الجامعة الإسلامية العالمية ماليزيا
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DESIGN OF MICROSTRIP MINIATURE ANTENNA FOR RFID APPLICATIONS

BY

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A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Science (Communication Engineering)

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ABSTRACT

Radio Frequency Identification (RFID) has drawn great attention nowadays, because of its great potential for use in many applications. Size of the RFID tags, its read range and its ability to work with metallic objects are among the main challenges to this technology. Miniaturize the size of the RFID antennas cause gain degradation, while nearby metallic objects cause detuning of the antenna. Two different types of RFID tag antennas have been proposed to overcome these challenges. A compact planar inverted–F (PIFA) antenna was designed using two parallel patches. A PIFA of 50 mm × 50mm × 8 mm has a read range of more than 5 m at the resonant frequency of 915 MHz. compact. PIFA can be attached to metallic objects without performance degradation. Recently there are new interests on applying ultra-wideband (UWB) technology in developing RFID systems. UWB has advantages over the conventional narrowband RFID. Crescent antenna of 35 mm × 30 mm × 1.6 mm was designed for UWB-RFID tags. The conductive material has a great impact on UWB-RFID. To overcome this effect a layer of foam was attached to the antenna to act as a buffer. The proposed antenna has a maximum read range of between 0.9m and 4.4m with the ability to cover the UWB with the existing of metallic objects.

ملخّص البحث

جذبت تقنية تحديد الهوية باستخدام الترددات اللاسلكية المعروفة اختصارا بال (ار اف اي دي)، اهتماما كبيرا في الوقت الحاضر، لما لها من إمكانات كبيرة لاستخدامها في العديد من التطبيقات. تعتمد هذه التقنية على الاتصال فيما بين القارئ والمحدد الذي يتكون من هوائي ملصق بشريحة متناهية في الصغر. من بين التحديات الرئيسية لهذه التكنولوجيا حجم المحدد، ومدى قراءته، وقدرته على العمل مع الأجسام المعدنية. تصغير حجم المحدد يتطلب تصغيرا لحجم الهوائي مما يقلل من مقدار ربح الهوائي. هذه الرسالة تقترح نوعين من الهوائيات للتغلب على تلك التحديات. صمم هوائي المستوى على شكل حرف اف المقلوب (بيفا) وبلغ حجمه الكلي ٥٠ ملم × ٥٠ ملم × ٨ ملم، وبلغ مدى قراءته خمسة امتار على التردد ٩١٥ ميجاهيرتز. يرفق هذا الهوائي مع الاجسام المعدنية دون ان يتاثر اداؤه. تناقش الرسالة استخدام النطاق العريض جدا (يو دبليو بي)، في تطوير هوائيات المحدد. لهذا النطاق مزايا تفوق نطاق الحزمة الضيقة. تم تصميم هوائي الهلال بحجم 35 ملم × 30 ملم × 1.6 ملم ليعمل في النطاق العريض جدا. تم التغلب على مسالة المواد الموصلة بوضع طبقة من الفلين سمكها ٢٠ ملم بين الهوائي واي مادة معدنية. يبلغ الحد الأقصى لقراءة الهوائي المقترح الى اكثر من اربعة امتار مع قدرته على الاداء بنفس المستوى في حالة وجود مواد معدنية بالقرب من الهوائي.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Communication Engineering).

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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Signature Date

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ABBREVIATIONS

BPSK	Binary Phase Shift Keying
CMOS	Complementary Metal–Oxide–Semiconductor
CST	Computer Simulation Technology
DC	Direct Current
EIRP	Equivalent Isotropically Radiated Power
EPC	Electronic Product Code
FB	Fractional Bandwidth
FCC	Federal Communications Commission
FEM	Finite Element Method
FIT	Finite Integration Technique
Gbps	Gigabits per second
GPS	Global Positioning System
GSM	*Global System for Mobile* communications
HF	High Frequency
HFSS	High Frequency Structure Simulator
IFA	Inverted-F Antenna
ILA	Inverted-L Antenna
ISO	Organization for Standardization
LF	Low Frequency
LOS	Line of sight (LOS)
LPI/D	Low Probability of Interception and Detection
LTCC	Temperature Cofired Ceramic
MBOA	Multiband OFDM Alliance
MCMC	Malaysian Communications and Multimedia Commission
MSA	Microstrip Antennas
NLOS	Non-line of sight (NLOS)
OFDM	Orthogonal Frequency Division Multiplexing
ONS	Object Name Service
PAM	Pulse Amplitude Modulation
PEC	Perfect Electric Conductor
PIFA	Planar Inverted-F Antenna
PML	Physical Markup Language
PPM	Pulse Position Modulation
PSD	Power Spectral Density
RF	Radio Frequency
RFID	Radio Frequency Identification
RL	Return Loss
ROI	Return on investment
RTLS	Real-time locating systems
SCP	Short Circuit Plate
SNR	Signal To Noise Ratio
UHF	Ultra High Frequency
UWB	Ultrawide Band
VSWR	Voltage Standing Wave Ratio

WIFA	Wearable Inverted-F antenna

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

RFID is an abbreviation for Radio Frequency Identification, which is a technology that allows for the automatic identification of objects using radio signals. It is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. RFID is a technology that can be traced back to October 1948 (Aroor and Deavours, 2007), however RFID had to wait for years to be realized before the technology flourished, and the first commercial product came in 1960s. Some researchers (Ukkonen et al,2006) emphasizes that this technology is moving rapidly from the research lab to mass applications in a similar way to GSM mobile phones in the 1990s. RFID system consists of a chip, an antenna, a reader, and a database, where information about tagged objects is stored. An RFID tag is an object that can be attached to or incorporated into a product, animal, or person for the purpose of identification using radio waves. There are several methods of identifying objects using RFID, but the most common method is to store an ID or serial number that identifies a specific product along with other information, on a tag, which consists of a small microchip attached to an antenna (Roberti, 2004). The antenna enables the chip to transmit whatever identification information it contains to a reader then the reader converts the radio waves from the RFID tag into digital information which can be processed by software system. Typically, when a reader reads a tag, it passes three things to a host computer system: the tag ID, the reader's own ID, and the time the tag was read. Antennas used within in RFID are integrated into two different areas of the system, the reader and the tag. Both the reader and tag use antenna to perform their given tasks. The antenna in an RFID tag is a conductive element that permits the tag to exchange data with the reader. In Passive RFID tags, the antenna create a magnetic field through coiling of the antenna make use of a coiled antenna and uses the energy provided by the reader's carrier signal. In the reader configuration, the antenna emits radio waves from which the tag responds by sending back its data. The design of antenna for RFID is critical, since RFID system performance depend on it. Size, read range and cost are basic considerations in designing of these antennas.

1.2 PROBLEM STATEMENT

A key challenge in the RFID technology is to have reliable communication with the tag, which requires that the tag antennas have longer read ranges while they should maintain small sizes. Miniaturizing the size of these antennas cause gain degradation, hence it causes reduction in the read range of these antennas. Many items that require identification using RFID technology contain or are totally made of conductors, e.g., packages in retail stores. Even though if the item doesn't contain conductors, it may be placed on or near metallic objects. Using metallic objects is another challenge to the design of the RFID systems due to the effects of the conductors on the tag antenna performance. The effect of the metallic objects is stronger for the UWB systems.

1.3 RESEARCH OBJECTIVES

Several objectives have been specified for this research as follows:

(1) To design a tag antenna for UHF-RFID system.

(2) To design a tag antenna for the UWB-RFID, that is able to cover the FCC band (3.1-10.6 GHz).

(3) To optimize the design of each of the above two antennas for RFID system, especially miniaturizing the antenna size and improving the read range.

(4) To investigate the effect of the metallic objects in the design of each of the above two antennas such that the antenna should keep its required behavior when it is placed on metallic objects.

(5) To maintain the read range at acceptable range without and with the existence of metallic objects.

1.4 RESEARCH METHODOLOGY

This research work demands a lot of investigation to realize the state of art, therefore:

(1) Information about the different kinds of antennas that could be used for RFID tags have been gathered.

(2) Antennas have been miniaturized and the affect of size reduction on the read range was studied.

(3) According to these studies a small antenna with good read range is selected for further investigations.

(4) The selected antennas are analyzed and simulated in order to find novel design for the current challenges.

(5) New structure of antennas is designed and simulated (UHF-RFID and UWB-RFID tag antennas).

(6) Parametric studies are performed to optimize the design of the proposed tag antennas in terms of the dimensions of the structure and the read range.

(7) The effects of the metallic objects near the antenna are investigated.

(8) The optimized design is simulated and measured to compare the actual performance of the developed antennas with the required specifications for the RFID.

The research methodology is shown in Figure 1.1. Two antennas are proposed for RFID system with ability to be attached to metal objects. Simulations is carried out using computer tools based on Finite Integration Technique (FIT), using CST electromagnetic simulator, and Finite Element Method (FEM), using HFSS electromagnetic simulator.

1.5 THESIS OUTLINE

The second chapter of this thesis presents an overview of the RFID systems, state of art. Chapter three is about types of antenna which could be used for the design. Comparative study of designs, simulations and investigations of different antennas are shown in chapter four. Chapter five is about narrow band type of antenna. Compact planar inverted-F antenna is designed and simulated. Chapter six discusses the UWB type of antennas for UWB-RFID systems. Suggestions to overcome the metallic object effect are presented. UWB-RFID fabrication and measurement are presented also in chapter six. Finally in chapter seven, the results is summarized and discussed, and the thesis is concluded by proposing future works that can be done as extension to this research work.

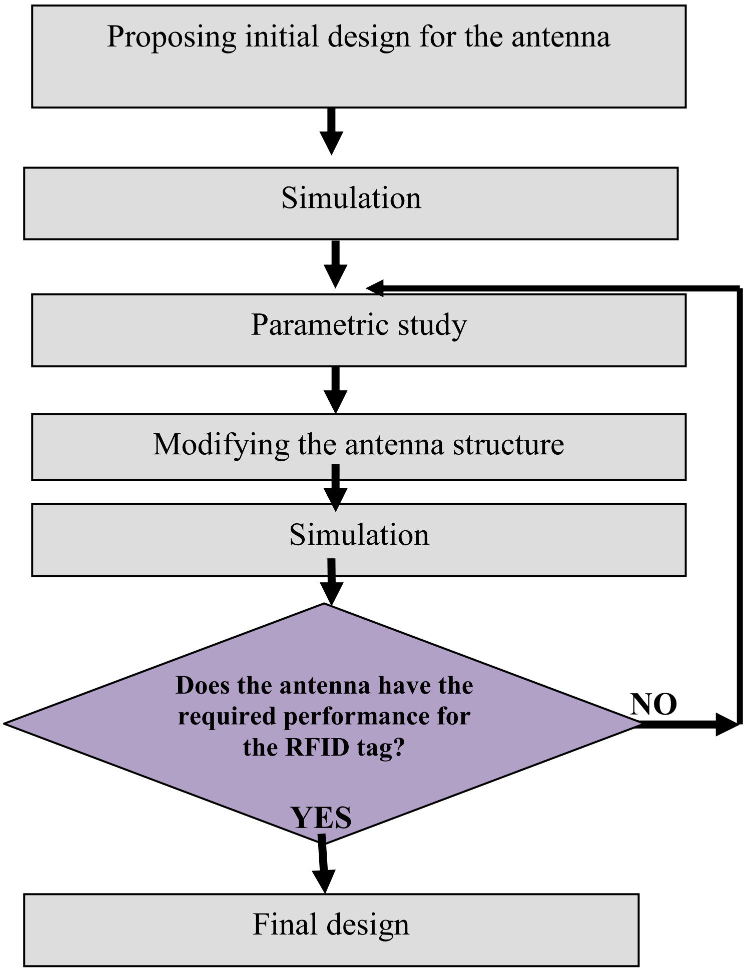

Figure 1.1: Research methodology

CHAPTER 2
RFID TAG ANTENNA

2.1 INTRODUCTION

Antennas for radio frequency identification (RFID), have gained growing interest in the research world and markets. In RFID a reader device transmits a signal to the identification tags, in which the data is stored. RFID can be understood to be similar to the bar code systems. However, the amount of data and reading ranges are much higher. Also, reading is possible without visual contact. Thus, RFID systems can be used to identify objects for example in logistics and industrial production or in key cards. Moreover, sensors can be attached to RFID platforms to allow the distributed monitoring of the environment. Generally two kinds of RFID systems exist, near-field (HF) and far-field (UHF) RFID. In near-field systems, the wireless coupling is done through magnetic or electric field with inductors or capacitors as coupling elements and thus, the reading distances tend to be in the order of a few centimeters. On the other hand, in far-field RFID, electromagnetic coupling is utilized and the reading distances are several meters. The electronics part of the tag (chip) is extremely small and in many cases, is embedded in the antenna substrate making the antenna the largest component. Thus, small size and platform insensitivity are the main design characteristics of RFID antennas. Also, the antenna is matched directly to the reactive impedance of the IC, and thus, the antenna impedance is not real as in traditional antenna design cases.

The majority of the RFID tag antennas on the market today are two-dimensional Structures; mainly printed dipoles. Two-dimensional structures are small in size, inexpensive and suitable for mass production

2.2 RFID ARCHITECTURE

Figure 2.1 shows the identification process in RFID. This process depends mainly on the antenna in the reader and in the tag. The characteristic of the antenna determines the read range and the size of the tag.

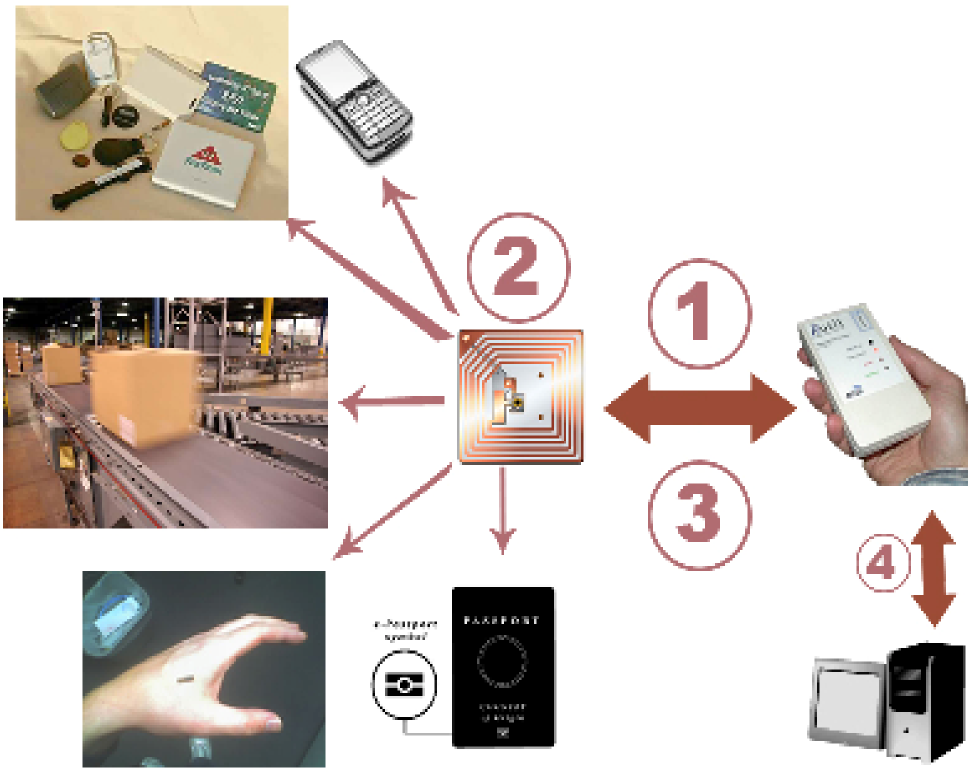

Figure 2.1: RFID identification process

1. A reader is mounted at specific localities to transmit signals.
2. When a tagged object passes near any reader, the reader communicates with the tag, the radio signal activates the RFID tag.
3. The tag and the reader authenticate one another in, and then, the tag sends its information to the reader.
4. The reader transmits data to a host computer for processing. A secure database contains the identifying information associated with the serial number on the tag.

The host computers send the information from several localities about tagged objects to a central location. The information is integrated at the central location into database management systems and can be analyzed by enterprise applications. As RFID applications increase e.g., using RFID readers in entrances to stores and car parking, obtaining more information about visitors etc., new methods for authentication and authorization, encryption, integrity protection, and prevention of unauthorized read/write operations have to be addressed. Since tag costs have to be kept in certain limits, new effective methods for mutual authentication of transponders and interrogators have to be developed (Finkenzeller, 2003).

2.3 COMMUNICATION TECHNIQUES

It is the transfer of energy which contains the information coded in it through RF waves. There are two main communication techniques that the RFID antennas in reader and tag use to communicate with each other. These techniques are coupling and backscattering.