication technology can ease human daily life.

Otherwise, RFID technology also can be implemented for the Long Range RFID (LRRFID) application. It can be applied for the monitoring system for the railway station such as information of train location, passengers, cross-road detection and automatic speed control. It also used to ensure automatic observation of driving instructions by tracking the trains and enforcing speed control.

From these two simple examples, there are differences between SRRFID and LRRFID technology in term of operating frequencies, distance, and external power source. Therefore, fundamental of RFID technology need to be understood clearly before applying it to the real scenario.

There are several aspects that should be taken into consideration before applying RFID technology. RFID technology uses electromagnetic (EM) propagation for data transmission. EM will propagate across the various space of environment, where's affect the communication between the reader and tags in term of range and performance. So, types of RFID should be clearly understood to ensure the performance of RFID technology when applied to the real scenario. Types of tag are referred to the existence of external power source for transponder. RFID technology can be consists of three division, namely; active system, passive system and semi passive system as shown in Table 1.1. In [3], it is clarified that passive tags is cheaper compare to the active and semi-active tags where it does not have power source.

**Table 1.1** Comparisons of Different Tags [3]

	Active	Passive	Semi-Passive
Power Source	Battery	Induction from EM wave emitted by a reader	Battery and Induction
Functional distance	Up to 30 meters	3-7 meters	Up to 30 meters
Cost	Expensive	Cheap	Expensive

Besides, operating frequencies to activate RFID technologies are crucial before it is applied to the system. As mentioned earlier, RFID technology uses EM wave to transmit the data between reader and tags. It operates on frequencies and power allocated by following the RFID standard regulation managed by the Federal Communication Consumer (FCC). There are different standards between the European Union (EU) and United State (US). Table 1.2 shows the details of RFID standard frequency regulation form FCC [4] and each country needs to follow the standard in order to avoid the interference frequencies. According to the Standard Radio System plan reported in [5] by the Malaysia Communications and Multimedia

Commission (MCMC), requirement from RFID device in Malaysia is operated in the frequency band from 919 MHz to 923 MHz.

**Table 1.2** RFID standard frequencies allocation [4]

Frequency	Country				Note
	EU		US		
	F <sub>c</sub>	BW	F <sub>c</sub>	BW	
Low Frequencies	125 kHz	-	125 kHz	-	Not in FCC planning
	13.56 MHz	-	13.56 MHz	-	Allocation unification
Lower UHF Band	440 MHz	40 MHz	888.5 MHz	1 MHz	-
	-	-	915 MHz	26 MHz	-
ISM Band	2.45 GHz		2.45 GHz		-
	5.8 GHz	150 MHz	5.8 GHz	150 MHz	-

Therefore, it is very importance for each developer or researcher to understand clearly about RFID standard regulation in term of power allowance and frequencies before apply the system to the real application.

Normally, RFID technology consists of two components; reader and tags or transponder. It has own unique identity and it will be attached to the object to be identified and programmed by a unique number. Electromagnetic EM from the tags will be broadcasted when read by the RFID reader [4]. Reader will boost the electromagnetic wave to energize the transponder using the specified frequency and read the tag identification. Connections between reader and transponder are established via electromagnetic EM field produced by the front-end component. This signifies the importance of antenna in RFID system.



Since antenna is one important component for RFID technology, it needs to be designed careful to ensure it can improve the performance system. There are varieties of antenna design in RFID technologies. Ordinarily, dipole antenna is used for RFID tags antenna. Dipole antenna has an Omni-directional pattern where it can be read by the reader in all direction. It requires to be designed with wideband to satisfy frequency agility tuned in reader. Moreover, characteristic such as circular polarization, get affected when attached to the object and sensitivity need to be consider when designing the tag antenna [4].

Similar with the antenna tags, RFID antenna reader need some consideration before designing the antenna. The most importance characteristics are antenna pattern where it relates to the application system either directive or omni-directional. Difference between directive and omni-directional antenna pattern looks very obvious in term of antenna size and types. As we know, dipole and monopoles antenna type have omni-directional pattern while patch antenna type has directive radiation pattern. Comparison between dipole and patch antenna is shown in Figure 1.1. It shows that dipole antenna has small in size compare to the patch antenna. Selection of antenna design for RFID reader is important to ensure the systems be able to work base on the application successfully.



Figure 1.1: Comparison between patch and monopole antenna

Thus, as the front-end of RFID technology, antenna is crucial factor in ensuring the RFID technology performance. Author is interested in designing the antenna for reader because it can increase the performance of the RFID system by little modification on antenna design. Some consideration should be taken before

making the design such as high gain, portable or fixed-point to ensure it is suitable for RFID system. Besides that, there are many invention of multiband RFID reader for multipurpose application. Combination between UHF and ISM band in single RFID reader was done for multi application system since ISM band also can be used for WLAN application. Therefore, Multiband antenna design is needed to fulfill this requirement.

## **1.2 Problem Statement**

In recent years, there are various antenna types used in RFID reader for different purposes whether in long or short range application. Plenty of antenna reader has only one specific frequency band, capable of supporting single frequency RFID reader only. A small number of multiband frequencies in single RFID readers have been invented to fulfill multi application system. This is where multiband antenna for RFID reader is required, since it can cater for varieties of different frequencies. Antenna needs to be designed properly to ensure electromagnetic EM propagation from reader to tags is able to communicate effectively. Usually, tags antenna can radiate in all direction, therefore it can be placed in any orientation when it is attached to the object. As a result, antenna reader is difficult to predict the electromagnetic signal from the tag antenna.

## **1.3 Objectives**

The main objective of the research is to design an antenna for RFID application with dual band capabilities. The project will involve antenna designing, fabrication process, and performances measurement in order to develop the optimum type of antenna for RFID usage. Specific objectives of the research project are:

- (i) To design, simulate, fabricate and develop the dual-band antenna RFID reader at Ultra High Frequency (UHF) and Industrial Sciences Medical (ISM) band for uni-directional application.
- (ii) To design, fabricate, simulate, and develop the dual-band antenna for RFID reader with circular polarization capability.

#### **1.4 Scope of Works**

The research project begins with an extensive study on the basics of RFID technology; components, frequencies, tags types, and related applications. The scope of the RFID research fields will be narrowed down for purposed of developing Radio Frequency (RF) front-end reader antenna. But, there are some constraints in term of facilities to design, develop and measure the proposed antenna.

The antenna will be designed at UHF and ISM band for RFID reader. Since antenna is designed below 1 GHz, antenna size becomes bulky and huge. For that reason, the proposed antenna is suitable for fixed-point RFID antenna application. The proposed antenna is designed with directional radiation pattern where it is applicable for long ranges application.

Proposed antenna design will be simulated using the Computer Simulation Technology in Microwave Studio<sup>®</sup> 2010 and all the antenna performance will be discussed in term of return loss, current distribution, radiation pattern, and antenna efficiency. Then antenna will be fabricated and comparison between simulation and measurement will be discussed in term of return loss and normalize radiation pattern only.

## 1.5 Thesis Outline

The thesis is divided into six chapters. The thesis will be organized as follow:

A brief overview of RFID technologies has been discussed in chapter one. It consist the examples related to the Malaysia environment that applied to the Electronic Toll Collection (ETC). A basic fundamental of RFID, types of RFID tags, power allowance for RFID application and frequency regulation by the FCC is discussed in this chapter. Then, the author presents the problem statement with valid objectives to overcome that problem. But, there are some limitation on doing this research project is discussed on scope of this research project.

Chapter 2 describes the theoretical regarding the microstrip antenna, antenna properties, microwave properties and circular polarization antenna. Details explanation on circular polarization will be discussed in this chapter. Then, a lot of literature review from previous research related to dual band and circular polarization antenna will be discussed to ensure the proposed antenna has some contribution compare to other antenna design.

Chapter 3 will explains the methodology of the project. It starts with details explanation on the flow chart of the project consists the design consideration, simulation tools, fabrication and measurement process.

Chapter 4 provides the details discussion on antenna designs. It started with explanation of SMA connector design with  $50 \Omega$  impedance matching. Fundamental of microstrip patch antenna design also discussed in this chapter as a kick off of the antenna design. Then, modification on microstrip patch antenna is clarified to develop dual band antenna with novel structure. Finally, enhancement from the developed antenna become circular polarized antenna is elaborated.

Chapter 5 will explains the performance of the antennas design. There are two antenna design; dual band linear polarization antenna and dual band circular polarization antenna. It's consists the simulation process, resultant optimum value and a comparison between simulated and measured results for both antennas design.

All the simulation process and technique related to the design of the proposed antenna are presented clearly in this chapter. Simulation result will be compared with the measurement result to validate the simulation data.

Chapter 6 concludes this research project. Finally, research work in this thesis will be summarized in this chapter, followed by some comments on any futures work stemming from this project.

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