DEVELOPMENT OF COMPACT ANTENNA FOR RFID APPLICATION

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A project report submitted in partial fulfilment of the requirement for the award of the Degree of Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
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Sincerely dedicated to my beloved Mother and Father...
ACKNOWLEDGEMENT

Deep and humble gratitude to ALLAH Almighty for providing the opportunity and giving me the strength to complete this work.

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Most importantly I would like to thank my parents who have always been there for me for their support financially and for their endless encouragement and prayers, not to forget my sisters, my brothers, other family members and friends in Somalia and Malaysia for supporting me spiritually throughout this work and my life in general.

Finally honorable thanks to all my colleagues, lecturers and everyone involved directly and indirectly towards completion of this work especially Mr. Abdul Rashid Omar Mumin, faculty of Electrical and Electronic Engineering and all UTHM stuff.
ABSTRACT

In recent years, microstrip antennas have met commercial requirements. The advent of wireless applications requires a compact antenna, easy to manufacture. The goal of the project is to develop a microstrip monopole antenna for RFID tag applications that reduce size. The purpose of this antenna is to operate at 2.4 GHz. Due to its low-profile, a microstrip monopole antenna was chosen as a design model for the project. CST Microwave studio 2015 has been used to simulate the design of antennas for preliminary design purposes. This can be recognized as being unique to the advantages of the antenna. The proposed antenna was etched on an FR4 substrate with an overall size of 40 mm × 17 mm × 1.6 mm. The successful implementation of the modified ground plane allows the miniaturization and provides excellent performance. The performance of an antenna shows agreement between both simulation and measurement results.
ABSTRAK

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LIST OF SYMBOLS AND ABBREVIATIONS

\( c \) - Speed Of Light
\( D \) - Directivity
\( E \) - Efficiency
\( f \) - Operating Frequency
\( f_C \) - Centre Of Frequency
\( f_H \) - Upper Frequency
\( G \) - Gain
\( h \) - Substrate Thickness
\( L \) - Length
\( L_{\text{eff}} \) - Effective Length
\( R_{\text{in}} \) - Antenna Resistance
\( S_{11} \) - Return Loss Or Reflection Loss(Db)
\( X_{\text{in}} \) - Antenna Reactance
\( W \) - Width
\( Z_{\text{in}} \) - Input Impedance
\( Z_0 \) - Characteristics Impedance
\( \lambda \) - Free Space Wavelength
\( \varepsilon_r \) - Dielectric Constant
\( \Delta L \) - Extended Length Due To Fringing Field Effect
\( \Gamma \) - Reflection Coefficient
\( \text{dB} \) - Decibel
\( \text{HPBW} \) - Half Power Bandwidth
\( \text{PCB} \) - Printed Circuit Board
\( \text{RL} \) - Return Loss
\( \text{SWR} \) - Standing Wave Ratio
\( \text{VSWR} \) - Voltage Standing Wave Ratio
CHAPTER 1

INTRODUCTION

1.1 Background Study

The extraordinary development in the field of RFID and its use and related applications has led to the need for smaller and more low-profile components that may be suitable for an application. Most RFID applications operate with a bandwidth of approximately 180 to 300 MHz for different frequencies, such as 120-150 kHz low frequency (LF), 13.56 MHz high frequency (HF), very high frequency (UHF) 433 MHz, 865 Frekans 868 MHz (Europe) 902-928 MHz (North America) UHF band, microwave band of 2450-5800 MHz and very broad band of 3.1 to 10 GHz [1].

Radio Frequency Identification (RFID) is a two-way contactless technology that uses electromagnetic induction and radiation. The generic RFID system includes a scanner unit, called a reader, and a series of remote transponders connected to objects that need to be identified by a tag [2]. It also includes software (middleware) and server processor (usually a PC) that communicates with remote tags. RFID is one of the promising technologies used as an alternative to addressing some of the problems associated with current identity technologies such as barcodes and optical systems. It sees RF waves to transmit data between the reader and the moving element to identify, classify and monitor. Currently, RFID technology advanced reading range, no sight of line, low cost, ability to use many things in one scan [3].

In recent years, RFID technology has been widely used in logistics transportation, traffic toll collection, employee participation records and animal husbandry management. Specifically, Internet of Things (IoT) development in industry and home applications brings stricter requirements for reliability, high-speed
data rate, multi-band operation and cost-effectiveness to the reader antenna [4]. RFID tags are always routed in practical applications and the tag antennas are mainly linearly polarized (LP). Compared to LP waves, circularly polarized (CP) waves provide greater flexibility in the orientation angle between the reader and the tag. Therefore, the CP reading antenna is the primary solution for improving the communication security of the RFID system. In general, CP waves can be obtained by two or more LP orthogonal positions with equal amplitude and phase difference of 90° [5]. The recent development of wireless technologies for health application has led many scientists to industrial research. As the need for modern medical devices increase every day, the cost of medical care and hospitalization increases [6].

Radio Frequency Identification (RFID) is one of the fastest growing areas of automatic identification and collection of data in the medical industry. They are widely used to focus on patients, tracking and locating surgical instruments; supply chain observation, patient medication monitoring, neonatal identification, etc. In addition to the above, it is also useful for screening hospital staff, detecting blood bags, preventing detection of pharmaceutical products, access control to prevent theft of medical equipment, keeping a patient-friendly diet with laser markers and access to the status of medicines in biomedical applications [7]. RFID technology was actually developed around the Second World War. This bidirectional contactless data communication includes the transmitter and receiver components of the system. For example, a reader tags UHF RFID system that receives a signal from an RFID reader antenna from an open area in an RFID reader antenna [8-10]. Another application that uses this RFID technology is the successor of barcodes for retail supply chain, remote monitoring and medical surveillance.

1.2 Problem Statement

The RFID application has become essential in today's wireless technology. This application requires a radio frequency antenna, which is small enough to receive limited communication devices. Therefore, the aim of this project is to design and develop a monopoly microstrip antenna for RFID applications. The microstrip monopole antenna has been chosen for its advantages over conventional antennas. Conventional antennas are large and not suitable for RFID applications. The use of a
microstrip patch antenna provides several advantages, with a compact shape and good radiation manners. On the other hand, microstrip monopole antennas have the additional advantages of compatibility with reduced size, weight, assembly compatibility, microwave and millimetre wave integrated circuits, and microwave monolithic integrated circuits (MMICS).

The main functional drawbacks of microstrip monopole antennas are the very narrow frequency bandwidth, which is usually only a fraction of a percentage or a maximum of a few percent. In addition, loss of dielectric and conduction at thin spots may be significant, resulting in insufficient antennas. However, microstrip antennas are easy to construct and support linear and circular polarizations.

1.3 Objectives

The objectives of this project are:

i. To design and develop a microstrip patch antenna operating frequency at 2.4 GHz for the RFID application.

ii. To develop and analyse the antenna performance using modified ground

iii. To verify the simulation results with measurement results.

1.4 Scope of Study

The scope of this project is follows:

i. A microstrip monopole antenna designed and simulated using Computer Simulation Technology (CST) Microwave. The microstrip monopole antenna at 2.4 GHz for RFID applications. The antenna was fabricated using FR4 substrate material.

ii. Modified ground is applied to improve the antenna performance.

iii. The antenna was simulated with the computer simulation technology microwave studio. This software was chosen because it is a specialized Tool for 3D simulation of high frequency components.

iv. To fabricate antenna using circuit technology and validate the simulated result with measured results.

v. The microstrip monopole antenna will be tested by using Network Analyser.
1.5 Thesis outline

The thesis outline, it will be covered in its entirety. This report is divided into sections. Each section will cover the topics needed.

As far as Chapter 1 is concerned, it covers the introduction of the project. Few explanations will be made due to the project. It also includes objectives, scope and thesis outline.

Chapter 2 is a chapter that provides a literature review of the project. This chapter focuses on specific topics. The literature review starts with the introducing the antenna calculations, formulations, line of the transmission and antenna trends.

Chapter 3 deals with the methodology, focusing on the method with which the project was accomplished. The methodology is shown in the organization chart. Moreover, it is detailed in the form of sentences. The expected result and the analysis are discussed in Chapter 4.

This chapter will provide details on the expected results for the entire project, as well as the frequency response to be achieved at the end of the simulation process. In addition, it also provides a detail on the analysis of the result due to the fabrication and fluidity of the tests. The discussion focus on the formulations, calculation, fabrication and testing.

The last chapter is Chapter 5, which is a general conclusion for the project. There are also works in the future. The conclusion refers to the plan. It is important to ensure that our goal is achieved.
CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter describes some similar earlier work, pertinent journals and research that include the design of microstrip monopole antennas that can provide an idea for the implementation of this project. This chapter also covers the background of the RFID application, the RFID key, the microstrip monopole structure of the smaller antenna, and the antenna parameters as well.

2.2 Background of RFID

Radio Frequency Identification (RFID) is an Automatic Data Acquisition System (AIDC) that has the potential to have a major impact on the economies of many industries [11]. Although Radio Frequency Identification (RFID) is a comparatively old technology and uses Radio Frequency signal for communications, the latest advances in technology have made RFID suitable for new consumer applications and configurations. These developments tend to transform, human resources, logistics, and other areas. As a result of research and development, technological advances and human development stimulate the need to store and process information in real time and the use of radio frequency identification in various areas have expanded.

RFID also enables staffs to achieve organizational goals throughout production while managing data via RFID technology. RFID technology makes it easy to track a wide range of objects, including people, goods, vehicles and assets. The explosive growth of the population and the introduction of large data have
placed RFID technology at the top of each domain. RFID systems are an automatic detection system such as an optical barcode. Barcode can persist the best solution, especially in the average term. RFID is not as low-cost as traditional labelling techniques, but adds value and is currently at an important price level where consumer products can spread widely. Currently, the biggest drop is the cost of personal RFID tags and the cost of installation of the system [12]. Table 2.1 makes a contrast of the features for bar codes and RFID.

Table 2.1: Evaluation of Bar-code vs. RFID

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Bar-code</th>
<th>RFID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>➢ inexpensive</td>
<td>➢ No need line-of-sight</td>
</tr>
<tr>
<td></td>
<td>➢ broadband consumption</td>
<td>➢ Huge memory data transfers along with</td>
</tr>
<tr>
<td></td>
<td>➢ readable for human</td>
<td>products</td>
</tr>
<tr>
<td></td>
<td></td>
<td>➢ Read dynamic data</td>
</tr>
<tr>
<td>Negative</td>
<td>➢ Line-of-sight needs for data transferring</td>
<td>➢ expensive</td>
</tr>
<tr>
<td></td>
<td>➢ data storage is limited</td>
<td>➢ Reads easily the product</td>
</tr>
<tr>
<td></td>
<td>➢ Environmentally sensitive</td>
<td>➢ Adoption is limited</td>
</tr>
</tbody>
</table>

The foundations of RFID technology date back to World War II. The Germans, Japanese, Americans and British all were warned of the approaching plane when they were away in 1935 using radar discovered by Scottish physicist Sir Robert Alexander Watson Watts. However, it was impossible to distinguish the enemy planes from country’s own ones. The Germans found that when the aircraft was transferred, when it returned to the base, the reflected radio signal would change, warning the radar personnel on the ground. The Germans used this simple method to identify their aircraft. The British developed the first active friend or enemy identification system (IFF) by simply installing a transmitter on each British aircraft that received signals from the aircraft. This makes the aircraft very friendly [13].
In the past few decades, RFID technology has gone through many stages. This technology has been used to track delivery of goods, courier services and baggage handling. Other applications include automatic toll payment, departmental access control for large buildings, personal and vehicle control in specific areas, safety of items that should not dispensation the space, tools tracking by engineering companies, clinic file systems, etc [14]. Table 2.2 shows RFID development finished the past few decades.

Table 2.2: RFID development completed the previous decades [11].

<table>
<thead>
<tr>
<th>Period</th>
<th>Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940 - 50</td>
<td>Radio frequency identification technology was used for the period of the Second World War.</td>
</tr>
<tr>
<td>1950 - 60</td>
<td>Introduction to radio frequency identification technology, research laboratory testing.</td>
</tr>
<tr>
<td>1960 - 70</td>
<td>The improvement of the RFID system begins, the field tests initiate, the first Sensory and Control Point of RFID was established, the first EAS was out to prevent robbery.</td>
</tr>
<tr>
<td>1970 - 80</td>
<td>The rapid growth of RFID development, the acceleration of RFID testing, the implementation of initial implementation of RFID, the release of RCA and Fairchild, the &quot;Electronic ID System&quot;, the electronic charging test of the Port Authority of New York and New Jersey</td>
</tr>
<tr>
<td>1980 - 90</td>
<td>Saleable tenders for RFID are widely distributed. Tenders occur in the areas of transport, industry, access to people and animal identification. Toll roads are equipped with RFID worldwide</td>
</tr>
<tr>
<td>1990-2000</td>
<td>RFID is becoming part of everyday life, and with the advent of the first open RFID standards commonly used for toll collection, animal identification and personal identification, MIT finds the car identity.</td>
</tr>
</tbody>
</table>
RFID tags include microprocessors, transmitters, and antennas that can read and write data in text without contact between readers and tags. There are two broad classifications of RFID system and they are: passive tags and active tags. Active tags have power requirements, long-distance readings, and are commonly more costly than passive tags; they do not have, meaning they will not be used for affordable products. There are also semi passive RFID tags and runs for special tenders. Semi-passive tags use a battery to control the chip, but exchange data with the reader through the sector. Active and half-pass tags continue to broadcast their own signals, often used to accurately track assets in high-speed environments, such as payments or real-time. Passive tags are cheaper, do not need batteries or repairs, are powered by the magnetic field of the reader, and have a little read time. The tags also has an unlimited durability and is small to fit a practical adhesive tags. The use of passive RFID systems is economical for many industries due to the lowest price. Passive RFID tags include applications such as file monitoring, smart tags, chain supply management and access control system [15-19]. RFID tags can be classified into various categories shown in Table 2.3 there are two fundamentally different RFID design methods to transmit reader power to tags. Field system using transponder tag and repelling power induction (magnetic) coupling circulating around antenna and reader system. A long field related to the true power of free space spreading electromagnetic waves [20].

Both can continue running by sending enough power to the remote control. Usually 10μW to 1 mW, be contingent on the type of tag. Near-field coupling methods are typically practical to RFID systems in which operates in the low frequency and high frequency bands at comparatively low spaces, while for very high frequencies; the mass field coupling is higher (UHF) and microwave RFID systems. The length of the tag depends on the electromagnetic field generation system and closest resonance frequency or wavelength. Often one is called the Radian pattern. Since modifications in electromagnetic fields take place slowly, the limit does not precisely defined; the main magnetic field begins from the antenna and induces the electric field lines inside the room (near-field) [21-23]. The choice of technology for a specific application results from a thorough examination of the various characteristics, costs and performance characteristics of different RFID
technologies according to the needs of the program. RFID systems can only store small amounts of data on the tags (usually less than 2 kbit data = less than 250 characters or less than 8 characters). As a result, the design of the information stored on the label is an important element of the application [24].

Table 2.3: Categorization of RFID tags

<table>
<thead>
<tr>
<th>Used by design and technology</th>
<th>Passive</th>
<th>Semi-passive</th>
<th>Active</th>
</tr>
</thead>
</table>
|                             | ➢ also called "pure passive", "reflector" or "beam-fed"  
➢ Getting the power from the reader  
➢ The reader sends electromagnetic waves that cause current to the tag’s antenna, which reflects the transmitted RF signal and adds information by adjusting the reflected signal | ➢ Uses a battery to keep the memory on the tag or to power the electronic components allowing the tag to form the reflected signal  
➢ It communicates in the same way as other passive tags. | ➢ It works with an internal battery that controls the microchip circuit and sends a signal to the reader  
➢ mostly offers a wider range of active tag readings more |

<table>
<thead>
<tr>
<th>By the tag’s memory type</th>
<th>Class 0</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-programmed passive tag, Read Only.</td>
<td>Read Many (WORM) passive tag, Write Once.</td>
<td>Passive Read / Write tags that can be written in the supply chain at any time</td>
<td>Read-write with built-in sensors that can record parameters such as temperature, pressure and motion.</td>
</tr>
</tbody>
</table>
2.4 RFID Reader

The reader for RFID, sometimes referred to as interrogator is a collection of data collection that is responsible for powering and transmitting tags with signals, utilization and the computer network. Readers are equipped with an antenna to send and receive signals, transceivers, and code / data interrupt processors. In passive systems, RFID readers emit the energy field that produces tags and raises their chips, and allows them to send or store data. The active tags send signals periodically, so that the data can be collected by a plurality of scattered readers [25].

Readers may possibly moveable terminals or fixed devices placed at calculated points, similar to stock entrances, gathering lines, or toll booths (door readers). Readers can use PCMCIA cards (International Computer Memory Card Persons Association) to attach laptops that are usually power-driven by their own power (battery) or vehicle. Readers usually operate on radio frequencies, so if tags from three different manufacturers use three different frequencies, the seller may have several readers in some places, which adds to the cost.

Table 2.4: Types of RFID readers

<table>
<thead>
<tr>
<th>By design and technology used</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Read</strong></td>
<td></td>
</tr>
<tr>
<td>➢ only reads data from the tag</td>
<td></td>
</tr>
<tr>
<td>➢ Usually a micro-controller unit with wound output coil, sensor top, comparable designed to send energy tags and reading data there from by sensing rear scattering.</td>
<td></td>
</tr>
<tr>
<td><strong>Read/write</strong></td>
<td></td>
</tr>
<tr>
<td>➢ reads and writes data from/on the tag</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>By fixation of the device</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stationary</strong></td>
<td></td>
</tr>
<tr>
<td>➢ The device is attached in a fixed way, for example at the entrance gate, respectively at the exit gate of products</td>
<td></td>
</tr>
<tr>
<td><strong>Mobile</strong></td>
<td></td>
</tr>
<tr>
<td>➢ The reader is a handy, movable device.</td>
<td></td>
</tr>
</tbody>
</table>
2.5 Frequency range of RFID

The range of the RFID tag varies with frequency. Most RFID systems operate under Industrial Science (ISM). It is available free of charge in low power and low power systems [27]. The team defined the International Telecommunication Union (ITU). Different power and bandwidth rules are subjected to operating devices on each. Table 2.5 lists the operating frequencies and RFID performance characteristics. This frequency decided that we do not lack, to oppose, would be a compliment, that the problems of not bothering to keep. The RFID tag was chosen to be placed in the application. RFID tags are different at different frequencies. EPG is the most important global ISO group working on the development of international standards in the UHF RFID band [28]. To avoid the use of different radio frequencies, most of the world's communities want to meet standard ITUs. Four frequency bands used in the design of the tags:

i. Low frequency (125-135 KHz)  
   ii. High frequency (13.56 MHz)  
   iii. Ultra-high frequency (860-960 MHz)  
   iv. Microwave (2.45 and 5.8 GHz)

Tags have Different frequencies and different functions. They are different when they are characterized by different types of materials. The reading interval varies from a few centimetres to several meters. Due to government regulations and customer orders, multiple frequencies selected can be selected.

I. Low frequency tags (125-135 KHz)

The LF tag requires helical antenna or a Spiral Antenna with a few hundred core revolutions. They are expensive to produce. Water suppression is lower than for high frequency tags. These tags are used for the first time and are always used to track animals. LF Do not rotates or moves the metal. The LF Bridge is suitable for applications that need to read a small amount of data at low speed and minimum distance.
II. High frequency (13.56 MHz)

The HF has a simple antenna design with a low spool (5 to 7 turn) and is as a result thinner and cheaper to fabrication than lower frequency. Low Frequency is not pretentious by water due to high frequency. High-frequency are very useful for tenders needing a small reading distance or where the identified items enclose water comparable pharmaceuticals, humans, and animals., referred to as medications, humans and animals. LF and HF readers have lower data like LF and UHF readers. HF has been used in European and the classic read range of HF tags is about 30-70 cm. HF reading antennas fill the volume around antenna and should be Omni-directional.

III. Ultra-high frequency (860-960 MHz)

The Ultra-high frequency tag requires very good communication without line-of-sight (except "lossy" materials). They always have a higher data rate and a normal reading range of up to 5 m. The adjustable UHF antenna reader provides an adjustable reading zone. This is the frequency range most frequently discussed in supply chain management applications. Ultra-high frequency does not enter water / tissue, Ultra-high frequency readers are more costly than HF, and technology is not more mature than HF. In addition, regulations on the use of UHF vary in dissimilar parts of the world. Different countries allow different frequencies, number of channels, maximum power and duty cycle.

IV. Microwave Frequency (2.45, 5.8 GHz)

Microwaves also have a good visibility communication (with the exception of "lossy" materials). It gives you more data rates and distance reading up to 15 meters. This tag is also effective for metals with tuning / design adjustment. The microwave reader antenna is directed to ensure controlled reading area. Table 2.5 below summarizes the RFID frequencies and related applications.
REFERENCES


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