DESIGNING 2.45GHZ RECTENNA FOR LOW VOLTAGE APPLICATION

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"For my late father, mum and sibling"

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ABSTRACT

This project is another method to harvest energy compared to solar energy because solar energy because solar energy have some limitation. In space, even the satellite has a solar panel to generate energy, radio frequency also can be generated using as a backup power. The main objective of this project is to design a rectenna which operates at 2.45 GHz, frequency centered at ISM band that can capture the microwave signal or RF signal and convert it into DC power. Besides that, the other objective is to fabricate the rectenna for wireless transmission and applied it in low voltage application. In order to achieve these objectives, a patch antenna and rectifying circuit had been designed separately using CST Microwave Studio and then will be fabricated on FR4 board. The impedance matching for both designs are set at 50 ohms. Two Shcottky diodes (HSMS 2860) are used in the rectifying circuit that provide full wave configuration to generate DC voltage. Measurement experiment had been done by using several antennas as the transmitter and rectenna as the receiver to measure output voltage at different power transmit and load. Based on the experimental result, the maximum output voltage produce at the receiver is 2.112V for load 820kΩ and input power, 20dBm by horn antenna. This rectenna can replace power source such as battery to activate either RFID or wireless sensor. Besides, it can use to power up small electronic device such as LED and buzzer. This project is successfully proved that microwave signal can be converted to DC power by using rectenna and new energy could be harvested.

ABSTRAK

Projek ini adalah satu lagi kaedah untuk menuai tenaga berbanding dengan tenaga solar kerana tenaga solar mempunyai beberapa batasan. Di udara, walaupun satelit mempunyai panel solar untuk menjana tenaga, frekuensi radio juga boleh dihasilkan untuk digunakan sebagai kuasa sandaran. Objektif utama projek ini adalah untuk mereka bentuk rectenna yang beroperasi pada 2.45GHz,frekuensi tengah ISM band yang boleh menangkap isyarat gelombang mikro atau isyarat RF dan menukarkan ia menjadi kuasa DC. Selain itu, objektif lain adalah untuk mereka rectenna untuk penghantaran tanpa wayar dan digunakan dalam aplikasi voltan rendah. Dalam usaha untuk mencapai objektif ini, antena dan litar penerus telah direka secara berasingan menggunakan CST Microwave Studio dan kemudian dicetak pada papan FR4. Padanan impedans bagi kedua-dua reka bentuk telah ditetapkan kepada 50 ohm. Dua Shcottky diod(HSMS 2860) digunakan pada pada litar penerus yang menyediakan konfigurasi gelombang penuh untuk menjana voltan DC. Eksperimen telah dilakukan dengan menggunakan beberapa antenna sebagai penghantar dan rectenna sebagai penerima untuk mengukur voltan keluaran pada kuasa dan beban yang berbeza. Berdasarkan keputusan eksperimen, voltan keluaran maksimum yang dihasilkan pada penerima adalah 2.112V untuk 820KΩ beban dan kuasa input, 20dBm oleh antenna horn. Rectenna ini boleh menggantikan sumber kuasa seperti bateri untuk mengaktifkan sama ada RFID atau sensor tanpa wayar. Selain itu, ia boleh digunakan untuk menghasilkan elektrik untuk peranti elektronik kecil seperti LED dan pembaz. Projek ini berjaya membuktikan bahawa isyarat gelombang mikro boleh ditukar kepada kuasa DC dengan menggunakan rectenna dan tenaga baru boleh dituai.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AC	-Alternating Current
DC	-Direct Current
FR4	-Flame Retardant 4
RF	-Radio Frequency
RECTENNA	-Rectifying Antenna
ISM	- Industrial, Scientific and Medical
RFID	- Radio Frequency Identification
LED	-Light Emitting Diode
MPT	-Microwave Power Transmission
HF	-High Frequency
SMA	-Sub Miniature Version A
UV	-Ultra Violet
WPT	- Wireless Power Transmission
HPBW	-Half Power Beamwidth
FNBW	-First Null Beamwidth
CP	-Circular Polarization
UHF	- Ultra High Frequency
SWR	- Standing Wave Ratio

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 also explain briefly the overall project progress from beginning until the project is complete.

1.1 Introduction on a Rectenna

This project is focusing on designing a rectenna for energy harvesting. The rectenna is an important element for the wireless power transmission.Applications of the rectenna are mainly for receiving power where the physical connections are not possible.The emerging microwave tubes is during World War II where the rectification of microwave signals for supplying DC power through wireless transmission has been proposed and researched in the context of high power beaming since the 1950s by W. C. Brown. In the early 1960's, the first receiving device for efficient reception and rectification of microwave power emerged [1]. Microwave power transmission (MPT) has been developed since the half of the previous century. A large number of investigations presents the MPT technology as a possible solution for the problems caused by decreasing of fossil energy resources. The first circuit converting RF energy to exploitable DC energy was developed by W.C. Brown and called rectenna [2].

The rectenna (rectifying antenna) is an important device for converting microwave signal into useful DC power. A rectenna contains an antenna as the receiver which collects microwave signal and a rectifying circuit to convert RF power into DC power.

A rectifying circuit is often made up of a combination of Schottky diodes, an input HF filter, an output bypass capacitor and a load resistor. The input HF filter, localized between the antenna and diodes, is a low-pass filter which rejects harmonics created by the nonlinear diode behavior. It also acts as a matching circuit between the antenna and the rectifier.

The modeling of individual elements such as patch antenna, diode and low pass filter gives us better insight towards the optimization of parameters for enhanced efficiency of rectenna [3]. But, usually microstrip line technology is used to develop rectenna circuits. In this approach, filter components are made by varying geometric parameters of connected lines. This method constrains us to use electromagnetic simulations coupled with circuit simulations to design the rectenna circuit.

1.2 Objectives

The objectives of this project are to design and testing a rectenna which operates at 2.45GHz, frequency centered at ISM that can capture the microwave signal or RF signal surrounding us and convert into DC power. Besides, the other objective is to fabricate the rectenna for wireless transmission and applied it in low voltage application. In today's fast paced world, this project will give more benefit to nature due to the green technology because it uses microwave signal to generate new energy .Microwave energy apparently has the potential to provide environmentally clean electric power for a very large number of users.

1.3 Problems Statement

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 has a solar panel to generate energy, they also can use a microwave or radio frequency to generate energy as a backup power. Besides, ambient frequency which is wasted surround us can be converted into DC voltage. Another problem is regarding the lifetime of the batteries which is very limited even for low power batteries, requiring impractical periodical battery replacement.

Furthermore, there are some problems reported regarding the designing a rectenna and overcome due to the problem. Based on the International Journal of Engineering Science and Technology, R. K. Yadav et al reported that in general it is difficult to predict how the rectenna system is optimized for the maximum conversion efficiency [4].Besides, J. A. G Akkermans reported that using rectenna, the amounts of power that can be transferred are limited due free space path loss [5].

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1.4 Project Scope

The scope of this project involves the design, implementation and testing of rectenna circuitry for converting a 2.45GHz signal to DC power. The antenna is used to capture the electromagnetic signal surrounding us. Meanwhile, filter is used to pass the desired frequency and block unwanted harmonic frequency that occurs due diode properties and antenna. Rectifying circuit used to rectify the incoming microwave signal and convert it into a DC signal. The load is consisting of resistor for output measurement but for the low voltage application the load can be replaced with LED, RFID and wireless sensor.

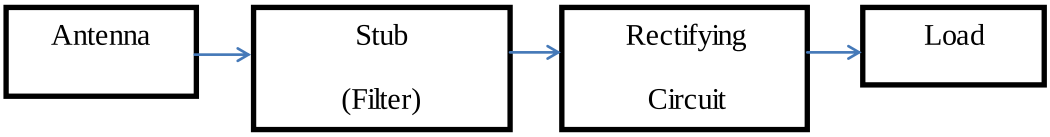

Figure 1.1: Block diagram of rectenna design

1.5 Methodology

The project is started on designing a printed antenna that can operate on 2.45GHz by using CST Microwave Studio. The antenna is design separately from the rectifying circuit. The proposed antenna design is designing with truncated edges to generate circularly polarized which is attractive for wireless transmission to maximize the output of the conversion.

Then, the rectifier which is matched with the impedance of the antenna is designed. There are two methods of designing the rectifier which is a half wave rectifier with single diode configuration and full wave rectifier with dual diode configuration. Full wave rectifier was selected for this project because it can provide twice higher DC output compared to half wave rectifier. To suppress re-radiation and to maximize the power conversion, low pass filter (or band pass filter) is placed between the antenna and rectifier setup. The cutoff frequency for low pass filter has been selected such that second harmonic signals are rejected. Numerous types of filters have been reported for rectenna second harmonic rejection [6] [7].Rectifier should be designed with zero biased Schottky diode [8]. The selected diode should be able to rectify at very low input power, typically -10 dBm to 0 dBm.

The filter designed is a band pass filter that passes the frequency 2.45GHz and with low insertion loss. Besides, this filter design can block higher order harmonic frequency. To avoid unwanted power dissipation, the harmonics generated by the diode need extra attention. To avoid dissipation of the harmonics in the load, a radial stub that is placed between the Schottky diode.

Then, the matching circuit between the antenna and rectifying is done. The impedance antenna and the rectifying circuit must be matched because the output of the antenna will be the input for rectifying circuit. The impedance matching stage is essential in providing maximum power transfer from the antenna to the rectifying circuit.

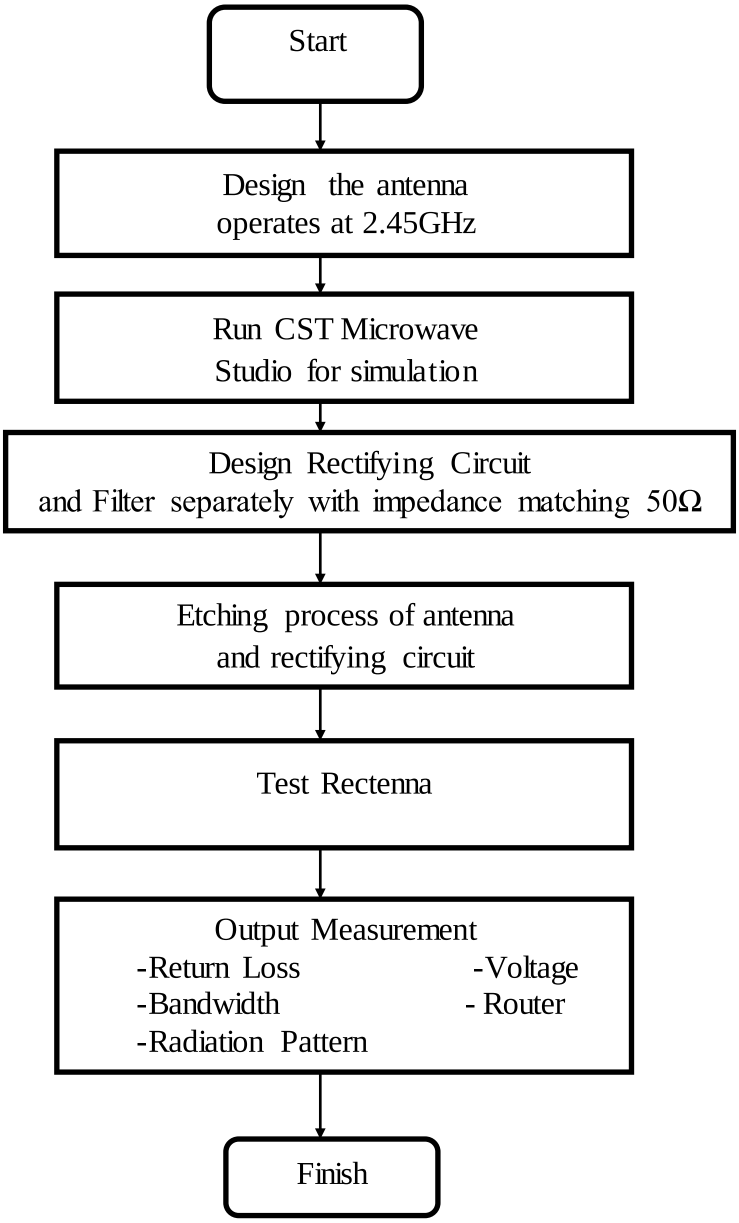

Figure 1.2 : Flow Chart for the Rectenna Project

1.6 Thesis Outline

This report consists of six (6) chapters which are will explain detail about the project of designing a 2.45GHz rectenna for wireless energy harvesting.

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

The second chapter is a literature review. This chapter delved into the history of RF and discussed the pioneering effort of the early scientists who showed and confirmed the presence of RF within the electromagnetic spectrum. The developments that have taken place and the improvements since the Second World War are also highlighted.

The third chapter is theoretical background. This chapter will review the equipment and devices used to complete the experiments. The best techniques and materials will be chosen to implement in this project.

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

The fifth chapter will present in the results of the project and conditions that were met from the implementation and realization of the rectenna system for low voltage application.

The last chapter gives the conclusions and future work proposed for the Wireless Power Transmission concepts. Besides, the improvement of the design of the rectenna will also discussed.

CHAPTER II

LITERATURE REVIEW

This chapter will discuss about the fact and information about microwave wireless power transmission and current study of finding of rectenna.

2.1 Overview of Microwave Wireless Power Transmission

The concept of Wireless Power Transmission (WPT) is to transmit DC power from one point to another through the atmosphere without the physical need of transmission lines. WPT could be realized by microwave or electromagnetic. This process usually involves direct current (DC) to alternating current (AC) power conversion. Besides, this process followed by the transmission of electromagnetic wave through radiation from the antenna. The electromagnetic wave is collected and converted into DC to power load for receiving part. The load is either a resistor or low voltage devices.

The difference between WPT and microwave transmission for communication is the concentration of electromagnetic energy. WPT tends to be focused with a higher concentration of beam energy towards the receiver as illustrated in Figure 2.1. Usually microwave WPT involves conversion of DC power to radio frequency (RF) for transmission. At the receiving station, the radio