EFFICIENT ANTENNA ENERGY HARVESTING SYSTEM DESIGN TOWARDS AUTONOMOUS RFIDS AND WIRELESS SENSORS

NURZAIMAH BINTI ZAINOL

This Report Is Submitted In Partial Fulfillment of Requirements for the Bachelor Degree of Electronic Engineering (Telecommunication Electronics) with Honours

Faculty of Electronics and Computer Engineering

Universiti Teknikal Malaysia Melaka

JUNE 2014

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

TajukProjek : **EFFICIENT ANTENNA ENERGY HARVESTING SYSTEM DESIGN TOWARDS AUTONOMOUS RFIDS AND WIRELESS SENSORS**

SesiPengajian : 1 3 / 1 4

Saya**NURZAIMAH BINTI ZAINOL**

mengakumembenarkanLaporanProjekSarjanaMudainidisimpan di Perpustakaandengansyarat-syaratkegunaansepertiberikut:

1. LaporanadalahhakmilikUniversitiTeknikal Malaysia Melaka.
2. Perpustakaandibenarkanmembuatsalinanuntuktujuanpengajiansahaja.
3. Perpustakaandibenarkanmembuatsalinanlaporaninisebagaibahanpertukaranantarainstitusipengajian tinggi.
4. Silatandakan (√) :

☐	**SULIT***	*(Mengandungimaklumat yang berdarjahkeselamatanataukepentingan Malaysia seperti yang termaktubdi dalam AKTA RAHSIA RASMI 1972)
☐	**TERHAD****	**(Mengandungimaklumatterhad yang telahditentukanolehorganisasi/badan di manapenyelidikandijalankan)
☑	**TIDAK TERHAD**	

Disahkanoleh:

(TANDATANGAN PENULIS)

(COP DAN TANDATANGAN PENYELIA)

Tarikh: 6 June 2014.

Tarikh: 6 June2014

"I declare that this thesis is the result of my own work except the ideas and summaries which I have clarified their sources"

Signature : .....

Author : NURZAIMAH BINTI ZAINOL

Date : 6 JUNE 2014

"I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the cope and quality for the award of Bachelor of Electronic Engineering (Telecommunications) With Honours"

Signature : .....

Author : MOHAMED SAEDD JAWAD

Date : 6 JUNE 2014

For lovely mom, Che Nolia Binti Abdul Kadir and lovely dad, Zainol Bin Ibrahim

ACKNOWLEDGEMENT

First of all, I am thankful to Allah S.W.T for giving me guidance and strength internally and externally to enable me to finish my final year project successfully. I would like to convey my greatest gratitude to my dearest supervisor Mohamed Saedd Jawad for his guidance, brilliant ideas and his expertise in this field are sincerely appreciated.

I also want to express my special thanks for my lovely dad and my lovely mom who is Zainol Bin Ibrahim and Che Nolia Binti Abdul Kadir because they always support me and their advice become an inspiration and strength to me in completing this research successfully. Lastly, I dedicate a valuable thankful to my classmates and colleagues at this university who always support me directly or indirectly.

ABSTRACT

An efficient antenna topology is investigated to be used for energy harvesting system design towards autonomous RFIDs and wireless sensor. Currently, the usage of autonomous and electronic device is increasing and these devices all require a battery. In order to minimizing the need of battery and realize self-powered wireless sensors, the design of proposed antenna must be able to capture as much as possible RF energy from surrounding to be used as energy harvesting system. A PCB substrate of FR-4 is used to fabricate an antenna as it is not expensive and can be obtained easily. The high gain of microstrip patch antenna array that operating at 2.45GHz at ISM Band is achieved with additional slot introduced on the rectangular patch antenna element with 14.08dB from the simulation results and 10.46dB by experiment. The minimum output power able to operate rectifier part of this harvesting system which the voltage is test to turn on LED and produce the output voltage ranging from 0.01V to 3.94V. This harvesting system shows good performance both simulation and measurement and RF to DC conversion.

ABSTRAK

Pelbagai topologi antena dikaji untuk digunakan dalam reka bentuk sistem penuaian tenaga ke arah RFIDs autonomi dan pengesan tanpa wayar. Pada masa ini, penggunaan peranti autonomi dan elektronik semakin meningkat dan alat-alat ini semua memerlukan bateri. Untuk meminimumkan keperluan bateri dan menyedari sensor tanpa wayar diri berkuasa , reka bentuk antena yang dicadangkan mesti berupaya untuk menangkap sebanyak tenaga RF mungkin dari sekitar untuk digunakan sebagai sistem penuaian tenaga. FR -4 substrat digunakan untuk mereka bentuk antena kerana ia tidak mahal dan boleh didapati dengan mudah. Keuntungan tinggi "microstrip antenna patch" yang beroperasi pada 2.45GHz di ISM Band dicapai dengan slot tambahan diperkenalkan pada unsur segi empat tepat antenna dan „gain" antenna ialah 14.08dB daripada keputusan simulasi dan 10.46dB melalui eksperimen. Kuasa keluaran minimum dapat beroperasi sebahagian penerus sistem penuaian ini yang voltan adalah ujian untuk menghidupkan LED dan menghasilkan voltan keluaran dari 0.01V untuk 3.94V . Sistem penuaian menunjukkan prestasi yang baik kedua-dua simulasi dan pengukuran dan RF ke DC penukaran.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PCB	-	Printed Circuit Board
FR-4	-	Flame Retardant
VHF	-	Very-high Frequency
UHF	-	Ultra-high Frequency
GSM	-	Global System for Mobile
ISM	-	Industrial, Scientific and Medical
WLAN	-	Wireless Local Area Network
CPS	-	Coplanar Strip-line
IEEE	-	Institute of Electrical and Electronics Engineers
PSM	-	*Projek Sarjana Muda* (Final Year Project)
VSWR	-	Voltage Standing Wave Ratio

LIST OF SYMBOL

λ	-Wavelength
c	-Speed of light; $3x10^8$
f	-Frequency
ε_o	-Effective dielectric constant of patch
Z	-Impedance
Ω	-Unit of impedance, Ohm

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

The work presented in this thesis is in the area of Radio Frequency energy harvesting which is all about efficient antenna energy harvesting system design towards autonomous RFIDs and wireless sensor. In few years back, many new technologies have been applied in order to enhance our life quality. One of these technologies is the cost-saving system in a house which uses self-powered devices which is domestic lighting application which uses a sensor system to operate. The light is automatically turned on once the sensor detects a specific level of darkness in the room. The smart system not only offers a more comfortable living, but also a large scale of energy saving and a lower cost solution. For instance, battery-less remote control and mobile phone charger which operates using harvested energy is currently having a great demand from users since they contribute to reduce cost and saving time. The goals of this work is to design an efficient antenna for energizing low power devices that integrate with rectifier and

will applied in small devices based on wireless sensor technology. The performance of harvesting system will focus on the gain of an antenna to operate rectifier part and this rectenna was implementing on PCB Board and conducted an experimental test on it.

1.1 Project Background

There is an active research in investigating several methods significantly extracting ambient energy from surrounding and convert it into electrical energy [1] for energizing low power wireless sensors which can get the required power from rectenna circuit. Indeed, RF energy scavenging from the ambient will become more beneficial at future of microelectronic which will be flexible of green electronics devices due to self-powered wireless sensor and energy autonomous [2]. In fact, there are many energy from external sources such as solar power, magnetic, vibration and RF energy. The advantage harvested RF energy from the ambient because the energy is feely available in space. Thus, RF energy is captured by a receiving antenna and rectified into a usable DC voltage.

In recent years, there has been a growing usage of sensor-based wireless networks and applications which directly leads to the increased battery usage. Until today, the limitation of energy supplies has become a crucial issue for the lifetime of these sensors since they operate on conventional batteries with a limited lifespan and fixed energy rate. These electronic devices and wireless sensor require an antenna for communication system which is used in transmitting and receiving electromagnetic waves. Usually in telecommunication research area, patch antenna is popular due to their simple design and easy to fabricate. However, many types of patch antenna exist such as Meander Line Antenna (MLA) [3], linear polarized [4], circular polarized [4]. The best antenna topology is investigated along with a circuit capable of converting RF signals into DC voltage to replace the need for batteries.

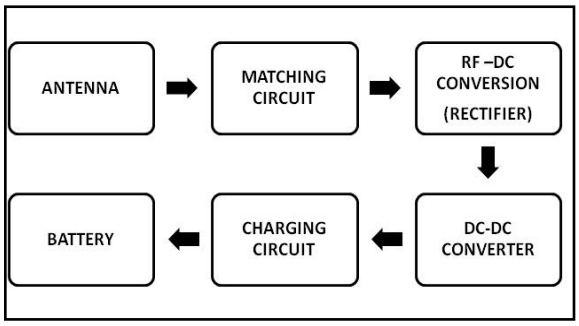

Figure 2.0: Basic Block Diagram of RF Energy Harvesting System [5]

Generally, communication devices have omni-directional radiation pattern of antennas that propagate RF energy in most direction thus maximizes the coverage for mobile applications. The energy harvesting system design promotes a promising future in low power consumer of electronics devices and wireless sensor networks. In reality, the energy that is transmitted from the wireless sources is much larger but only a small amount of energy can be scavenged due to energy dissipated as heat or absorb by other materials. RF energy harvesting system is made up of microwave antenna, prerectification filter, rectifying circuit and DC pass filter that rectifies incoming electromagnetic waves into DC current. The rectifying circuit can be in any types like full-wave bridge rectifier or as a single shunt full-wave rectifier [5][6].

In order to obtain an optimum power transfer, a low pass filter between the antenna and rectifier will be used. The purpose of using this filter is to achieve impedance matching between them. Then, after signal is rectified, a DC low pass filter will be used to smooth the output DC voltage and current by attenuating the high frequencies harmonics that present in the RF signals or generated by the highly nonlinear rectifying process itself. The best is collecting the maximum power before deliver it to the rectifying diode, and then to suppress the harmonics generated by the diode that reradiate from the antenna as the power lost [6]. For RF energy harvesting many things is important like antenna transmitted power, antenna received power, conversion efficiency and conversion circuit analysis [7]. In order to increase the conversion efficiency, several broadband antennas, large antenna arrays, and circularly polarized antennas need to be implemented. This is

because the broadband antenna receives relatively high RF power from various sources, and antenna array increases incident power delivered to the diode for rectification [6] [7].

1.2 Problem Statement

Based on literature review studies, it is clearly found that there is still a need for antenna energy harvesting system design for some wireless infrastructure such as RFID and wireless sensor. Recently, growing usage of this sensor-based wireless networks and applications which directly leads to the increased battery usage gives limitation of energy supplies which become a crucial issue for the lifetime of these sensors since they operate on conventional batteries with a limited lifespan and fixed energy rate. The usefulness of a wireless sensor expires when its battery runs out and thus RFID sensors are required to be autonomous and energy-independent. One of the solutions proposed to overcome these issues is to implement energy harvesting system design which is comprise self powered mechanism towards autonomous RFIDs and wireless sensor and mostly applied to enhance the efficiency of a system and to enable new technology.

1.3 Objective

The main objective of this project is to design an efficient antenna for energy harvesting system for energizing low power devices towards autonomous RFIDs and wireless sensor that integrates with rectifier. This designed antenna work at operating frequency of 2.45GHz (ISM Band) and the antenna design‟s performance with the focus on the gain to operate rectifier part will be evaluated. Then, the proposed antenna was implemented on PCB Board and conducted an experimental test on it.

1) To design an efficient antenna for energizing low power devices that integrates with rectifier.

2) To evaluate antenna design‟s performance with the focus on the gain to operate rectifier part.

3) To implement an antenna on PCB Board and conducted an experimental test on it.

1.4 Scope of Works

This project is about efficient antenna for energy harvesting system design toward autonomous RFIDs and wireless sensor. The antenna design operates at 2.45GHz (ISM Band). The proposed microstrip patch antenna should be simpler in design but the circuit must be able to receive minimum power. The least cost also took into consideration since FR-4 substrate is used and the most importantly, the required power from receive signal can allow in powering the circuit itself. The performance of high gain microstrip patch antenna will be evaluated and the simulation results will compare with the experimental test. Antenna parameter such as return loss, bandwidth, radiation pattern, antenna efficiency, directivity and gain will analyze using software CST Microwave Studio 2011. To model a matching and rectifier circuit which important to convert RF signals to DC voltage, use software Agilent Advanced Design System (ADS) 2011.

1.5 Project Significance

This project gives high commercial values since the active research motivated for the search for an alternative source of energy to power wireless sensor network especially at 2.45GHz frequency band (Industrial, Scientific and Medical) application that requires sensors to be installed for a long duration where battery replacement is not practical. The antenna design at this frequency band is important to work in for many applications. The microstrip patch antenna design at different frequency band between [9] and [10] is compare which is the operating frequency is at 5.25GHz and 2.4GHz in term of method that they used. Researcher in [9] design microstrip patch antenna without slot whereby researcher in [10], introduced additional slots to rectangular patch in order to achieve single band functionality.

Then, the performances of antenna gain which same operating frequency of antenna at 2.45GHz is analyzed between [11], [12], [13] and [34]. In [11], researcher proposed four planar dipole elements placed in two parallel lines whereas in [12], a compact wideband microstrip thinned array antenna using EBG substrate is designed. Then, researcher in [13] proposed 2x1 and 4x1 linear antenna array whereas in [34], 4-element microstrip linear array antenna with Butler matrix beamforming network is designed, analyzed and implemented using microstrip technology in completely planar structure. The gain of antenna design by researcher in [11], [12], [13] and [34] is 7.5dBi, 8.2dBi, 9.186dBi for 2x1 linear antenna array and 11.0452dBi. Hence, the different existing microstrip patch antenna with and without slot tested in different frequency band is significance with my project which operates at 2.45GHz due to able to get high gain antenna array with additional slot introduced on the rectangular patch and air gap between FR-4 substrate.

1.6 Project Methodology

Research methodology includes designing antenna using CST software that enable researcher to measure various parameter like bandwidth, gain, efficiency and so forth. There are several steps before analyzing and validate the prototype. If the finding result

not achieves the requirement, repeat step until get desired one. Briefly, this project comprising of 4 stages in order to complete the task; design stage, simulation stage, fabricating stage and test stage. In the design and simulation stage, the software of CST Microwave Studio will be involved to draw and illustrate the 3D layout of the antenna as well as simulate it so that it will operate at the fixed parameters obtained from researches. The next last two stages involved the manufacturing of the hardware of this project; fabricating the layout of the antenna from CST software onto a PCB substrate of FR-4 and test the antenna using the equipment ready in the lab and thus the result will be compared to ensure the accuracy of the fabricated antenna.

1.7 Thesis Plan

Throughout this thesis, chapter 1 covers the background study of this project, the problem arise in past work that will be solved through this project, objectives that require to be accomplished, scope covered throughout project, project significance and brief method used in the project. Then, based on problem statement and scope need to cover as state in chapter 1, chapter 2 covers the literature review of the RF energy harvesting system design including the concept of RF energy harvesting system, the principle of operation of the antenna and the rectifying circuit that is commonly used. It will literalize the project‟s framework by presenting the significant theory involved. Then, in chapter 3 will be clarifying comprehensively the procedures involved for resolving the proposed problem from the beginning until the end of the project. In chapter 4, it will presents the results and a discussion of the RF energy harvesting system using microstrip patch antenna array with additional slot and air gap in between the FR-4 substrate with the basic rectifier circuit which include both simulation and measurement results and lastly in chapter 5 will concludes the project and clarifies some improvement and any recommendation at future work about this project.