DESIGN OF ANTENNA AT 1.8GHz WITH RECTIFYING CIRCUIT FOR RF ENERGY HARVESTING

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Tajuk Projek : DESIGN OF ANTENNA AT 1.8GHz WITH RECTIFYING CIRCUIT FOR RF ENERGY HARVESTING

Sesi Pengajian : 1 2 / 1 3

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DEDICATION

To To Allah

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

To My Mother

Tuan Kamariah Binti Ibrahim

Thank you for your sacrifice and love. No such compensate except from Allah.

To My Supervisor and Lecturer's

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

To all friends

Thank you for your support, advice and motivation

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In the Name of Allah, Most Gracious, Most Merciful

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Last but not least, Thanks to my beloved mother Tuan KamariahBt Ibrahim and my family for supporting me throughout my final year project. Without your support, I will never get to complete my final year project.

Mohd Nabil Imran Bin Kamaruzaman. June, 2013

ABSTRACT

This thesis presents the design of antenna at frequency 1.8GHz with a rectifying circuit for RF energy harvesting system. This system is a combination of a receiving antenna and integrated to a rectifying circuit that efficiently converts RF energy to DC signals for power harvested. Microstrip patch antenna design has been chosen as receiving antenna design due to its low profile, low cost and ease of fabrication. Two types of antenna i.e, rectangular patch and circular patch antenna design have been proposed in this project as a receiving part in the energy harvesting system. The design process of antenna has been done by taking consideration of all antenna parameters including return loss, gain, bandwidth and directivity. The RF-DC energy conversion module is a voltage doubler or rectifier circuit used to convert the harvested energy received by the antenna from ambient RF sources to DC voltage. The RF signals received by the antenna will be transformed into DC signals by a diode based rectifying circuit or voltage multiplier. For this RF energy harvesting system design, the Villard voltage multiplier circuit is presented for energy conversion where the rectifier circuit. Lastly, the integration between the antenna and rectifying circuit is successful implemented to obtain a reliable DC output well as a proof of concept for the RF energy harvesting system.

ABSTRAK

Tesis ini menerangkan tentang rekabentuk antenna pada frekuensi 1.8GHz bersama dengan litar penerus untuk tujuan sistem penuai tenaga RF. Sistem ini adalah kombinasi antara antenna penerima dan disambungkan kepada litar penerus yang berfungsi menukarkan isyarat tenaga RF yang diterima kepada bentuk arus terus (DC) sebagai kuasa yang dituai. Rekabentuk mikrostrip tampalan antena telah dipilih sebagai antena penerima kerana mempunyai ciri-ciri seperti profil yang rendah, kos rendah dan proses fabrikasi yang mudah. Dua jenis rekabentuk antena i.e. iaitu tampalan segi empat tepat dan tampalan tampalan bulat telah dicadangkan didalam projek ini sebagai sebahagian dari bahagian penerima didalam sistem tuaian tenaga. Proses merekabentuk antenna telah dilakukan dengan mengambil kira semua antenna paramater termasuk ‘return loss’, ‘gain’, ‘lebar jalur dan ‘directivity’. Sistem penukaran tenaga RF-DC adalah pengganda voltan atau litar penerus yang digunakan untuk menukarkan tenaga yang diterima oleh antena dari sumber RF pada persekitaran ke bentuk voltan DC. Untuk tujuan rekabentuk sistem tuaian tenaga RF ini, litar yang dicadangkan adalah litar pengganda voltan Villard untuk tujuan penukaran tenaga. Akhir sekali, gabungan antenna dan litar penerus telah berjaya dilaksanakan untuk mendapatkan voltan keluaram DC sebagai bukti untuk sistem penuaian tenaga RF.

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LIST OF ABBREVIATIONS

AC	Alternative Current
ADS	Advanced Design System
CST	Computer Simulation Technology
DC	Direct Current
GSM	Global System for Mobile Communication
RF	Radio Frequency

CHAPTER I

INTRODUCTIONS

1.1 Introduction

This chapter will introduce the overall objectives of the project. Energy harvesting is the process of capturing energy that are available from different source such as RF source, solar energy or piezoelectric [1] .Radio frequency (RF) energy harvesting is the process of capturing ambient RF signal where this signal is in the form of electromagnetic energy and converting this signal into suitable DC power. This system is a combination of a receiving antenna integrated to a rectifying circuit that efficiently converts RF energy to DC signals. The basic RF harvesting system consist of a microwave antenna, impedance matching network, rectifier circuit, the next stage of low pass filter for DC path and a resistive load. Figure 1.1 shows the basic block diagram of RF energy harvesting system.

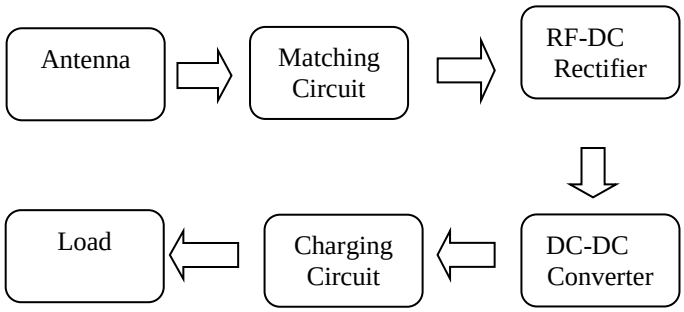

Figure 1.1: RF energy harvesting block diagram

The RF energy system requires the use of antenna as an efficient RF signal power receiving circuit [2]. In transmitting system the RF signal is generated, amplified, modulated and applied to the antenna. Meanwhile, in receiving systems the antenna collects electromagnetic waves that are 'cutting' through the antenna and induce alternating currents that are used by the receiver. An antenna ability to transfer energy from the atmosphere to its receiver with the same efficiency as it transfers energy from the transmitter into the atmosphere. The RF signals received by the antenna will be transformed into DC signals by a diode based rectifying circuit or voltage multiplier. This project will represent the design of antenna with rectifying circuit based on a concept of RF energy harvesting system. The CST Studio Suite software will be used for design process of antenna and ADS-2008 software will be used to design rectifier circuit.

1.2 Project Objectives

The objective of this project is to design an antenna with a rectifying circuit for RF energy harvesting system at operating frequency of 1.8GHz. Two types of antenna design have been proposed in this project as a receiving part in the energy harvesting system. The design of the antenna with rectifying circuit is expected to achieve higher efficiencies of RF-DC conversion for a maximum power transfer.

1.3 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 we 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 advanced 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. 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. 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.

1.4 Scope of work

The main objective of this project is to design a narrowband antenna with a rectifying circuit for the energy harvesting system. The first step in designing process is to find and gather the information regarding to the project such as from journal and paperwork on the internet. This project will focus on design and analysis, testing and measurement of microstrip patch antenna capture electromagnetic energy from RF signals that have been radiated by the communication system at GSM 1800 frequency range. Computer Simulation Technology or CST Studio Suite will be used for design process of antenna. There are two types of antenna will be designed that is a circular patch antenna and rectangular patch antenna. After complete the design process, the next procedure is to fabricate the circuit and doing the testing and measurement procedure. Then, the result will be compared within the measurement result and the actual result. Other antenna parameters such as return loss level, gain, and radiation pattern also will be look of antenna design. The rectifier circuit will be designed by using the Advance Design System (ADS 2011) software. For this RF energy harvesting system design, the proposed used of Villard voltage multipliers are presented. The combination between antennas with the rectifying circuit will be tested by using lab equipment to measure the performance of RF-DC conversion. The performance of the circular patch antenna will be compared to the rectangular patch antenna.

1.5 Methodology

This project will begin by doing the literature review process to study and learn about the antenna fundamentals, the rectifier circuit and basic RF energy harvesting system. After all the parameter involves in this antenna design is calculated, the physical layout of the design antenna will be constructed. Then the simulation will be carried out by using the CST software. The design of the antenna will be optimized by considering all antenna basic characteristics such as a resonance frequency, return loss, bandwidth, gain, and directivity. After completing the design process for both antenna types, the antenna will be fabricated. The fabricated antenna then will be measured to observe the result of return loss, bandwidth, gain and directivity of the antenna. For rectifier part, the rectifier circuit will be designed using the ADS software after the suitable circuit topology has been determined. When all the specification meets the requirement, the fabrication process of the antenna and rectifier circuit will be carried out. Next the testing and measurement of the fabricated antenna and rectifier will be carried out hence again will compare it with all the calculated and simulated results. All experimental results will be included in the final report. Figure 1.2 shows the flow of the project development.

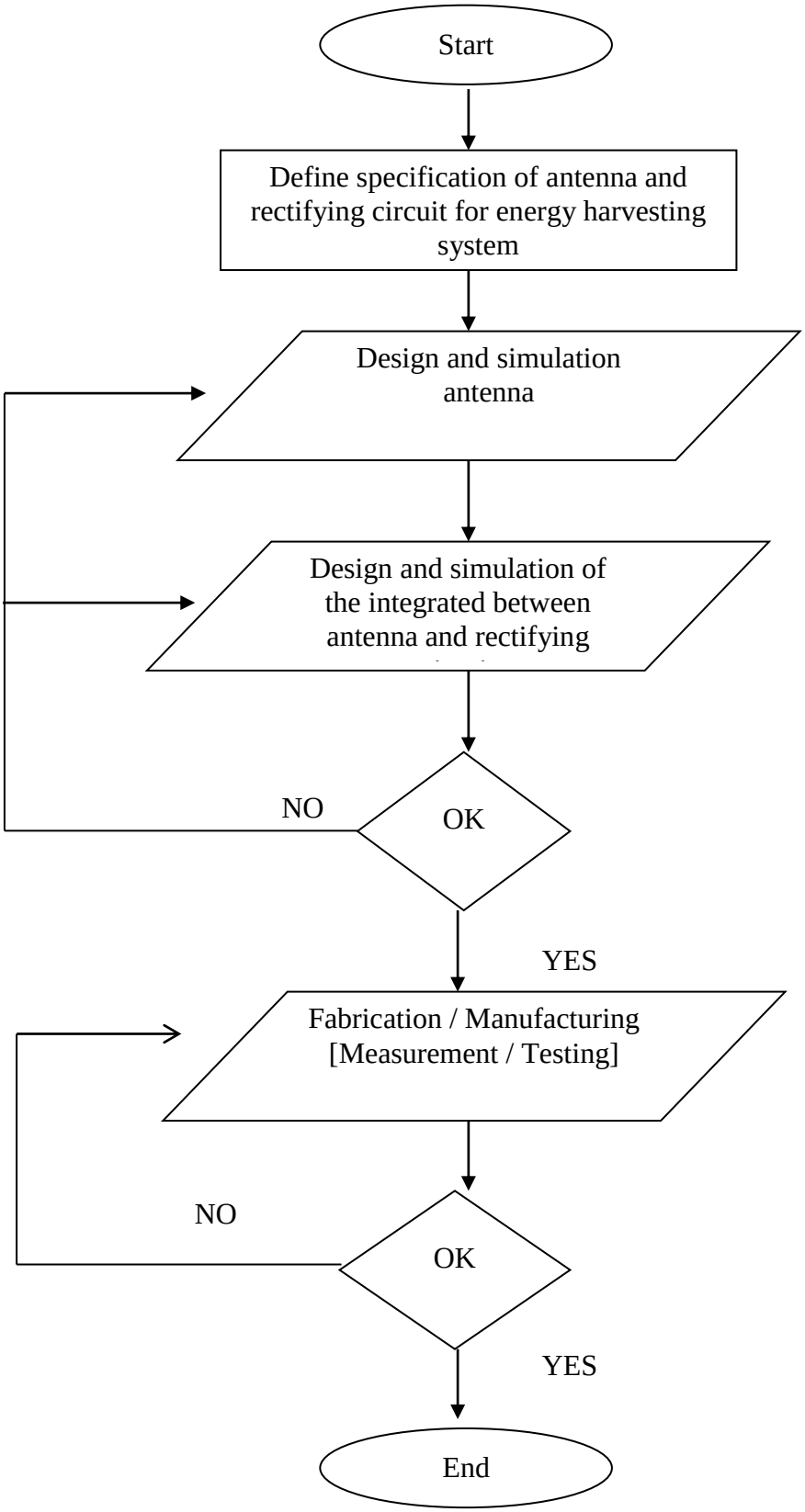

Figure 1.2: Project flow charts

1.6 Chapter Review

Chapter 1 describes the general overview of this project. This chapter presents the objectives, problem statement and review of all chapters of this thesis.

Chapter 2 describes the introductions to the antenna and microstrip antenna is presented. This chapter will explain the basic concept of the antenna. Then the introduction of the microstrip patched antenna concept and design will be introduced. This chapter also gives the information about the parameter and synthesis technique involved in this antenna design project. Next, this chapter will explain the basic concept of rectifier circuit as a function of RF-DC conversion and synthesis technique involved in this rectifier design process.

Chapter 3 presents the methodology used or the design process in this project. The methodology involves the procedure of getting important data regarding to the antenna design and rectifier circuit design. The method that had been used, the equation usage and calculation process also included in this part. This section also explains about the optimization process that involved in this project.

Chapter 4 presents the results achieved from this project. These results involve the simulation and measurement result of the antenna, the comparison between the measurement and simulation, the simulation and measurement result of rectifier circuit, and the output power transfer obtained from the combination between the antenna and rectifier circuit for RF-DC conversion also included.

Chapter 5 will present the conclusion of this project. After all the theoretical, simulated and experimental result is achieved, the conclusion comes to conclude the overall project achievement and also the future work involved.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter will explain the basic concept of the RF energy harvesting system, antenna and rectifying circuit. Then the introduction of the microstrip patched antenna concept and design will be introduced. This chapter also gives the information about the parameter and process technique involved in this antenna design and rectifying circuit.

2.2 RF Energy Harvesting System

Energy is everywhere in the environment surrounding us and available in many forms such as thermal energy, solar energy, wind energy and radio frequency (RF) energy. Energy harvesting is the process of capturing energy from one or more of this energy, accumulating and storing them for later use [3]. RF energy harvesting is the idea of capturing transmitted RF energy at ambient and converts it into suitable DC power either storing it to later user or using it directly to power up a low power circuit. The principle behind RF energy harvesting system is shown in Figure 2.1 where this system consist of an antenna, matching network, rectifier circuit for RF-DC conversion and load circuit.

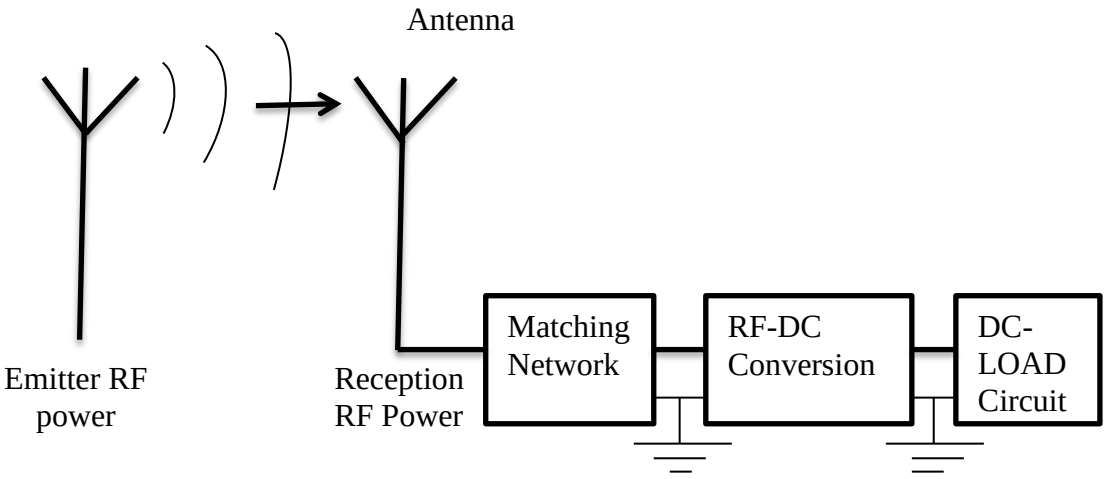

Figure 2.1: RF Energy Harvesting System Conceptual Views

The concept of this energy harvesting system needs an efficient antenna connecting with a circuit that capable to convert received RF signals to DC form. The antenna is one of the important parts in an RF energy system because it is responsible for capturing radiated energy from a nearby source. Thus, the choice of antenna type and its frequency band is very essential to optimize the harvested DC power. The gain of the antenna must be as high as possible in order to capture high RF energy. Other antenna parameter including radiation pattern, return loss and bandwidth could affect the amount of power received by the antenna.

RF signal received by the antenna is in AC form and it cannot be used to power up the application that used DC to turn them on. Thus, the rectifier circuit that consists of simple diodes and capacitor is used to convert the AC signal to DC signal. Although the RF signals carry low energy, the receivable power since then can be high enough to turn on low power sensor or low power circuits.

Before beginning with the design process, research was carried out by performing a literature review on several journals related to research topics of RF energy harvesting system. Literature studies have been conducted on journals to collect relevant information and facts that can be used in the design process of this project. Table 2.1 shows a sample summary of the literature reviews that have been done.