UNIVERSITI PUTRA MALAYSIA

MINIATURIZATION OF UHF RFID TAG ANTENNA

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By

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The main aim of this research is to reduce the size of RFID tag antenna using several miniaturization techniques. The tag antenna comprises of meandered lines and capacitive – tip loading integrated with two square split – ring resonators (S – SRRs). It was simulated using 3D full – wave electromagnetic simulator (CST Microwave Studio 2013) on FR4 epoxy substrate with the dielectric constant of 4.4, the loss tangent of 0.02 and the thickness of 1.53 mm. The UHF RFID chip used in this design was MURATA RFID Magicstrap LXMS31ACNA-010 chip with the impedance of 12 – j106.3 Ω at 921 MHz. The antenna has been designed to cover the frequency range in Malaysia, 919 MHz to 923 MHz. A parametric study of the proposed tag antenna was carried out in order to optimize the main effected parameters. The performance of the proposed tag were analysed in terms of return loss, antenna gain and maximum readable range. As compared to other passive UHF RFID tag antenna it is found that the size of antenna has achieved 61% reduction in size. It occupies the volume of 48 × 22 × 1.53 mm^3. The measured read range of the proposed tag antenna is 4.60 m. Details of the proposed tag antenna design and measurement results are presented and discussed.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

PENGECILAN UHF RFID ANTENA LABEL

Oleh

NOR HIDAYAH BINTI DAUD

Januari 2015

Pengerusi: Prof. Madya Alyani Binti Ismail, PhD

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Tujuan utama penyelidikan ini dilakukan adalah mengenai proses pengurangan saiz antena label menggunakan beberapa teknik pengecilan. Antena label yang dicadangkan mengandungi dipol yang mempunyai garis lenturan dan kemuatan hujung yang berintegrasi dengan dua struktur *square split – ring resonators (S – SRRs).* Ia disimulasi menggunakan *3D full – wave electromagnetic simulator (CST Microwave Studio 2013)* di atas substratum epoksi FR4 dengan pemalar dielektrik bernilai 4.4, kehilangan tangent sebanyak 0.02 dan ketebalan bernilai 1.53 mm. UHF RFID cip yang digunakan di dalam rekabentuk ini adalah cip MURATA RFID Magicstrap LXMS31ACNA-010 dengan galangan 12 – *j*106.3 Ω pada 921 MHz. Antena label yang dicadangkan di rekabentuk meliputi keseluruhan julat frekuensi di Malaysia, 919 MHz kepada 923 MHz. Kajian parametric kepada antena yang dicadangkan telah di bawa bersama dalam mengoptimis kesan parameter yang utama. Prestasi terhadap antena yang dicadangkan dianalisis dari segi *return loss*, gandaan antenna dan julat bacaan yang maksimum. Jika dibandingkan dengan UHF RFID antena label yang lain, didapati bahawa saiz antena yang dicadangkan telah mecapai kadar pengurangan saiz sebanyak 61%. Ia mencapai isipadu 48 × 22 × 1.53 mm^3. Pengukuran bacaan julat kepada antena yang dicadangkan ialah 4.60 m. Lanjut mengenai rekabentuk antena yang dicadangkan dikaji secara terperinci dan keputusan pengukuran dibentangkan dan dibincang.

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I certify that a Thesis Examination Committee has met on 30 January 2015 to conduct the final examination of Nor Hidayah binti Daud on her thesis entitled "Miniaturization of UHF RFID Tag Antenna" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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This is to confirm that:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASIC	Application Specific Integrated Circuit
AUT	Antenna Under Test
CST	Computer Simulation Technology
FR4	Flame Retardant 4
EAS	Electronic Article Surveillance
EPC	Electronic Product Code
EIRP	Effective Isotropic Radiated Power
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
GHz	Gigahertz
HF	High Frequency
HPBW	Half-Power Beamwidths
IC	Integrated Circuit
ISM	Industrial-Scientific-Medical
ISO	International Organization for Standardization
LCP	Liquid Crystal Polymer
LOS	Line – of – sight
LF	Low Frequency
LH	Left – Handed
MCMC	Malaysian Communications and Multimedia Commission
MHz	Megahertz
MLA	Meander Line Antenna
MTMs	Metamaterials
PCB	Printed Circuit Board
PET	Polyethylene terephthalate
PRC	Power Reflection Coefficient
PTFE	Polytetrafluoroethylene
RF	Radio Frequency
RFID	Radio Frequency Identification
SHF	Super High Frequency
SMA	SubMiniature version A
SRD	Short Range Devices
SRR	Split-Ring Resonators
UHF	Ultra High Frequency
UPC	Universal Product Code
UV	Ultra Violet
VNA	Vector Network Analyzer

CHAPTER 1

INTRODUCTION

1.1 Radio Frequency Identification (RFID)

Radio frequency identification, or simply known as RFID, is a method of automatic identification. The continuous research on RFID grows rapidly in recent years. The era of RFID technology has been explored as direct consequences from the radio and radar development. The United Kingdom has applied the RFID during the Second World War to differentiate between the English and German airplane. In 1980, the RFID technology entered the new phase in the improvement of tracking system and exploration of application in manufacturing and other environments. The RFID was applied by the United States in electronic toll collection technology. This is occurred in the year 1991, in the Oklahoma City, where the world's first highway electronic tolling system was opened. Nowadays, RFID system is widely used in different area like security system, animal tracking, chain management and many more (Uddin et al., 2009; Want, 2006; Sanjay et al., 2003; Landt, 2001).

Tag antenna should also be low cost, small in size, have good impedance matching and insensitive to the attached objects to keep performance consistent. Meanwhile, omni directionality of the tag antenna is preferred to ensure the identification ideally radiate from all directions (Curty et al., 2007). There are several techniques to reduce the dimensions of conventional antennas. Meandering, folding, and bending are techniques for antenna miniaturization, are widely used in the literature (Tirado-Mendez et al, 2013).

However, the application of RFID tag antenna using square split – ring resonators (S – SRRs) was found to be another alternative to the miniaturization technique (Bazrkar, 2012; Ferdous et al., 2012; Booket, 2011; Dacuna and Pous, 2007). The process of miniaturization of RFID tag was commonly conducted using parametric studies and optimization of main effected parameters. Thus, further studies to reduce the physical size of the radiating elements in wire antennas using effective techniques are needed to be explored for the miniaturization of tag antenna.

1.2 Problem Statement

Performances of an RFID tag depend on the properties of the antenna. The tag antenna must fulfill the requirements such as the antenna must be robust, longer read range, low cost and small enough to be attached to the required object. In addition to that, the tag antenna should be in omnidirectional and provide a maximum possible signal to the application specific integrated circuit (ASIC) (Aivazis et al., 2011; Koski et al., 2011; Laran RFID, 2004; Qing and Yang, 2004; Foster and Burberry, 1999).

To enhance the performance characteristics of the tag antenna, researchers have modified the conventional dipole structure using numerous techniques. Several approaches have been done in an attempt to reduce the tag size. Some articles have sought achieving improved gains and small size by using different configurations of miniaturization method. Existing literatures provide several techniques for reducing the tag size (Mehrparvar et al., 2012; Hu et al., 2011; Kim et al., 2010; Wu et al., 2010). The most common method used by the researchers to reduce the tag antenna is by meandering method. Even though the meandering method showed its capability in reduction size of antenna, there were some disadvantages related to it. It produced low radiation efficiency, narrow bandwidth and not capable to operate at multiband frequencies (Faudzi et al., 2013a; Faudzi et al., 2013b; Jahanbakshi et al., 2012; Hu et al., 2011; Dobkin, 2008). The used of capacitive tip loading provide a satisfactory reduction in size and contribute in improving the gain. It can be done through formation of a large structure at the end of the dipole antenna (Faudzi et al., 2013a; Faudzi et al., 2013b; Hu et al., 2011; Ghiotto et al., 2010; Im et al., 2009; Dobkin, 2008). However, the capacitive tip loading does not contribute in improving the gain significantly due to size limitations.

Besides, the use of fractal geometries is also capable in reducing the size of RFID tag (Aivazis et al., 2012 and Manjibhai et al., 2012). Their applicability to RFID tags is good promising, even though the theory behind fractal antennas is quite complex. The geometries of fractal shapes were generated in iterative patterns. Nevertheless, the fractal antennas have several drawbacks which include loss in gain, very complex and degrade the antenna parameters after a few iterations. Another method to reduce the tag size is using the planar inverted – F antenna (PIFA). It has a high gain but the size of the antenna becomes large due to the additional ground plane (Kim et al., 2011; Kim and Choi, 2010; Chen et al. 2010a; Uddin et al., 2009; Marroco, 2008).

In Malaysia, RFID industry had grown since year 2005. The operating frequency for Radio Frequency Identification (RFID) has a range which varies from 919 MHz – 923 MHz. The permissible frequency allocation in Malaysia has been controlled by the Malaysian Communications and Multimedia Commission (MCMC) (Minan, 2007). Nowadays, there are a lot of works done in miniaturizing the RFID tag antenna based on operating frequency in Malaysia (Faudzi et al., 2013a and Tan & Ismail, 2012). However, there are still some performances need to be improved, such as the size of tag, gain, and read range performance which based on the several miniaturization techniques. Both of their studies utilize CST Microwave Studio for simulation process. As a result, it is important to find out the suitable miniaturization method to reduce the size of tag antenna.

1.3 Objectives

This research aims to study a compact RFID tag antenna. The specific objectives are as below:

1. To identify the suitable antenna design and investigate the potential of integrating several miniaturization techniques as a method to reduce the size of RFID tag.
2. To analyze parametric effect of the designed antenna such as size of tag, gain, radiation pattern, and matching impedance.

3. To investigate the effectiveness of the designed tag in terms of reading range measurement.

1.4 Scope of Research

This study was conducted within its scopes. The scopes of this study were listed below:

- The meandered dipole antenna integrating with square split – ring resonators (S- SRRs) and capacitive – tip loading was utilized.
- The tag performance was assessed in term of size, gain, radiation pattern, matching impedance and read range measurement. These parameters were common parameters measured, as indicators to assess the tag performance.
- A UHF RFID reader (Model: UHF – RW – G2 – 232) was chosen as an equipment for measuring read range performance. The performance of maximum read range was assessed through the comparison of the result obtained from the calculated part with those obtained by the measurement reader.

1.5 Overview of Research Methodology

The first step in the methodology consists of the studies about the challenges and the potential research in designing the RFID tag antenna. The tag antenna will be designed by modeling, simulating, and optimizing by monitoring the size of tag, antenna gain, return loss and input impedance. Tag antenna was designed using the simulation on full – wave electromagnetic simulator (CST Microwave Studio, Version 2013). Parametric study for an antenna is performed until the requirements are met. If the design requirements are satisfied, the antenna design is ready. Otherwise, the design is further modified and optimized until requirements are met. Once the RFID problems were initialized, RFID requirements can be translated into the selection of antenna type and its parameter. Then, the proposed tag antenna can be fabricated after optimization. Finally, measurement can be implemented on the proposed tag antenna to validate the design methods. The developed methodology for designing RFID tag antenna is illustrated in a flow chart as shown in Figure 1.1.

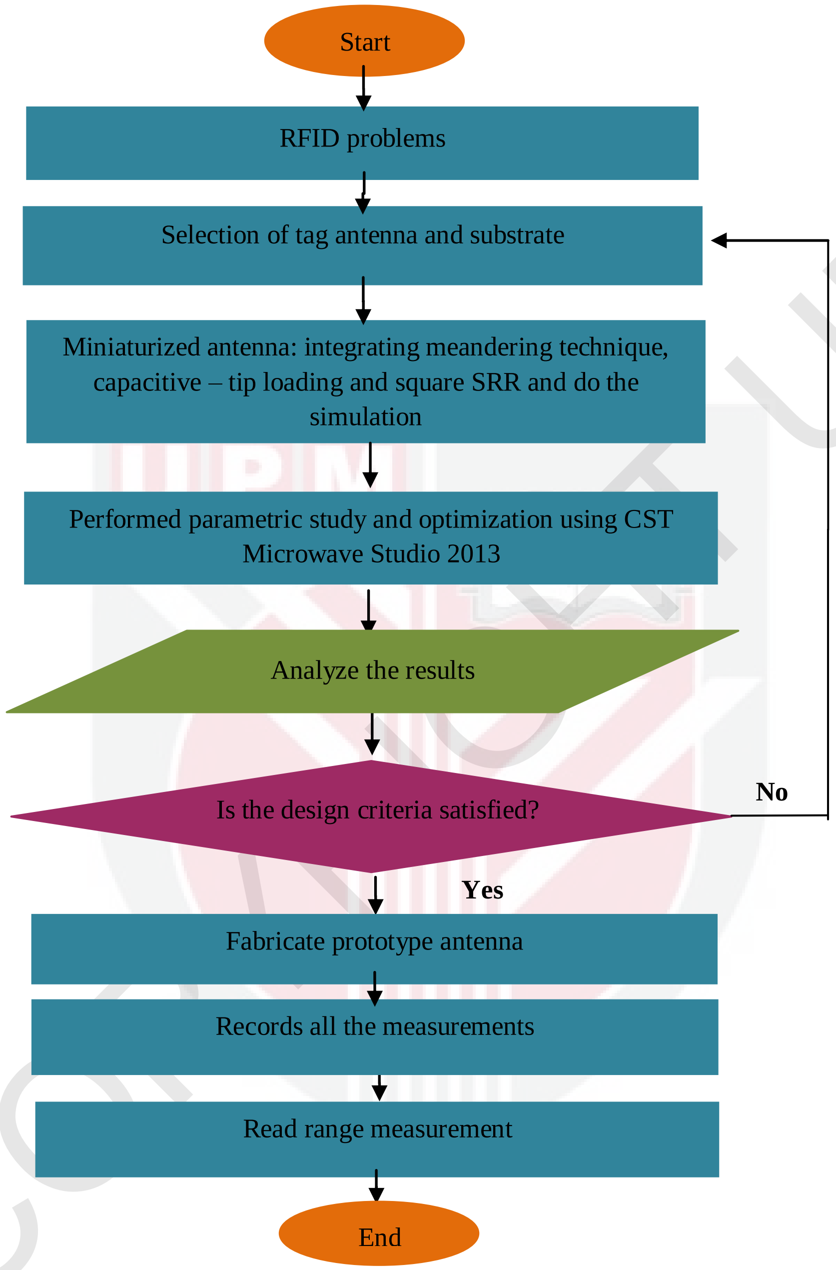

Figure 1.1. Flow Chart of the Design Process UHF RFID Tag Antenna

1.6 Organization of Thesis

This thesis consists of five chapters. It was organized as follows.

Chapter 1 presented an introductory part for the overview of the history and the current scenario of RFID tags in Malaysia. This introductory part also provided the basic discussion of the problem associated with the design of RFID tag antenna. Problem statements, objectives and scope of the study also outlined in this chapter.

Meanwhile, Chapter 2 presents a detailed description on the literature reviews which based on the RFID Technology. It includes the components of the RFID system, the regulations in RFID which covers the operating frequency. This part reviews all the work done found from the various publications by the previous researchers. The details explanations about the fabrication process in producing RFID tag antenna, power reflection coefficient analysis, input impedance and the maximum read range

In Chapter 3, the experimental methodology involved in this study is explained and interpreted in the form of a flowchart. Chapter 4 presents the results obtained from the experimental work, in the form of graphs and tables that included the detailed explanation. Last but not least, the conclusion of the study and some recommendations for future work are provided in Chapter 5.

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