ENERGY HARVESTING BY USING RECTENNA

SUHAIMI BIN MAT DIN

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

Faculty Of Electronic And Computer Engineering
Universiti Teknikal Malaysia Melaka

June 2012

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : **Energy Harvesting By Using Rectenna**

Sesi Pengajian : | **0** | **8** | **/** | **1** | **2** |

Saya **SUHAIMI BIN MAT DIN**

mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (**√**) :

☐	**SULIT***	*(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	**TERHAD****	**(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☐	**TIDAK TERHAD**	

Disahkan oleh:

_____ (TANDATANGAN PENULIS)

_____ (COP DAN TANDATANGAN PENYELIA)

Tarikh: …….. Tarikh: ……..

"I hereby declare that this report is the result of my own work except for quotes as cited in the reference"

Signature :

Author : SUHAIMI BIN MAT DIN

Date : 15 JUNE 2012

"I hereby declare that I have read this report and in my opinion this report is Sufficient in terms of the scope and quality for the award of Bachelor of Electronic Engineering (Telecommunication Electronics) With Honours"

Signature :
Supervisor's Name: ENGR. NAJMIAH RADIAH BINTI MOHAMAD
Date : 15 JUNE 2012

"For my lovely parents, siblings and friends"

ACKNOWLEDGEMENT

I am grateful to the Almighty with His grace and guidance that I was able to complete this report.

First and foremost, my utmost gratitude is to Engr. Najmiah Radiah Binti Mohamad, my project supervisor for his guidance, encouragement, advice and ideas that have been poured out to me throughout this project.

I also wish to express my appreciation to my friends, Muhammad Farid and Mohd Saufi for sharing the literature and similar research interest and also for their help and encouragement in designing rectenna. I also thank my parents and family for their unceasing encouragement and support throughout my all my studies at University.

I also placed on record, my sense of gratitude to lecturers, classmates and also all who, directly or indirectly, have lent their helping hand in this project.

ABSTRACT

This thesis describes the original work on designing a rectenna for energy harvesting. Rectenna is the device that uses to capture and convert microwave signal into DC power and it is use as receiving terminal. This project is undertaken as a solution to generate the power without using either electricity or solar because in some places, this two power source is not available due to some limitation. For example in space, even the satellite have solar panel to generate energy, they also can use microwave or radio frequency to generate energy as a backup power. So, the objectives of this project is to study and design a 2.45 GHz rectenna to capture and convert microwave signal into DC power. Generally, rectenna consist of an antenna and rectifying circuit and both of them will determine the overall performance of rectenna. Rectenna was design by using CST microwave studio software and fabricated on FR4 board because the printed rectenna is low cost and easy to manufacture. Measurement experiment is carried on by transmitting different input power by using horn antenna and being measured at different load. Based on the experimental result, the maximum output voltage measure at the load is 0.842 V for 510kΩ resistor and 20 dBm input power. This project is successfully proved that new energy could be harvest by using rectenna technology.

ABSTRAK

Tesis ini menerangkan kerja-kerja asal untuk menghasilkan rectenna yang digunakan untuk penuaian tenaga. Rectenna digunakan untuk menangkap dan menukarkan isyarat gelombang mikro ke kuasa DC dan ia digunakan sebagai terminal terimaan. Projek ini bertujuan sebagai satu penyelesaian untuk menjana kuasa tanpa menggunakan samada elektrik atau solar kerana di sesetengah tempat, kedua-dua sumber kuasa ini tiada disebabkan oleh beberapa had. Sebagai contoh di angkasa, walaupun satelit mempunyai panel solar untuk menjana tenaga, ia juga boleh menggunakan gelombang mikro atau frekuensi radio untuk menjana tenaga sebagai sumber kuasa kedua . oleh itu, objektif projek ini ialah untuk mengkaji dan mereka bentuk 2.45GHz rectenna untuk menangkap dan menukarkan isyarat gelombang mikro ke kuasa DC. Secara amnya, rectenna terdiri daripada antena dan litar penerus dan kedua-duanya penting dalam menentukan prestasi keseluruhan rectenna. Rectenna direka dengan menggunakan perisian CST studio microwave dan difabrikasi di atas papan FR4 kerana rectenna cetakan lebih rendah kos dan mudah untuk direka. Pengukuran dijalankan dengan menghantar kuasa yang berbeza dengan menggunakan antena hon dan diukur pada perintang berlainan. Berdasarkan keputusan eksperimen, voltan keluaran maksimum pada perintang adalah 0.842V untuk perintang 510kΩ dan kuasa masukan 20dBm. Projek ini berjaya membuktikan bahawa tenaga baru boleh dihasilkan dengan menggunakan teknologi rectenna.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AC	-Alternating Current
DC	-Direct Current
FR4	-Flame Retardant 4
LHC	-Left-Handed Circular
PCB	-Printed Circuit Board
RHC	-Right-Handed Circular
RF	-Radio Frequency
RECTENNA	-Rectifying Antenna
SPT	-Space Solar Power Transmission
UV	-Ultra Violet
WPT	-Microwave Wireless Power Transmission

CHAPTER I

INTRODUCTION

This chapter will give an overview about the project as project background, project objective, project scope, project methodology and summary of the project. This chapter will explain briefly about the overall project progress from beginning until the project is complete.

1.1 Overview on Rectenna Technology

Since the last century, space solar power transmission (SPT) and microwave wireless power transmission (WPT) has become an interesting topic to been discussed as renewable energy in the future. Rectifying antenna or rectenna is one of the most important components in the application of SPT and WPT [1]. Generally rectenna is a device that converts microwave or radio frequency (RF) energy to direct current (DC) power. It is useful as the receiving terminal of a power transmission system where DC power needs to be delivered to a load through free space, where physical transmission lines are not feasible. It is also useful in applications where DC power needs to be distributed to a large number of load element in an array. The power distribution is achieved by the distributed nature of microwave energy in space, eliminating the need for a large number of physical interconnects to individual load elements [2]. Rectenna was use as receiving terminal in ground to ground,

ground to space and space to space transmission system [1].

The main important part in this project is an antenna. The frequency selected for antenna is 2.45 GHz which means the antenna should be able to operate in that frequency. Frequency 2.45 GHz were selected as operating frequency of this rectenna because the probability to get high efficiency rectenna is high [3] and it unlicensed frequency band. The second part in this project is to design the stub that act as filter to suppress harmonics signal. This part must be design to match the antenna and diode impedance, so that the rectenna could rectify effectively. Then the rectenna will convert the RF energy into DC power by using rectifier circuit. Rectifier circuit is consisting of schottky diode and the load resistor for power measurement. This project will be focusing on the ability of rectenna to convert RF signal to DC power.

1.2 Objectives

The objectives of this project is to study and design a 2.45 GHz rectenna to capture and convert microwave signal into DC power. Another objective is to simulate and fabricate the rectenna for wireless power transmission purpose. This rectenna project will convert the microwave energy into the DC power which is much more useful to run the device. Due to the green technology that highly demands these days, the project seem to be useful in future because it using microwave energy to generate new power and it also can be use as alternative power source in future.

1.3 Problems statement

The research regarding rectenna had been done long time ago, but there are problem reported regarding rectenna design and performance that need to fix. For example, 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 free space path loss

[4]. From another journal, Yu-Jiun Ren and Kai Chang reported that the dual diode rectenna only can provide 76% of conversion efficiency [1]. Hu Hao, Kong Li also reported that, higher rectenna frequency (e.g. 35 GHz) can reduce the aperture area and increase the transmission range but the component to generating that frequency are expensive and inefficient [5].

This project is undertaken as a solution for how to generate the power without using either electricity or solar because in some places, this two power source is not available due to some circumstance. For example in space, even the satellite have solar panel to generate energy, they also can use microwave or radio frequency to generate energy as a backup power. This project also undertaken as a solution for problems reported in related journal about designing good rectenna.

1.4 Project scope

The scope for this project is to find solution to convert the energy from 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.

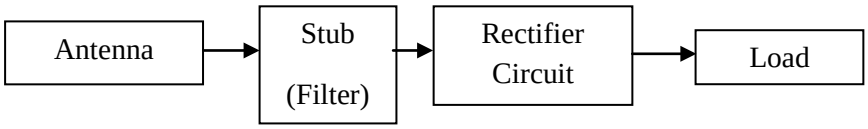


Figure 1.1 Block diagram of rectenna design

The antenna is used to capture the input incoming microwave signal and delivered to rectifier circuit. The rectifying circuit which is consist of stub (filter) and schottky diode is use to change AC microwave signal into a DC signal. The properties of diode will determine the overall performance.

The schottky diode is chosen for rectifying circuit is because that diode has lower built-in voltage that would realize a higher rectifying efficiency [6]. The function of stub (filter) in rectifier circuit is to block any harmonic generated by

diode and antenna itself. However, this project is only focus on the output and the capability of rectenna to convert microwave signal into DC power only.

1.5 Methodology

The project is started by selecting the type of antenna use for rectenna design and the operating frequency of an antenna. Then, the matching network and stub (filter) is designed to make sure the antenna is match with the circuit and reject the high order harmonic signal. Lastly, the rectifying circuit is design to convert the microwave signal to DC power.

For the antenna part, the 2.45 GHz microstrip antenna is selected for this project. Microstrip antenna is selected because it is inexpensive and small size. In this project the basic rectangular patch with slot at feeding line is chosen for rectenna configuration. An antenna is design by using CST microwave studio software

For the stub (filter) part, it is designed to pass the frequency of 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 type of diode configuration, the first is single diode configuration which is provide half-wave rectifier and the second is dual diode configuration which provide full-wave rectifier. For this project, dual diode configuration is selected.

1.6 Thesis Outline

This report consists of six (6) chapters which are will explain detail about the project of designing rectenna for wireless energy harvester.

The first chapter in this report is an introduction. This chapter will give an overview about the project as project background, project objective, project scope, project methodology and summary of the project. This chapter will explain briefly about the overall project progress from beginning until the project is complete.

The second chapter is a literature review. This chapter will discuss about the fact and information from various source before proceed to the project. This part also discuss about the current study of rectenna findings.

The third chapter is theoretical background. This chapter will review about the materials and equipments that will be use in this project. The best techniques and materials will be chosen to implement in this project.

The forth chapter is a methodology where it will describe the methods and techniques that have been used in this project. This chapter will give detail information about the materials, equipment, and experiment procedures that have been used in this project.

The fifth chapter is about result and discussion. This section will explain about the findings of this project and analysis of result. This chapter also explains about the method used to analyze the result.

The last chapter in this report is conclusion and recommendation which is will conclude the overall project and will suggest the improvement about this project.

CHAPTER II

LITERATURE REVIEW

This chapter will discuss about the fact and information about energy harvesting from various source before proceed to the project. This part also discuss about the current study of rectenna findings.

2.1 Introduction to Energy Harvesting

Energy harvesting is the process of generating energy from external resources. Energy harvesting devices will convert external resources into electrical energy that much more useful to run the devices. Some systems convert motion into electric energy such as wind turbine, water turbine, ocean waves and many more. Nowadays, there are a lot of new method to harvest the energy have been founded such as by using Vibration energy, magnetic resonant frequency, and microwave.

2.2 Energy Harvesting By Using Vibration

Vibration energy harvesting is an attractive technique for the potential powering of wireless sensors and low power devices. While the technique can be employed to harvest energy from ambient vibrations and vibrating structures, a

general requirement independent of the mechanical to electrical energy transfer mechanism is that the vibration energy harvesting device operates in resonance at the excitation frequency.

The tuneable energy harvesting device describe here consists of a cantilever beam made up of piezeoelectric material with a tip mass. Four magnets are used to apply attractive and repulsive forces, which are placed on the devices as shown in figure 2.1 [7].

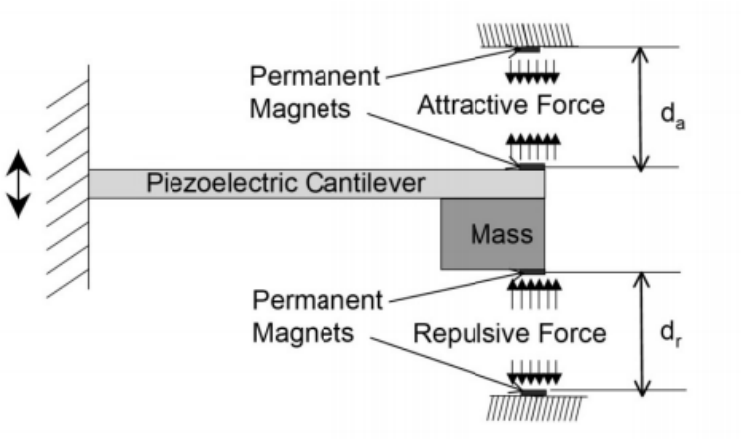
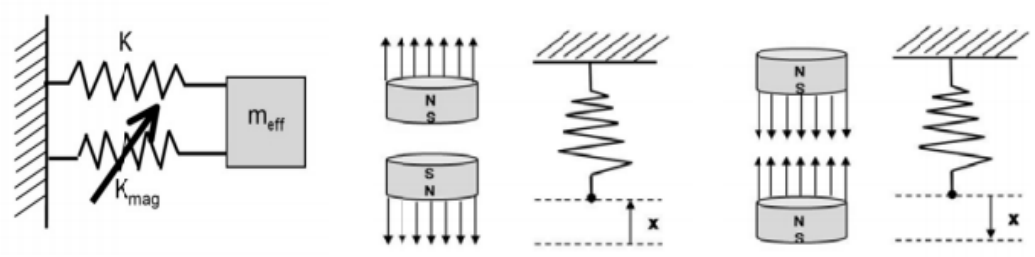


Figure 2.1 Schematic of resonant frequency tuneable energy harvesting device

These magnets apply attractive and repulsive forces at the top and bottom of the cantilever beam and can be readily interchanged. These magnetic forces induce an additional stiffness on the beam which alters the total stiffness of the device and subsequently the resonance frequency. Here the distance between the magnets is varied in order to provide the required magnetic force to tune resonance frequency.

The resonant frequency of the beam can be shifted to match booth lower and higher excitation source frequencies based on the mode (attractive and repulsive) of magnetic force. The device can be represented as a lumped model, with magnetic force as a spring constant as shown in Figure 2.2[7].



(a) Lumped model of the device

(b) Repulsive force (increased stiffness)

(c) Attractive force (decreased stiffness)

Figure 2.2 Spring equivalents for repulsive and attractive forces between magnets

2.3 Energy Harvesting By Using Magnetic Resonant Frequency

Magnetic resonant frequency is a wireless energy transfer which is the enable to provide electrical energy to remote objects without wires using oscillating magnetic fields. It is based on strong coupling between electromagnetic resonant objects to transfer energy wirelessly between them.

This differs from other methods like simple induction, microwaves, or air ionization. The system consists of transmitters and receivers that contain magnetic loop antennas critically tuned to the same frequency. Unlike the far field wireless power transmission systems based on traveling electro-magnetic waves, wireless electricity employs near field coupling through magnetic fields similar to those found in transformers except that the primary coil and secondary winding are physically separated, and tuned to resonate to increase their magnetic coupling. These tuned magnetic fields generated by the primary coil can be arranged to interact vigorously with matched secondary windings in distant equipment but far more weakly with any surrounding objects or materials such as radio signals or biological tissue.

The power can be transferred over a certain distance, but neither the power nor the distance is large enough according to current study. MIT has recently proposed a high frequency (HF, Frequency>10MHz) scheme based on strongly-

coupled resonances for medium range and non-radiative wireless Energy transfer. The scheme which is considered to be non-radiative and anti-jamming could achieve a medium-range wireless energy transfer [8].

They investigated the range and rate of coupling and the interference of extraneous objects in the view of magnetic field coupling. Based on the comparison of two resonant systems, it is discovered that the magnetic near-field in their scheme is non-lossy and the two coils are strongly-coupled. Numerically, it achieved about 60W power transfer between two resonant coils with the distance of 2m. MIT's investigation mainly focuses on the medium range non-resonant mechanism of wireless energy transfer from the perspective of the magnetic field. However, the adopted method is based on the general physical analysis for resonant coupling objects and purely physical theory, which is unfamiliar to electrical engineers. Furthermore, due to the structure of parasitic parameters resonant coil, it is difficult to determine the capacity of the parasitic capacitance accurately, which is not conducive to the circuit design. In addition, the volume of the coil is slightly larger for general mobile devices [8].

In order to analyze the relationship of the parameters in the intermediate frequency wireless energy transfer method from the mathematical point of view, a simplified model for the transfer mechanism is analyzed based on the familiar circuit theory in electrical engineering. Instead of the complex calculating on the coil mutual inductance, a macroscopic analysis of the energy transfer process can be given with the simplified model. In addition, the high order impedance characteristics of the resonator are investigated based on the electromagnetic theory. The working characteristics in the intermediate frequency of the resonator are obtained. Finally, the method was justified by simulation and experiment [8].