INVESTIGATION OF THE PERFORMANCE OF ANTENNA WITH RECTIFIER FOR RF ENERGY HARVESTING APPLICATION AT 2.45 GHz

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DEDICATION

I dedicate this thesis to my parents, Norman Teo bin Abdullah and Jalilah binti Deros, for encouraged me to finish this thesis and for financial support.

ABSTRACT

In the last decades, energy attained from various sources, for example; wind energy, thermal energy, solar power and RF energy has been in use for countless purposes. Radio frequency energy harvesting is an energy conversion technique employed for converting energy from the electromagnetic field into the electrical domain. Therefore, the purpose of this project is to design microstrip patch antenna integrated with rectifier that will operate at 2.45GHz for RF energy harvesting. This project is undertaken as an approach to generate the electricity without the usage of both power electricity or solar electricity due to some limitation that occur in space. This project is also to analyze an efficient technique to transfer the energy without degrading the performance of the rectifying circuit. To obtain the objectives, a patch antenna and rectifying circuit need to design by using CST Microwave Studio then fabricated on FR4 board. The parameter involve in this research study would be all antenna basic characteristics such as a resonance frequency, return loss, bandwidth, gain, and directivity. While, for rectifier circuit would be DC output voltage and the RF to DC conversion efficiency. The microstrip patch antenna and rectifier will be optimized to improve its performance so that it is reliable for RF energy harvesting application.

ABSTRAK

Dalam dekad yang lalu, tenaga diperoleh daripada pelbagai sumber, sebagai contoh; tenaga angin, tenaga haba, tenaga solar dan tenaga RF telah digunakan untuk tujuan yang tidak terkira banyaknya. Penuaian tenaga frekuensi radio ialah teknik penukaran tenaga yang digunakan untuk menukarkan tenaga dari medan elektromagnet ke dalam dominasi elektrik. Oleh itu, tujuan projek ini adalah untuk merekabentuk antena bersepadu dengan penerus kecekapan tinggi yang beroperasi pada 2.45GHz untuk penuaian tenaga RF. Projek ini dilaksanakan sebagai pendekatan untuk menjana elektrik tanpa menggunakan kedua-dua kuasa elektrik atau elektrik solar. Untuk mendapatkan objektif, antena tampalan dan litar pembetulan perlu direkabentuk satu demi satu dengan menggunakan Studio CST Microwave. Parameter yang terlibat dalam kajian penyelidikan ini adalah semua ciri asas antena seperti frekuensi resonans, kehilangan pulangan, jalur lebar, keuntungan, dan pengarahan. Walaupun begitu, untuk litar penerus akan menjadi voltan keluaran DC dan kecekapan penukaran RF ke DC. Antena dan penerus akan dioptimumkan untuk meningkatkan prestasinya supaya dapat dipercayai untuk aplikasi penuaian tenaga RF.

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I have gained a lot of knowledge of this research and it has been beneficial to my development in furthering my career and my studies in the future. I would like to express absolute gratitude to my beloved supervisor, Madam Maizatul Alice binti Meor Said for her kind words, encouragement and persistent support in my undertaking of this research.

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LIST OF SYMBOLS AND ABBREVIATIONS

dB	:	Decibel
ADS	:	Advanced Design System
CST	:	Computer Simulation Software
DC	:	Direct Current
FR4	:	Fire Retardant Type 4
GHz	:	Giga Hertz
PCB	:	Printed Circuit Boards
Mm	:	Millimeter
IEEE	:	Institute of Electrical and Electronic Engineers
RFID	:	Radio Frequency Identification
SMA	:	Sub Miniature version A
SMD	:	Surface Mount Device
RF	:	Radio Frequency
UV	:	Ultraviolet
WPT	:	Wireless Power Transfer
VSWR	:	Voltage Standing Wave Ratio

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CHAPTER 1:

INTRODUCTION

1.1 Background Study

Radio frequency (RF) energy harvesting is an energy conversion technique employed for converting energy from the electromagnetic field into the electrical domain. In the city such as busy areas, there are large range of RF electricity resources which includes broadcast televisions, smartphone indicators and wi-fi networks. This part of the power energy can be gathered and convert it into usable DC voltage.

RF energy harvesting plays significantly important role for supplying power to low power level devices. The RF energy harvesting principally getting a high expectation to be research because of ecological inviting and free vitality sources. Furthermore, it

can also improve the unwavering quality of the general system and avoid power interferences.

1.2 Problem Statement

In the past few years, there was a fast growth within the use of wireless devices in packages which includes smartphones and sensor networks. These devices are powered through a transportable device, that are also used limited power of battery. The used of the batteries has several disadvantages, which the batteries have a limited life span and need to be replaced frequently. Other than that, batteries contain heavy metals (acid), if the batteries do not well dispose when their life has ended, it can leak the contains into the surroundings that can causes the pollution to increase. Therefore, the usage of green technologies need to introduce. For example, RF energy system is one of the solutions to triumph over the problem for growing wireless broadcasting and communications systems that generated the free electricity.

From the literature studies, due to huge path loss, energy harvested from RF signal is so rare and precious. It is difficult to obtain high conversion efficiency by collecting maximum power because of the amounts of power that can be transferred are limited. Therefore, it is very important to employ appropriate strategies to improve the overall energy efficiency.

The key element of this project is rectenna, which consists of a rectifier and antenna to receive RF energy in free space and transform it into DC power. Hence, the purpose of this project is to investigation of the performance of antenna with rectifier for RF energy harvesting application at 2.45 GHz

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1.3 Objective

The objective of this project is to investigation of the performance of antenna with rectifier for RF energy harvesting application at 2.45 GHz. The objectives are:

1. To investigate Microstrip patch antenna integrated with rectifier that will operate at 2.45GHz for RF energy harvesting.

2. To analyze an efficiency technique to transfer the energy without degrading the performance of the rectifying circuit.

3. To fabricate and validate the design in the laboratory.

1.4 Scope of Project

The scopes of the project consist of four main steps to make sure that the scopes to be completed. The first step is to find and gather the information about the project from the previous research, journal and paperwork on the internet. This project will be focused on design and analysis as well as fabricate and validate for rectenna to improve the efficiency of RF energy harvesting system.

After that, the Advance Design System (ADS 2016) software will be used for design and simulate process on rectifier circuit to improve the performance of the rectifier circuit. Whereas, the CST Microwave Studio is used to design and simulate the antenna. The performance information of the antenna that need to obtain include return loss, bandwidth, radiation patterns and gain. The third step is antenna and rectifier circuit fabrication process. In this process, the antenna and rectifier circuit are fabricated on FR-4 material with dielectric constant = 4.3 and Substrate thickness, h = 1.6.

Lastly, the result that obtained will be compared between the simulation result and the measurement result. The combination between the antenna and rectifier circuit will be tested by using lab equipment to measure the performance of RF DC conversion efficiency.

1.5 Chapter Summary

This thesis report separated into 5 chapters and the content of every chapter is summarized as below.

Chapter 1 is an introduction of the project for energy harvesting antenna application. The scope of project, project objective and problem statement has been described in this chapter.

Chapter 2 covers a complete research work on literature review for RF energy harvesting system. The chapter start with the introduction, RF energy harvesting system applications, antenna design, review on microstrip patch antenna, explanation about basic antenna parameters, rectifier equivalent circuit, and summary of literature review.

For chapter 3, the flow of methodology for this project will be cover. It will briefly explain the method that will be used comprehensive for this project. The flowchart will be used to representing the method used in the methodology.

Furthermore, for chapter 4, the result and analysis from the measurement and simulation for the project will be explained. The comparison of both results in simulation and measurement are also done in this chapter.

Lastly, chapter 5 will present the conclusion for the project. The future work recommendations for the project are also will be explained. This chapter also to explain the achievement in objective of the project.

CHAPTER 2:

LITERATURE REVIEW

2.1 Introduction

From the studies of operational mechanisms and machine usage, wireless power transfer (WPT) is classified into numerous techniques, that is close to-area inductive or resonant powering, a long way-area directive powering, and some distance-area ambient radio frequency (RF) energy harvesting. Among these strategies, close to-area powering has been considerably commercialized for providing energy to portable wireless applications [1]. Despite the fact that, it isn't always handy because of extraordinarily short charging distances, restricting the usefulness of WPT, due to the fact the devices cannot be completely employed as they are located above a charging pad. Consequently, some distance-area directive or ambient powering have triumph

over this obstacle because of the long-distance charging functionality. A device can be constantly charged every time it is being use or not.

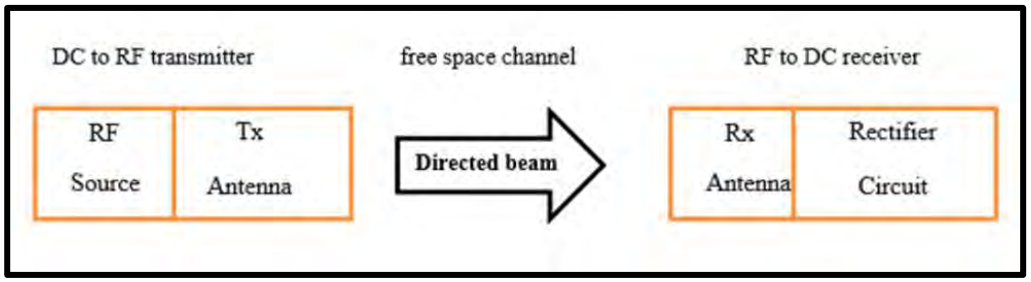

Figure 2.1 : Overview of project

The RF energy harvesting has accumulated more prominent significance in the course of recent decades, for developing radio transmitters communicate RF energy around the globe [6]. Such surrounding energy is considered as "free" powering resources, making this innovation more fascinating than different devoted WPT. In this way, the concentration of WPT places increasingly accentuation on RF energy harvesting, looking for the productivity streamlining of rectennas with low input power [2].

The rectenna is the combination of rectifying circuit and antenna which will convert the microwave signal into DC voltage. The rectenna is a vital tool to transform RF energy into DC power. It consists of an antenna which gathers microwave incident energy and a rectifying circuit. The rectifier has a nonlinear characteristic and converts RF power into useful DC power. A rectifier is comprised of a combination of Schottky diodes, and a resistive load [5]. Besides, rectenna which can change over RF energy to DC power assumes a vital part in free space for remote power transmission (WPT) [4].