OPTIMUM DESIGN OF RECTIFYING CIRCUIT OF RF ENERGY TRANSFER

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BORANG PENGESAHAN STATUS LAPORAN

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Tajuk Projek : OPTIMUM DESIGN OF RECTIFYING CIRCUIT OF RF ENERGY TRANSFER

Sesi Pengajian :

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Supervisor's Name : Assoc. Professor Dr. Zahriladha bin Zakaria

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By The Name of Allah the Most Gracious, Most Merciful

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ABSTRACT

Radio Frequency Energy Transfer is a research area of on demand technology, related to sustainability which could turn into a promising alternative to existing energy resources. Energy harvesting offer a potential solution to the barrier faced by Wireless sensor networks (WSNs) in order to supply power without the need of wiring and also replacement of battery. One of the crucial parts in RF Energy Harvesting is rectifying circuit that converts the RF signal to DC signal. In this project an optimum rectifying circuit is designed, simulated by using the Advance Design System (ADS) 2011 software then fabricated and measured in the laboratory. Frequency 2.4GHz are proposed for this project. This rectifying circuit consists of a single stub matching network, voltage doubler and dc to dc converter at the output port of rectifier. The simulation result of rectifying circuit is 6.7V while in the measurement the output result is 6.2V at input signal 20 dBm. When connect with dc to dc converter the output voltage boost to 10.5V at 20 dBm power input.

ABSTRAK

Penuai tenaga radio frekuensi adalah bidang penyelidikan mengenai teknologi permintaan, yang berkaitan dengan kelestarian tenaga dimana ia menjanjikan alternatif bagi menggantikan sumber-sumber yang sedia ada. Penuai tenaga menyediakan penyelesaian berpotensi bagi masalah yang dihadapi oleh rangkaian sensor tanpa wayar (WSNs) bagi membekalkan kuasa tanpa memerlukan pendawaian dan atau bagi menggantikan bateri. Salah satu bahagian yang terpenting dalam penuai tenaga RF adalah litar penerus yang menukarkan isyarat RF kepada isyarat DC. Dalam projek ini, optimum litar penerus telah direka, disimulasi, dibina dan diukur dengan menggunakan perisian Advance Design System (ADS) 2011. Frekuensi 2.4GHz telah dicadangkan untuk projek ini. Litar penerus ini terdiri daripada "single stub matching network", litar voltan pengganda dan pengubah dc ke dc. Hasil simulasi litar penerus adalah 6.7V manakala bagi hasil ukuran ialah 6.2V pada isyarat masukan 20dBM dan apabila litar penerus disambung bersama pengubah dc ke dc keluaran dihasilkan semakin meningkat kepada 10.5V.

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LIST OF ABBREVIATIONS AND ACRONYMS

AC	-	Alternate Current
ADS	-	Advanced System Design
DC	-	Direct Current
EM	-	Electromagnetic
HB	-	Harmonic Balance
FR4	-	Flame Retardant 4
PCB	-	Printed Circuit Board
RF	-	Radio Frequency
WLAN	-	Wireless Local Area Networks

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Power, when talking about wireless communications, is a feature that is really important to take into account because of the influence it has on the autonomy, weight and size of portable devices. Therefore, energy harvesting techniques have been proposed to try to give solution to this problem: there have a variety of alternative energy sources that are less harmful to the environment. This kind of environmental friendly energy sources include energy harvesting from rectennas, passive human power, wind energy and solar power. Power can extract from those techniques is limited by regulations and free-space path loss. As a general idea, small dimensions are a basic feature of portable devices, so the rectenna should be the same way. The small sizes devices, the received power will be low. As a conclusion, can be said that wireless power transfer is better suitable for low-power applications, e.g., a low-power wireless sensor.

The way technology advance every year allow the decrease of certain characteristics in digital systems, like size and power consumption, that will lead to the gain of new ways of computing and use of electronics, as an example wearable devices and wireless sensor networks. Currently, these devices are powered by batteries, however, they present many disadvantages such as: the need to either replace them or recharge them periodically and their big size and weight compared to high technology electronics. A solution proposed to this problem was stated before: to extract (harvest) energy from the environment to either recharge a battery, or even to directly power the electronic device. Fig.1.1 shows the improvements in technology comparing batteries with other devices.

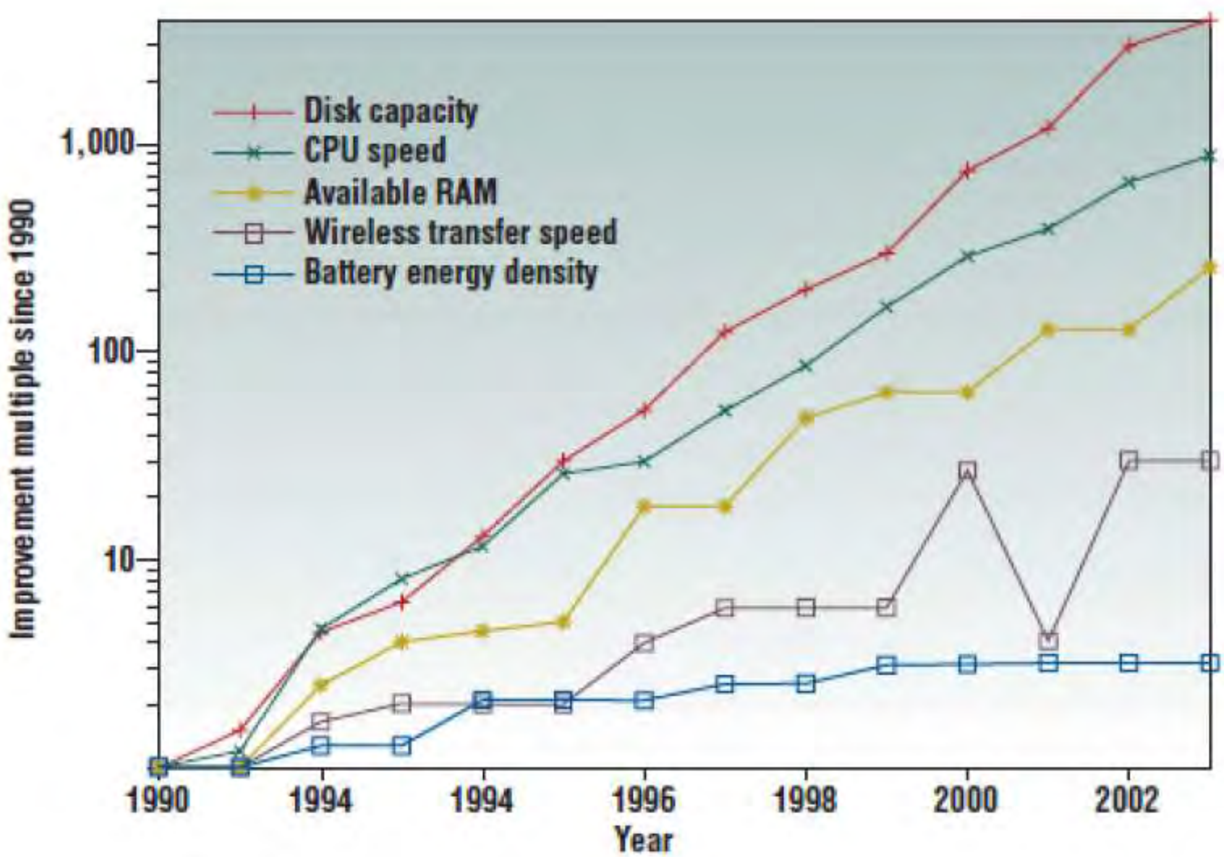

Figure 1.1: The improvements in technology comparing batteries with other devices [1].

Harvesting wireless power techniques are mostly based on radio-frequency identification, or RFID. Basically, the transmission part sends RF signals that carries information to a chip to convert it to DC electricity to power the application. Then, a tag composed by an antenna and a microchip responds by sending back data about the object it is attached to. In order to be able to transfer power wirelessly an efficient rectenna is needed. Therefore, a rectenna design modeled with numerical analysis and harmonic balance simulation. This provides a good insight in the effect of the several parameters on the performance of the rectenna. In Figure 1.2 show the system works: First, the antenna (a circularly polarized antenna) is in charge of capturing all the RF signals; then the rectifier circuit will"extract" the power from those signals and convert it in DC voltage efficiently. Finally there is a regulator circuit capable of working with low input voltages which is desirable for this kind of project.

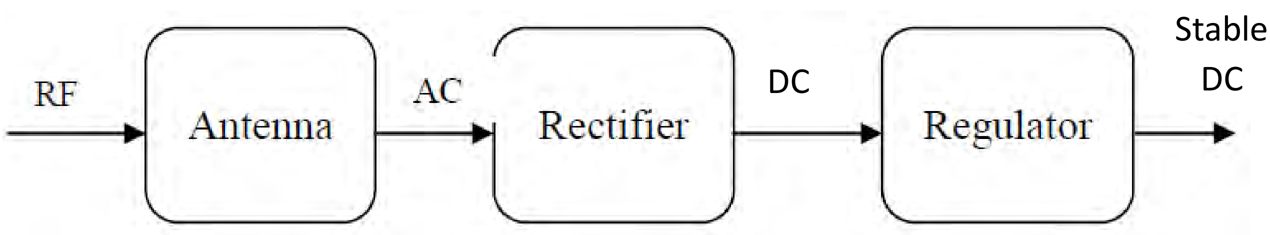

Figure 1.2: Complete system block diagram.

Several operating frequencies for the rectenna have been investigated in the literature. Traditionally the 2.45 GHz Industrial Scientific and Medical (ISM) band has been utilized due to the presence of Wi-Fi networks; additionally the 5.8 GHz ISM band has also been considered which implies a smaller antenna aperture area than that of 2.45 GHz. Both frequency bands present similar advantages because they have comparably low atmospheric loss, cheap components availability, and high conversion efficiency. The frequency bands corresponding to mobile telephone systems such as 800 MHz, 900 MHz and 1800MHz also present good alternatives for electromagnetic energy harvesting systems, although they require a larger antenna size.

This work has two goals: (1) powering of low-power applications and (2) RF energy recycling. If consider the use of batteries has some disadvantages like the limited life period they have, plus the pollution generated from their disposal, it is very encouraging to think that if every wireless sensor in the world have the kind of power source presented in this work, it would be a great progress in the way try to keep our planet clean.

1.2 Problem Statement

In recent years, there is a rapid increase in using of wireless devices in many applications such as mobile phones and sensor networks. These devices are powered by a portable and limited energy device such as a battery. This means that the increasing of application usage will cause the used of batteries also increased and these battery needs to be replaced so often. These batteries are containing of heavy metals, where if improperly disposed it can leak it contain into the surrounding environment thus increased pollution. Thus, the use of green technology like this RF energy system is one of the solutions to overcome this problem due to advance in wireless broadcasting and communication system that generated the availability of free energy.

The main problem in RF energy harvesting system is the amount of captured energy from ambient RF sources is very low. The current design of rectifier DC conversion efficiency about 50%. This low level power maybe caused by the level of RF energy and the mismatching of the antenna to the rectifier. In order to capture maximum power, the receiving antenna should be designed properly by taking consideration of many factors to achieve impedance matching between the antenna and the rectifier at the operating frequency and also to obtain maximum power transfer and reducing transmission loss from PCB traces. In this project the optimum design of rectifier DC conversion about 70%. Thus, to convert more of the antenna surface incident RF power to DC power, high efficiency of RF to DC conversion is required by the rectifying circuit.

1.3 Objective

The objective of this project is to study and analyze the behavior of impedance matching, power divider and rectifier circuit. Besides, to design cascade circuit to produce optimum efficiency as well as to fabricate and validate the design in the laboratory that can operate at frequency 2.4GHz

1.4 Scope of Project

The main purpose of this project is to design optimum rectifier that able to convert RF energy to DC energy efficiently. This project start with understanding and analyzing rectifying circuit that consists of single stub matching network, Wilkinson power combiner and also voltage divider. All the information is obtain through journals, books and paperwork on the internet.

This project is focus on the designing the optimum rectifier able to convert RF energy to DC power. The proposed frequency of this project is 2.4GHz. The performance of the rectifier influence by the load of the resistor. Several value of the loads is analyzed to give the optimum performance of the rectifier circuit. Besides, other main element that affect the circuit is the selection of the diode. A diode with fast switching time will produce high efficiency of the circuit.

The designing and simulation of all the circuit is using Advance Design System (ADS 2011) which is use the Harmonic Balance as simulation method. Last but not least, the complete circuit is fabricated and performance of the circuit is measured in the laboratory by using signal generator as power source.

1.5 Project Planning

The Gantt chart in Figure 1.3 show the step by step work need to be done on the right time. This Gantt chart helps to guide and complete each task on time. The flow chart show in Figure 1.4 the flow of the project development. This project start with the briefing on the final year project then analyze the specification of the rectifying. Lastly end with submission of fabrication circuit as well as thesis report.

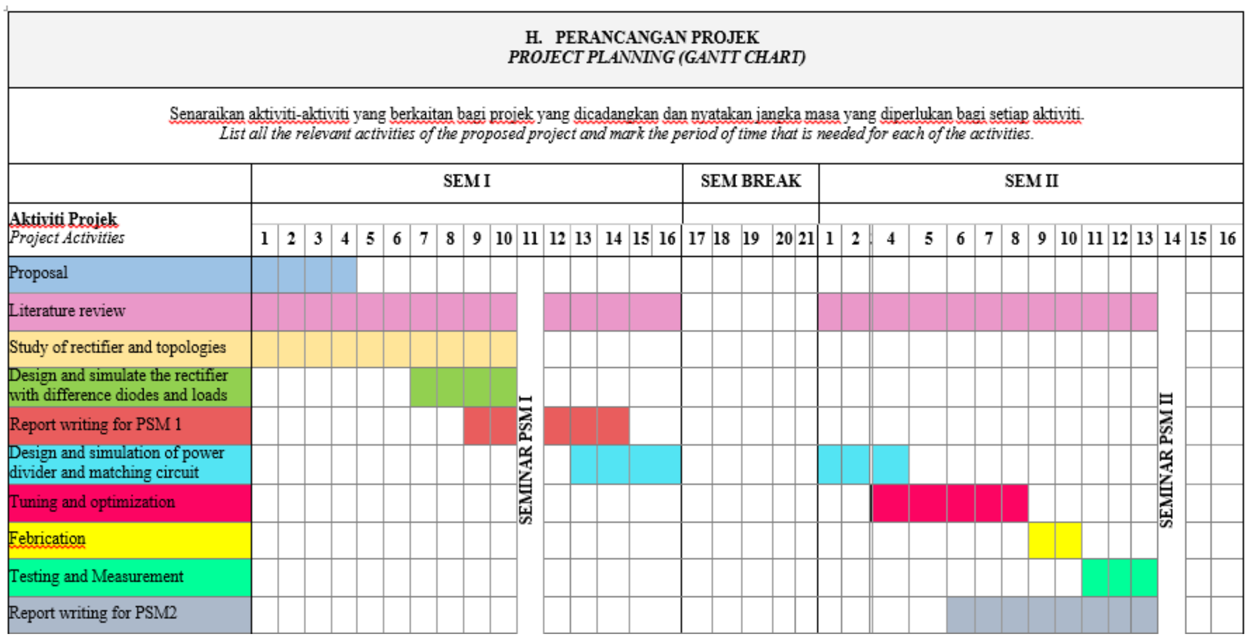

Figure 1.3: Gantt chart of the project planning

1.6 Outline of the Project

In this thesis consist of five chapter which organized as follow:

First of all, chapter 1 describe about research background of RF energy harvesting. This chapter consist of problem statement and objective of the project. Besides, the scope of the project and organization of the thesis as well.

In chapter 2, the theoretical of the main components of the project such as rectifier, matching network, power combiner, diode and loads use in rectifier, harmonic balance simulator as well as tuning and optimization are briefly explained in this chapter. Relevant work also presented.

Chapter 3 highlight on the methodology of the project, step by step task is carry on to complete the project. In this chapter also show the calculation part of impedance matching and the Wilkinson power divider. The transformation of lumped element to the transmission line also be explained. On top of that, the fabrication and the measurement part also be explained in this chapter.

Chapter 4 focuses on the result of simulation rectifier and the full circuit. The measurement will be compared with the measurement results. The result and finding are discussed and the setup used for RF measurement is also introduced.

In last chapter, chapter 5 highlight the outcome and conclusion of the project. It provides recommendations and future work for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In recent years the use of wireless devices is growing in many applications like mobile phones or sensor networks. This increase in wireless applications has generated an increasing use of batteries. Many research teams are working on the autonomy of the batteries by reducing the consumption of the devices. The charging of multiple applications is easy because the user can do it easily, like for mobile phones. But for other applications, like wireless sensor nodes located in difficult access environments, the charging of the batteries remains a major problem. This problem increase when the number of devices is large and are distributed in a wide area or located in inaccessible places. Besides, the growing implications of energy costs and carbon footprints, the need to adopt inexpensive, green energy harvesting strategies are of paramount importance for the long-term conservation of the environment and the global economy. [2]

The uses of the Wireless Power Transmission (WPT) allow the overcoming of these problems. The rectification of microwave signals to DC power has been proposed and researched in the context of high-power beaming since the 1950s [3]. It has been proposed for helicopter