DESIGN OF RECTIFYING CIRCUIT WITH IMPROVED RF-DC CONVERSION FOR WIRELESS POWER TRANSFER

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DECLARATION

I declared that this thesis entitled "Design of Rectifying Circuit with Improved RF-DC Conversion for Wireless Power Transfer" is the result of my own research except as cited in the reference

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APPROVAL

I hereby declared that I have read this thesis and in my opinion, this thesis is sufficient in term of scope and quality for the award of the Bachelor Degree in Electronic Engineering (Telecommunication Electroniocs) with Honours.

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ABSTRACT

Energy harvesting system is a system that able to generate power from the ambient sources such as Radio Frequency (RF), solar, wind, motional, thermoelectric, and piezoelectric. As the demand for power increased, energy harvesting system is found to be one of the methods that can be applied. Thus, a rectifying circuit for RF energy harvesting system was introduced. A single stage and double stage rectifying circuit are designed, simulated, fabricated and measured in this study by using the Agilent Advanced Design System (ADS) 2011. Simulation and measurement were carried out for various input power levels at frequency 2.45 GHz. An experimental study had been carried out by varying the load of the rectifying circuit, R. Voltage regulator circuit LP2951 is connected to the rectifying circuit in order to produce a stable regulated output voltage. An input power of 15dBm, the system managed to produce 3.838V for single stage rectifying circuit and 7.812V for the double stage rectifying circuit. When rectifying circuit connected with a voltage regulator circuit, whole system is able to produce 4.038V regulated output voltage at 20dBm for single stage and 4.07V regulated output voltage at 20dBm for double stage. From the measured output voltage result, the maximum efficiency is 8% for single stage rectifying circuit and 33% for the double stage rectifying circuit. The design of rectifying circuit can be used to run low power device such as emergence relief and temperature sensor. The rectifying circuit also can be used to charge up mobile phone.

ABSTRAK

Sistem penuaian tenaga adalah satu sistem yang mampu menjana kuasa daripada sumber-sumber persekitaran seperti Frekuensi Radio (RF), solar, angin, penggerakkan, termoelektrik dan piezoelektrik. Disebabkan permintaan terhadap kuasa meningkat, sistem penuaian tenaga didapati merupakan salah satu kaedah yang boleh digunakan. Oleh itu, reka bentuk litar untuk RF sistem penuaian tenaga diperkenalkan. Satu and dua peringkat litar direka bentuk, simulasi, fabrikasi dan diukur dalam kajian ini dengen menggunakan perisian Advance Design System (ADS) 2011.Simulasi dan pengukuran telah dijalankan bagi pelabagai tahap kuasa input pada frekuensi 2.45 GHz. Satu uji kaji telah dijalankan dengan mengubah beban litar,R. Litar Voltan pengatur LP2951 turut disambungkan dengan litar untuk menghasilkan voltan keluaran terkawal yang stabil. Bagi kuasa masukan sebanyak 15dBm, sistem berjaya menghasilkan 3.838V bagi litar satu peringkat dan 7.812V untuk litar peringkat berganda. Apabila litar disambungkan dengan litar pengatur voltan, seluruh system mampu menghasilkan voltan keluaran yang terkawal selia pada 20dBm adalah sebanyak 4.038V untuk peringkat satu dan voltan keluaran yang terkawal selia pada 20dBm adalah sebanyak 4.07V untuk peringkat berganda. Dari hasil voltan keluaran diukur, kecekapan maksimum ialah 8% bagi litar peringkat satu dan 33% untuk litar peringkat berganda. Litar boleh digunakan untuk menjalankan peranti kuasa rendah seperti isyarat kecemasan dan pengesahan suhu. Litar juga boleh digunakan untuk mengecas telefon mudah alih.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABRREVIATIONS AND ACRONYMS

RF	Radio Frequency
ADS	Agilent Design System
DC	Direct Current
AC	Alternating Current
PCB	Printed Circuit Board

LIST OF APPENDIXES

CHAPTER I

INTRODUCTION

1.1 Research Background

In recent years, the demand on the energy harvesting circuit for power and energy harvesting application has been increased. There are several types of energy harvesting, such as Radio Frequency (RF) energy harvesting, solar energy harvesting, wind energy harvesting, emotional energy harvesting, thermo-electric energy harvesting, and piezoelectric energy harvesting that can used to capture the energy from a controlled or ambient environment to power on the devices directly or store the energy in capacitors or in batteries. Energy harvesting is widely used for the low power device and low power circuit such as sensor, biomedical implants and radio frequency identification (RFID) [1].

Figure 1.1 shows the block diagram of the energy harvesting system. The source of the radio frequency (RF) can be generated from base stations, wireless internet, satellite communication, radio, TV and etc. The general energy harvesting system consists of an antenna that harvest RF energy, a matching circuit that connected between antenna and rectifier and power storage or port that can connect to a device. The basic functionality of the RF energy system is the antenna will receive the RF signal, then it will pass to rectifying circuit to perform conversion from RF to DC by diode. Then converted DC energy will be stored in storage device or directly as a power source to a low power consumption device.

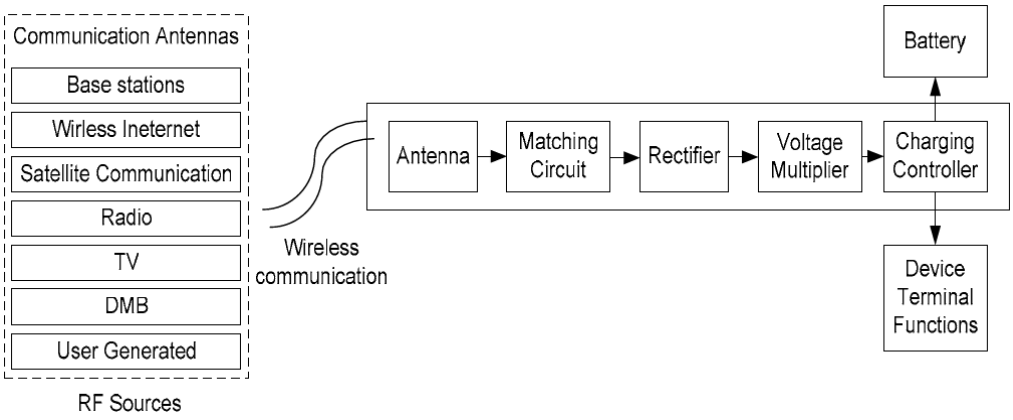

Figure 1.1: Block diagram of RF energy harvesting, courtesy of [2]

Furthermore, RF energy harvesting also can overcome the limited use of Wireless Sensor Networks (WSNs) that conventionally rely on battery. Application of RF energy harvesting in WSNs is able to reduce the cost of maintenance and extend the operation period of the WSNs [3].

1.2 Problem statement

Finite electrical battery life provides researchers and company's motivation to generate a new idea and technologies produce wireless mobile devices to have an infinite or enhanced period of time [2]. Battery in wireless mobile devices is the main power source of power on the device. Batteries in wireless mobile devices increase the size of the device. Besides, the battery is not environmentally friendly and cause pollution the environment [4]. RF energy harvesting is able to support various applications. Besides, RF energy harvesting can increase the lifetime of the devices. RF energy harvesting is able to reduce or eliminate the usage of the battery in the devices [1]. The challenge of this technology is the efficiency of the RF energy harvesting system to convert the RF energy into DC energy. Due to the rectifying circuit mostly will affect the performances of the energy harvesting system. Thus, the design of the rectifying circuit has to provide a great efficient in converting RF energy to DC. The ON/OFF characteristic and the threshold voltage of the diode in the rectifying circuit will affect the RF-DC conversion performance of the rectifying circuit [5]. In recent design such as [1] use CMOS to design the rectifier circuit. This type of method increases the cost to produce the rectifying circuit and cannot produce high DC voltage. Thus, by using a Schottky diode that provides low forward voltage and high switching speed and increase the stages of the rectifying circuit can increase the efficiency of RF-DC conversion for the rectifying circuit.

1.3 Objectives

The objectives of this project are to develop a high efficiency and low consumption of RF-DC conversion for rectifying circuit to covert the Radio Frequency (RF) energy into direct current (DC). In order to achieve this, some of the objectives need to be accomplished:

a. To design a rectifying circuit in order to improve the RF-DC conversion
b. To analyze the performance of rectifying circuit.
c. To fabricate and validate the simulation results with experimental results in the laboratory.

1.4 Scope of Project

The main objective of this project is to design a rectifying circuit with high efficiency and low consumption of RF-DC conversion for RF wireless power transfer. Before the design the rectifying circuit, firstly we have to do research on the RF energy harvesting to narrow down the scope of the research which is on rectifying circuit. Research can be based on journals from the internet or library. The focus of this project is to design, analyze, fabricate, test and measure the rectifying circuit to improve the RF-DC conversion for RF wireless power transfer. The software will be used to develop and analyze for the rectifying circuit is Agilent Advance Design System (ADS2011). Firstly, the analysis will be working on Schottky diode in the rectifying circuit. The Schottky diode must have a low forward voltage and high output voltage. Next, the analysis will be work on the stages of the rectifying circuit. Analysis only will work on the single stage and double stages of the rectifying circuit. Stages of the rectifying circuit can affect the performance of the rectifying circuit. Then, analysis will be carried on varies the value of the load resistor in the rectifying circuit from a range of 100 Ω to 1 MΩ. Then, design a voltage regulator to maintain the DC level from the rectifying circuit. Next, design a simple matching circuit and carry out the analysis of the matching circuit. When the rectifying circuit with impedance matching completed, the fabrication of rectifying circuit can carry out. Then, testing and measuring will carry out on the rectifying circuit. Finally, the rectifying circuit will be combined with antenna in order to carry out testing for the whole RF wireless power transfer system by using the lab equipment to measure the performance of the RF-DC conversion of the rectifying circuit.

1.5 Methodology

1.5.1 Project Planning

Project Planning is very helpful in tracking the progress of the project. A Gantt chart is constructed to implement the project. The Gantt chart is prepared for the purpose of to ensure the all the progress are meets the dateline and achieves the milestones. Figure 1.2 shows the Gantt chart of the project and milestone of the project.

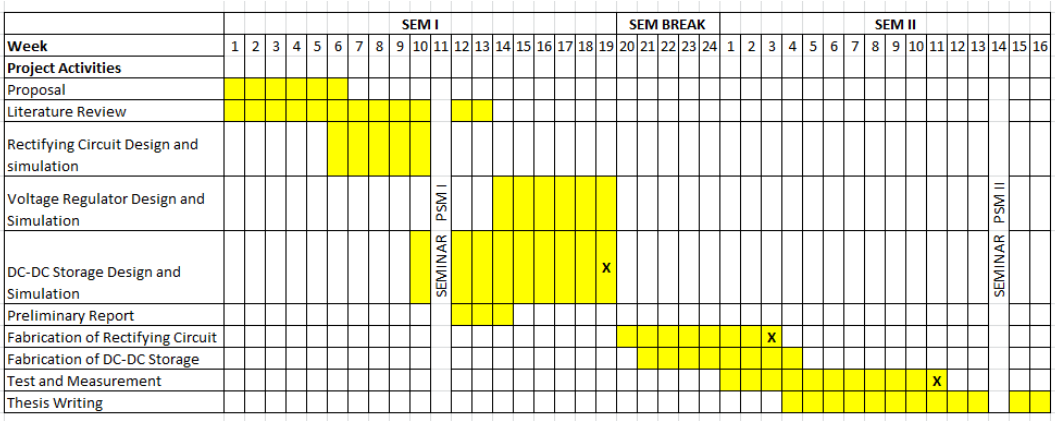

Figure 1.2: Gantt chart of the project.

1.5.2 Data Collection

Literature review is the first step has to be done before start to design the rectifying circuit. The literature review will be the focus of the research paper or journal that related to the RF energy harvesting and rectifying circuit. Literature