INITIAL OBSERVATION OF ENERGY CONVERSION BY USING RECTENNA

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This Report Is Submitted in Partial Fulfillment of Requirements for the Bachelor Degree of Electronic Engineering (Wireless Communication)

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

June 2013

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

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Special dedicate to my family, supervisor, and all my fellow friends to help me to accomplish my report.

ACKNOWLEDGEMENT

In the name of Allah, The Most Gracious, The Most Merciful. Firstly, an utmost gratitude to Allah S.W.T for giving me comforts patience and opportunity in time and space to successfully complete my final year project thesis or Project Sarjana Muda (PSM) 2.

Millions of thanks also are giving to my supervisor, Engr. Najmiah Radiah Binti Mohamad for the guidance and advice, including the feedback that enabled me to improve upon producing this report.

I wish to express my appreciation to my friends, Nur Hidayah Binti Mahmud for sharing the literature and similar research interest and also for her help and encouragement in designing rectenna. I also like to express my gratitude to all those who have helped me in one way or another way during the planning, information gathering, writing, editing and reformatting stages of this thesis report.

Besides that, I would like to express my gratitude to my parents for the love and support that they have given me. Finally, I would like to thank everyone who is willing to spend their precious time reading my thesis report.

ABSTRACT

Nowadays, the battery is one of a necessary device for everyone in their life. Battery always been the problem which is the lifetime of the battery is very limited and requiring periodical battery replacement. The deposition of battery is creating the problem of environmental pollution. So, this project was designed rectenna to capture and converts the microwave energy to DC voltage that can supply energy for low-voltage devices without using electricity or battery automatically. The law of conservation energy stated that the energy cannot be created and destroyed. Energy conversion is the process of converting one form of energy into another form. This thesis describes the original work on converting microwave energy to DC voltage by using rectenna. Rectenna is a combination of a rectifying circuit and an antenna. The antenna part will capture electromagnetic energy from free space and convert it into an electrical signal. It was designed by using CST microwave studio software and fabricated on FR4 board because the printed rectenna is easy to manufacture. The frequency selected for the antenna is 2.45 GHz, which means the antenna should be able to operate in that frequency because the probability to get high efficiency rectenna is high and it unlicensed frequency band. Rectenna will convert the microwave energy into DC power by using rectifier circuit. Rectifier circuit is consisting of Schottky diode and resistor for power measurement. Based on the experimental results, the highest output voltage measure is 1.695V at 820kΩ and 20dBm input power. This project is successfully proven that rectenna can power up low-voltage device such as LED, which is can replace the battery and can use for RFID application.

ABSTRAK

Kini, bateri merupakan salah satu alat yang diperlukan oleh setiap orang dalam kehidupan mereka. Bateri sentiasa menjadi masalah di mana jangka hayat bateri adalah sangat terhad dan memerlukan penggantian bateri secara berkala. Pemendapan bateri mewujudkan masalah pencemaran alam sekitar. Oleh itu, projek ini telah mereka rectenna untuk menangkap dan menukarkan tenaga gelombang mikro kepada voltan DC dan dijangka dapat memberi fungsi kepada peralatan voltan rendah tanpa menggunakan elektrik atau bateri secara automatik. Prinsip keabadian tenaga menyatakan bahawa tenaga tidak boleh dicipta dan dimusnahkan. Penukaran tenaga adalah proses menukarkan satu bentuk tenaga ke bentuk yang lain. Tesis ini menerangkan kerja-kerja asal untuk menukar gelombang mikro ke voltan DC dengan menggunakan rectenna. Rectenna merupakan gabungan litar penerus dan antena. Bahagian antena akan menangkap tenaga elektromagnetik dari ruang bebas dan menukarkannya menjadi isyarat elektrik. Ia direka bentuk dengan menggunakan perisian CST studio microwave dan difabrikasi di atas papan FR4 kerana rectenna cetakan lebih mudah untuk direka. Kekerapan yang dipilih untuk antena adalah 2.45GHz, iaitu bermaksud antena dapat beroperasi pada frekuensi tersebut kerana kebarangkalian untuk memperoleh kecekapan antena yang tinggi adalah besar. dan ia merupakan jalur frekuensi yang tidak berlesen. Rectenna akan menukar tenaga gelombang mikro ke kuasa DC menggunakan litar penerus. Litar penerus terdiri daripada diod schottky dan perintang untuk pengukuran kuasa. Berdasarkan keputusan eksperimen, nilai voltan keluaran paling tinggi adalah 1.695V pada 820kΩ dan 20dBm kuasa masukan. Projek ini telah berjaya membuktikan bahawa rectenna mampu memberi kuasa kepada peralatan bervoltan rendah seperti LED, dimana ia dapat menggantikan bateri dan boleh digunakan untuk aplikasi RFID.

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LIST OF ABBREVIATIONS

RF	**-**	Radio Frequency
AC	**-**	Alternating Current
DC	-	Direct Current
FR4	-	Flame Retardant 4
RECTENNA	-	Rectifying Antenna
FET	-	Field Effect Transistor
HEMT	-	High Electron Mobility Transistor
LED	-	Light-Emitting Diode
CST	-	Computer Simulation Technology
ISM	-	Industrial, Scientific and Medical
EM	**-**	Electromagnetic
LPF	-	Low Pass Filter
EDA	-	Electronic Design Automation
PCB	-	Printed Circuit Board
RHC	-	Right Handed Circular
LHC	-	Left Handed Circular
UV	-	Ultraviolet

CHAPTER I

INTRODUCTION

This chapter will include the overview of the project that consists of project background, project objective, project scope, project methodology, and summarization of the project.

1.1 Project Overview

The word rectenna is composed of rectifying circuit and antenna. The rectenna and its word were invented by W. C. Brown in 1960s. The rectenna can receive and rectify a microwave power to DC, is a passive element with a rectifying diode, operated without any power source. The antenna of rectenna can be any type such as dipole, Yagi-Uda antenna, microstrip antenna, monopole, coplanar patch, spiral antenna, or even parabolic antenna. The rectenna can also take any type of rectifying circuit such as a single shunt full-wave rectifier, full-wave bridge rectifier, or other hybrid rectifiers. The circuit, especially diode, mainly determines the Radio Frequency-Direct Current (RF-DC) conversion efficiency; rectennas with Field

Effect Transistor (FET) or High Electron Mobility Transistor (HEMT) appear in recent years (the rectenna using the active devices is not passive element).

G. A. Vera had developed rectennas which approximately 90% the RF-DC conversion efficiency at 8 Watt input of 2.45 GHz microwave and it was the world record. The RF-DC conversion efficiency of the rectenna with a diode depends upon the microwave power input intensity and the optimum connected load. When the power overload is not matched the efficiency becomes quite low. The characteristic is determined by the characteristic of the diode. The diode has its own junction voltage and breakdown voltage, if the input voltage across the diode is lower than the junction voltage or is higher than the breakdown voltage; the diode does not show a rectifying characteristic. As a result, the RF-DC conversion efficiency drops with a lower or higher input than the optimum [1].

1.2 Objectives

The objective of this project is to design and fabricate the rectenna which captures and converts the microwave energy to DC voltage. Due to the green technology that's highly demands these days, the project seems to be useful to a future because it uses microwave energy to generate new power, and it also can be used as the alternative power source in the future. Another objective of this paper is to observe and analyze the rectenna characteristics such as power efficiency. This project is expected can help to supply energy for low-voltage devices such as Light-Emitting Diode (LED) without the need any electricity or battery as the source.

1.3 Problem Statement

There are some problems that could lead to this rectenna. Among this is the ambient frequency from transmitting mobile stations, radio or TV broadcasting is wasted to surround us. Besides that, power source such as battery nowadays had

become part of human life. Battery always been the problem which is the lifetime of the battery is very limited even for low-power battery, requiring impractical periodical battery replacement. In addition, the deposition of battery is creating the problem of environmental pollution.

The research regarding rectenna was being done a long time ago, but there is also a problem reported regarding rectenna design and performance that need to fix. For example, Yu-Jiun Ren and Kai Chang reported that the dual diode rectenna only could provide 76% of conversion efficiency [2]. Besides that, J. A. G Akkermans and et al. reported in their journal that the amounts of power that can be transferred by using rectenna are limited due to free space path loss [3]. From another journal, Hu Hao and Kong Li also reported that, higher rectenna frequency (e.g. 35 GHz) could reduce the aperture area and increase the transmission range but the component to generating that frequencies are expensive and inefficient [4].

From our own finding after doing a measurement from designing an antenna are we found that the ambient frequency is not having sufficient power to produce high-output DC voltage. The transmit power will be sufficient when generate it using the RF signal generator.

As a conclusion, this project is undertaken as a solution for problems reported in a related journal about designing good rectenna and to get the better output.

1.4 Project Scope

The scope for this project is to find a solution to convert the energy from the microwave to DC power and to increase the efficiency of power conversion. Rectenna will be used to capture the microwave signal and convert it to DC power.

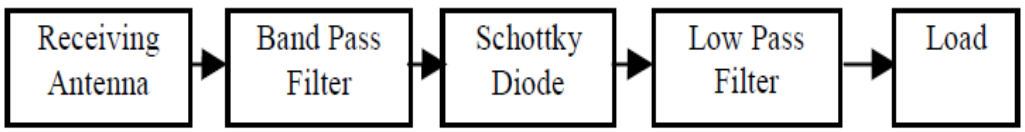

Figure 1.1 : Block diagram rectenna system

Receiving antenna converts the input microwave signal into voltages and currents. The rectifying circuit consists of a band-pass filter, a Schottky diode, and a low-pass filter. The diode is the main part of the rectifying circuit; it changes the AC microwave signal into a DC signal. The properties of the diode significantly impact the overall performance; a diode with a lower built-in voltage would realize a higher rectifying efficiency. Because of its nonlinear characteristics, the diode will create harmonic signals, which can in turn be radiated by the antenna into the ambient space and absorbed by the material of the rectenna. This harmonic generation process can notably decrease the rectifying efficiency to the system.

Consequently, a band-pass filter is usually incorporated within the system between the antenna and the diode to block any harmonics generated by the diode, as well as the diode-generated DC current, from flowing into the antenna. Analogously, a low-pass filter is typically introduced after the diode to prevent any AC signals from reaching the load. Rectenna was designed by using Computer Simulation Technology (CST) Microwave Studio software and fabricated on Flame Retardant 4 (FR4) board because the printed rectenna is low-cost and easy to manufacture. We have investigated the output rectifying efficiency with a resistor load. The resistor senses and, hence, measures the output power directly. However, this project is simply focused onto the output and the capability of rectenna to convert a microwave signal into DC power only.

1.5 Methodology

The project is started by study and review about energy conversion by using rectenna from journal, article and the book. Then, a microstrip patch antenna which will operate at Industrial, scientific and Medical (ISM) band frequency is designed and simulated using CST Microwave Studio software. Microstrip antenna is selected because it is inexpensive and small size. After meeting specification, the designed antenna and rectifier are fabricated using etching process.

Since the stub (filter) part, it is designed to pass the frequency of ISM band, which is 2.4 GHz to 2.45 GHz. The filter should be able to block higher-order harmonic frequency and must match with antenna and rectifying circuit. For the rectifying circuit, there are two types of diode configuration, the first is a single diode configuration which provides half-wave rectifier and the second is dual diode configuration, which provides full-wave rectifier. For this project, dual diode configuration was selected.

Rectenna is tested using the horn antenna because a horn antenna is one of the good antennas for testing method. The characteristics of the horn antenna are having the high gain and directivity. It is also used during the transmission and reception of microwave signals. Finally, the output voltage of the rectenna is observing.

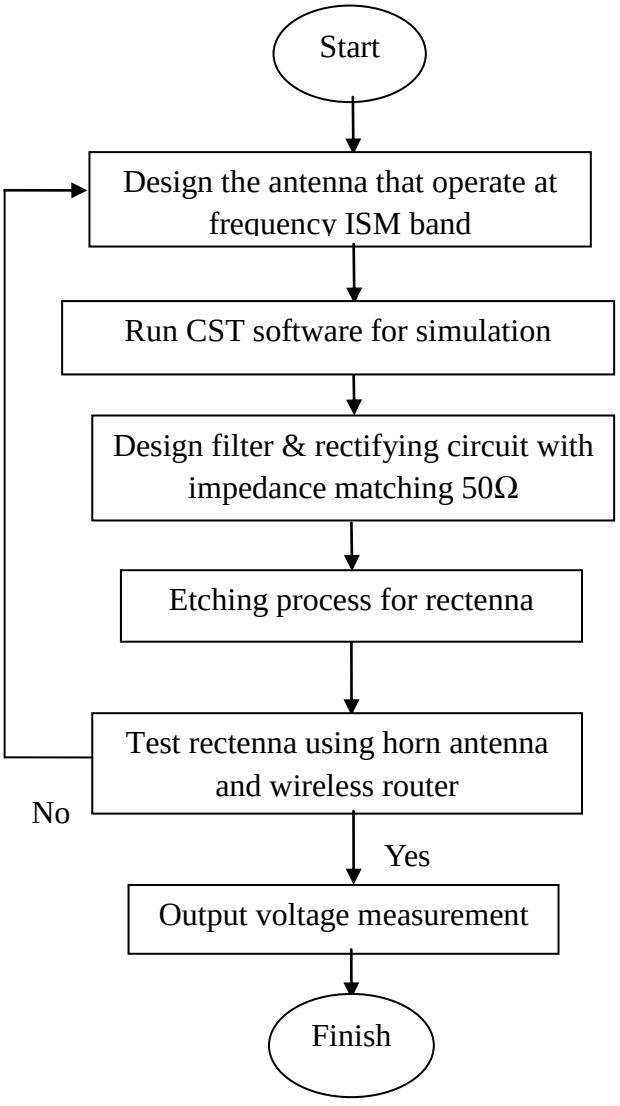

Figure 1.2 : Flow chart for the rectenna project

1.6 Thesis Outline

This report contains six chapters that will explain details on the project of designing rectenna which converting from RF energy to DC voltage.

The first chapter in this report is an introduction. This chapter will include the overview of the project which is project background, project objective, project scope, project methodology, and summarization of the project.

The second chapter is a literature review. This chapter will discuss about the fact and information from various sources before proceeds with the project. This part also discussed about the current study of rectenna findings.

The third chapter is a theoretical background for a project. This chapter will discuss about the fact, and obtains information from various sources required to precede the project. The component and any other material will be discussed within this chapter.

The fourth chapter is a methodology where it will describe the methods and techniques that have been used for this project. This chapter will give detailed information on the materials, equipment, and experimental procedures that will be used for this project.

The fifth chapter is about result and discussion. This section will explain as the result from the project, the analysis of results. The method used to analyze results will be explains.

The last chapter of this report is the conclusion and recommendation which will include overall of the project and will suggest an improvement about the project.

CHAPTER II

LITERATURE REVIEW

This chapter will discuss about the fact and information about the finding and research from various sources before proceeding with the project. This part also discussed about the current study of rectenna findings.

2.1 Wireless Energy Harvesting

Wireless energy harvesting is any of several methods of converting the signal to DC voltage without the use of cables or device-specific AC adaptors. It can be to power up or charging for a wide variety of devices, including cell phones, laptop computers and MPEG3 (MP3) players as well as larger objects, such as robots and electric cars.

S. Sudevalayam and P. Kulkarni stated that in conventional energy-constrained wireless networks such as sensor networks, the lifetime of the network is an important performance indicator since sensors are usually equipped with fixed energy supplies, e.g., batteries, which are of limited operation time. Recently, energy

harvesting has become an appealing solution to prolong the lifetime of wireless networks. Unlike battery-powered networks, energy harvesting wireless networks potentially have an unlimited energy supply from the environment. Consequently, the research on wireless networks powered by renewable energy has recently drawn a great deal of attention [5].

L. Liu and et al. stated that an ambient radio signals can be a viable new source for wireless energy harvesting to other commonly used energy sources such as solar and wind. Since radio signals carry information as well as energy at the same time, an interesting new research direction, namely "simultaneous wireless information and power transfer", have recently been pursued [6].

2.2 Microwave Energy

Microwave energy is electromagnetic waves used for wireless communication such as radio, television, and radar. There are three different microwave frequencies available for industrial application. The microwaves travel with the speed of light. Microwaves are electromagnetic waves with wavelengths longer than those of terahertz (THz) frequencies, but relatively short for radio waves. Microwaves have wavelengths approximately in the range of 30 cm at 1 mm. The term microwave generally refers to alternating current signals with frequencies between 300 MHz and 300 GHz.

Figure 2.1 shows the schematic diagram of microwave propagation, where E, H, λ, and c are electric field, magnetic field, wavelength, and speed of light, respectively as stated by Y. Kueon [7].