DESIGN A DUALBAND RECTIFYING CIRCUIT FOR RF POWER TRANSFER

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FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : A Dual Band Rectifying Circuit For RF Power Transfer

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DEDICATIONS

To Allah The Almighty

I devoted my life and death to You, Allah. May my life be within Your guidance.

To My Parents

Thank you for your sacrifice and love till the end of your life. Your souls have always remained forever in my heart. No such compensation except Allah.

To My Supervisor and Lecturer

Thank you for all the knowledge and support. Your support, patience, and encouragement give me strength throughout the whole course.

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ABSTRACT

Energy harvesting known as power harvesting is the process of capturing available energy from a variety of sources such as solar, wind and thermal, and convert it for any practical purpose. Radio Frequency (RF) be one of an available energy in the environment that can be harvested due to the number of mobile base station and handsets continues to increase. Nowadays, low application device or equipment are powered up by batteries which the batteries have a limitation in term of life span. Therefore, a dual band rectifying circuit for RF energy power transfer is invented to harvest an energy from RF source which has the potential to produce a low DC power energy. This dual band rectifying circuit is designed to operate at the frequency 1.8GHz and 2.45GHz with an additional Wilkinson Power Combiner circuit acts as a matching circuit to achieved a high performance of RF-DC conversion. Advance design system (ADS) is a tool used to analyze, validate and fabricate the design of the rectifying circuit. The rectifying circuit is injected with two different frequency while the input power is varying from -20dBm until 20dBm for both simulation and measured. As a result, if only 1.8GHz frequency is injected at once, the output voltage can achieve until 5V while for input frequency 2.45GHz the output voltage can obtain around 3V for input power 20dBm. But, if both input frequency is injected at the same time, the output voltage can reach until 7V for 20dBm input power. Based on the output voltage, the highest efficiency for this rectifier is 91.56% which is produced for the input power is 15dBm. As a conclusion, the output of the rectifier can be used to run any application such as wireless sensor network which needs a low power to turn it on.

ABSTRAK

Penuaian tenaga atau dikenali sebagai penuaian kuasa adalah proses menangkap tenaga yang tersedia ada dari pelbagai sumber seperti tenaga solar, angin dan haba, lalu ditukarkan kepada satu tenaga lain yang boleh guna pakai. Oleh kerana kadar peningkatan stesen pengkalan mudah alih dan telefon bimbit yang semakin meningkat, radio frekuensi menjadi salah satu sumber tenaga tersedia yang boleh digunakan untuk proses penuaian. Kini, hampir kesemua alat peranti elektrik dan elektronik menggunakan bateri sebagai sumber tenaga dimana bateri. Tetapi penggunaan bateri sangat had terutamnya dari segi jangka hayat. Oleh sebab itu, dua jalur litar penerus dicipta untuk memerangkap sumber tenaga dari radio frekuensi dimana arus tenaga terus dapat dihasilkan sebagai keluaran. Litar penerus inin dicipta untuk beroperasi pada frekuensi 18GHz dan 2.45GHz dengan penambahan litar penggabung Wilkinson yang berfungsi sebagai litar sepadan untuk menghasilkan penukaran tenaga Radio Frekuensi ke arus terus yang optimum. Perisian Advance Design System (ADS) digunakan untuk menganalisis, mengesahkan dan mereka cipta litar penerus tersebut. Dua jalur litar penerus tersebut akan dibekalkan dengan dua input frekuensi yang berbeza disamping kuasa input yang berbeza-beza bermula dari −20dBm sehingga 20dBm. Keputusan akhir menunjukkan, jika hanya satu input frekuensi iaitu 1.8GHz digunakan dalam sesuatu masa, voltan keluaran adalah 5V tetapi jika hanya 2.45GHz input frekuensi digunakn keluaran voltan boleh mencecah 3V untuk input kuasa 20dBm. Apabila kedua-dua input frekuensi digunakan secara serentak voltan keluaran boleh mencecah sehingga 7V. Kecekapan litar penerus ini boleh mencecah sehingga 91.56% apabila input kuasa 15dBm. Konkluksinya, keluaran dari litar penerus ini boleh diguanakan untuk pelbagai aplikasi seperti rangkaian pengesan tanpa wayar yang memerlukan sumber tenaga yang rendah untuk menghidupkannya.

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RF	Radio Frequency
DC	Direct Current
ADS	Advance Design System
FR4	Flame Retardant 4
WPT	Wireless Power Transmission
AC	Alternating Current
PCB	Printed Circuit Board

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CHAPTER 1

INTRODUCTION

1.1 Project Overview

Nowadays, energy harvesting has been a popular topic among the researchers, especially in the wireless communication field. The first concept of wireless energy transmission who is invented by Nikola Tesla in 1890 has been developed by researchers so that it can be applied in many applications. Normally, an active device like the battery is used to inject power into a circuit due it capability to produce an energy in the form of voltage or current. Since the battery has a life span, an unlimited power source is needed to replace the battery due to its limitation. The passive power device is introduced because this device can extract their power from unlimited sources such propagating radio waves or other forms without requiring any internal power sources.

One of the popular passively power devices is a radio frequency (RF) signal. (RF) energy harvesting is developed based on wireless energy transmission technique for harvesting and recycling ambient RF energy that is widely broadcasted by many wireless systems such as mobile communication system, Wi-Fi based station, and wireless portable devices. In addition, the increasing number of radio transmitter makes ambient energy is available in many frequency bands. This scenario makes RF harvester capable of

operating in multiple bands. At the end, this system can apply in any places as long there is the available frequency in that area.

Even RF energy is an unlimited source obviously, but it most limited source in term of power density, for example, RF (0.01~0.1μW/cm^2), photovoltaic (10μW/cm^2~10mW/cm^2) and thermal (10μW/cm^2~10mW/cm^2) **[1].**

Table 1.1: Energy harvesting source

Energy source	**Characteristics**	**Efficiency**	**Harvested power**
Light	Outdoor Indoor	10 ~ 24%	100mW/cm^2 100uW/cm^2
Thermal	Human Industrial	~ 0.1 % ~ 3%	60uW/cm^2 ~1 – 10mW/cm^2
RF	GSM 900 MHz WIFI	~ 50%	0.1uW/cm^2 0.001uW/cm^2

RF energy harvesting is a process that converts a suitable DC power from an unlimited source such an ambient RF energy. The main element of the RF energy harvesting system is shown in Figure 1.1. Matching circuit consist of the conductive and inductive element to ensure the maximum input power delivery from the antenna to rectifier **[2].** A good matching circuit depends on its capability to deliver maximum input power to the rectifying circuit. The challenges task to design dual band rectifier is to match the rectifier with a two frequency band and at the same time minimize the sensitivity of rectifier **[3].** Rectenna are the combination of rectifier and antenna that was initially designed by W. C. Brown for converting the microwave power into direct current DC power **[4], [5].** Rectenna is the key block of the front end receiving a portion of a wireless powering system. The rectifier will give a smooth DC power by transform RF energy that captured by antenna **[1].**

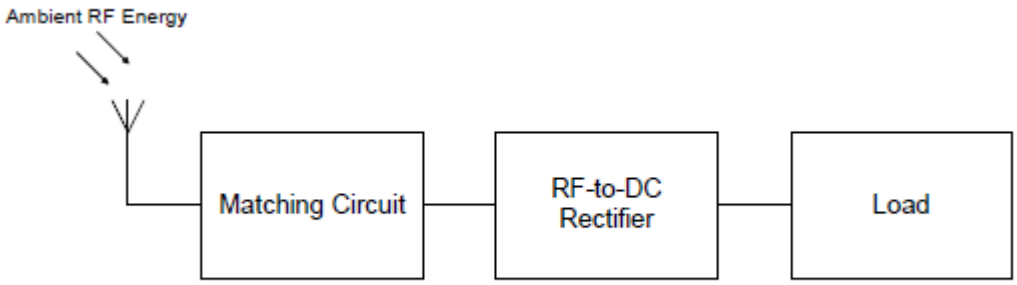


Figure 1.1: Block diagram of RF energy harvesting system

One of application is a rechargeable circuit. By applying this system to the rechargeable circuit, it's capable of extending the life of battery beside can replace the battery as an input source of the circuit. At the same time, the circuit becomes maintenance free. As long as the circuit is placed in available frequency area, the circuit will operate normally.

1.3 Problem statement

Energy harvesting system becomes more popular nowadays as this system can give a sufficient DC voltage as an output. Theoretically, this system working by recycling an ambient RF energy that widely broadcast in our environment such as mobile phone communication system. This concept can be implemented in electronic application since most of the electronic appliances used DC source to make it works. Normally, an active device like the battery is used as electronic appliance sources due it the capability to provide energy in the form of voltage and make a circuit works. But, life span is the limitation of the batteries. In addition, batteries add to the size and decomposition process of batteries causes environmental pollution. Energy harvesting system can replace batteries as an electronic appliances source due its capability to provide an energy in the form of voltage. RF harvesting system can categorize as green technology system because there is zero hazardous element build in this system which can give negative impact to the environment.

One of the factor that effect of RF-DC conversion is source power. The power density of ambient RF energy is very small and this is a challenging task to design a very high-efficiency RF-DC conversion. In order to overcome that problem, an efficient rectifier circuit is needed to provide high-efficiency RF-DC power conversion. The designed rectifier should be able to operate at multiband of frequency for obtaining the high power DC power for the end device **[6].** Single band rectifier only can capture for one RF signal at once. Normally, a single band rectifier circuit is not enough to produce a good performance of RF-DC conversion due to its limitation of power density. By designed multiband rectifier circuit, it can increase power delivery from source to rectifier because multiband rectifier can cover various frequencies. The Even multiband rectifier can cover various frequencies, but, designing multiband rectifier is not easy. The difficult part is to match the rectifier for more than one frequency bands at the same time minimize the sensitivity of the rectifier. Maximum power delivery can be obtained by design matching network for rectifying circuit **[3]**

1.3 Objectives

The main objective of this project is to develop high efficiency and low power consumption of RF-DC conversion for the dual band rectifying circuit in RF energy harvesting system. In addition, the sub-objectives are stated as follow:

- To design a dual-band rectifying circuit which operates at 1.8 GHz and 2.45 GHz with a good matching circuit.
- To analyze, fabricate and validate the design of the rectifying circuit.

1.4 Scope of project

Then the main objective of this project is to design a dual-band rectifying circuit which can operate at 1.8 GHz and 2.45 GHz with a good matching circuit. All related information from various resources like the internet for this project is gathering to be as guidelines to accomplish this project followed the time given.

This project is focused on design and analysis a dual band rectifier that can operate at different frequencies with a good matching circuit. In order to improve the efficiency of the RF energy harvesting system, power combiner, and filter design is adding on the rectifier circuit. The design process of the rectifier circuit can be formed by using Agilent Advance Design System (ADS 2011). ADS software can analyze the initial design of the dual band rectifier system in term of performance before proceed to the next process which is fabrication process.

The dual band rectifier is a combination of two single bands which operate at different frequencies 1.8GHz and 2.45GHz. A single band rectifier is designed and analyze for both frequencies before combining it into a dual band rectifier circuit. A good performance of diode need to be selected, otherwise, it will affect the performance of the rectifier. Since the circuit operates at high frequencies, harmonic frequencies will occur. The dual bandpass filter will be designed to overcome harmonic frequencies problem. Then, power combiner is designed to separate the operating frequencies of the rectifier and deliver an optimum input power that captured from an ambient environment. Next process is matching network design.

The matching network is designed to match between input and output part of the circuit and ensure the maximum power delivery from the antenna to RF-DC rectifier. Fabrication process will continue to convert a simulation design from ADS into a hardware part. The hardware designed will be tested and analyze to measure the performance of rectifier and all data are recorded to compare between simulation and hardware part.

1.5 Methodology

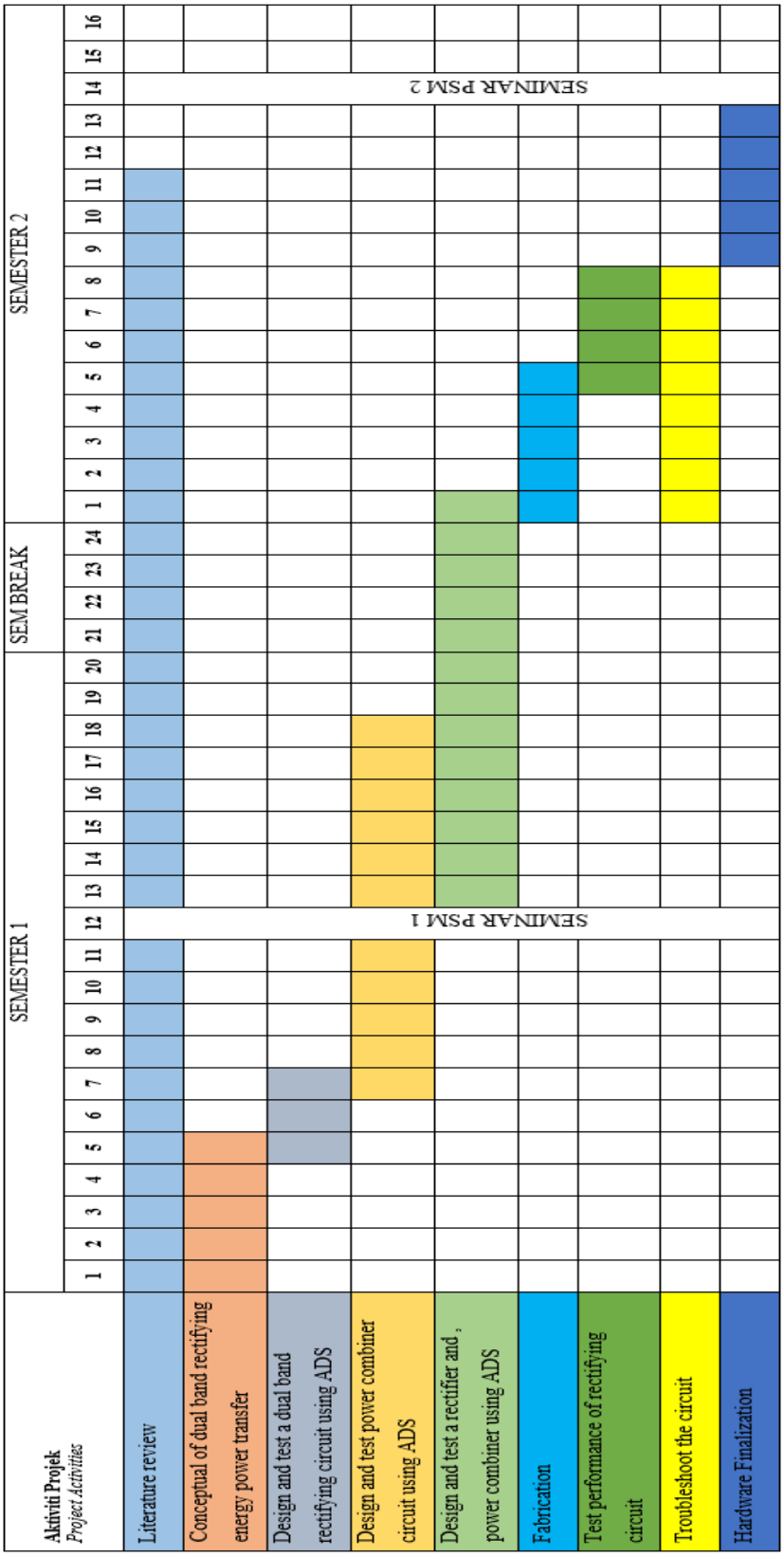
1.5.1 Project Planning

Project planning is one of the element to ensure the project is finished within the prescribed time with well-planned and organized. There are a lot of sub-activities to make a complete project and its will described by using Gantt chart. Gantt chart will manage each activity with a specific duration time so that project will be finished on time. Figure 1.5.1 shows the Gantt chart of the project.

1.5.3 Data Collection

This project is started by the review about dual band rectifying circuit and all information that relate to RF harvesting system. Single band rectifier operates at 1.8GHz is designed and tested using ADS to measure the performance of the rectifier. Then, it followed by designed another single band that operates at 2.45GHz before the combine to produce a dual band rectifier circuit. Power combiner, filter, and the matching circuit are designed after rectifier circuit is completed. The fabrication process is conducted after simulation analysis from ADS has met predefined specification using FR4 substrate. The fabricated rectifier is analyzed to find out the performance of rectifier. Analysis from the fabricated rectifier is measured and recorded to compare with the simulation analysis. Troubleshooting process will be carried out if there are problem on fabricated rectifier circuit

Table 1.5: Gantt chart of the project



1.6 Contribution

The project outcome is as follows:

a. A dual band rectifying circuit for RF energy harvesting is designed. This RF energy harvesting can operate at two different frequencies and provide a high performance of RF-DC conversion.
b. An optimum technique can implement on proposed rectifier to achieve an efficient RF-DC conversion performance for further research.
c. DC-DC converter can be implemented at the output of rectifier as a stabilizer to smooth the output DC value.
d. This project has an opportunity to be commercialized if further research is continued to obtain high performance of RF-DC conversion.

1.7 Organization of thesis

This thesis is organized as follows:

1. Chapter 1 describes the overall thesis in general and leads the reader to the problem statement of the project. Objective and scope of project are defined as well as project methodology to ensure project well organized besides achieve project objectives

2. Chapter 2 focuses on related information of the project. This chapter gives information in detail of dual band rectifying energy harvesting system and researcher's techniques to produce a high RF-DC conversion performance. The previous related projects and paper works can be as a guideline and idea to overcome problem statement that already stated before. The useful information from the related projects be as advantages and give more understanding about the project.