AN ARRAY ANTENNA DESIGN FOR RF ENERGY HARVESTING SYSTEM

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FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

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PROJEK SARJANA MUDA II

Tajuk Projek : **An Array Antenna Design for FR Energy Harvesting System.**

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Specially dedicated to my beloved mom and dad,
my siblings and family, for their encouragement and support;
my friends who always inspired and motivated me
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ABSTRACT

In RF energy harvesting, an antenna is very important part that used to capture the ambient RF signals. However, in many cases of RF energy harvesting, the gain of the antenna used is quite low so that it results in low output DC voltage of overall RF energy harvesting system. This project aims to design an antenna that provides a high gain so that the DC output voltage would be increased. 4×1 and 2×2 arrays antennas are designed in CST Studio Suite software. Optimization in CST software for the arrays antennas designed is done prior to fabrication process that is carried in the laboratory. Once the simulation and fabrication processes are done, comparison of the antennas performance is carried, in terms of antenna parameters such as gain, return loss, bandwidth, efficiency and radiation pattern. The arrays antennas are designed for WLAN applications operating at frequency of 2.45 GHz with return loss less than -20 dB and wide bandwidth greater 80 MHz. The DC voltage produced by RF Energy harvesting system can be used to power the low power devices such as mobile phones and wireless sensors used under the sea so that batteries do not have to be replaced frequently which will save environment of batteries waste and save a lot of money spent for replacing the low power devices batteries as well.

ABSTRAK

Dalam penghasilan tenaga RF, antena adalah bahagian yang sangat penting yang digunakan untuk menangkap isyarat RF ambien. Walaubagaimanapun, dalam kebanyakan kes penghasilan tenaga RF, dapatan antena yang digunakan agak rendah oleh itu penghasilkan voltan keluaran adalah rendah bagi keseluruhan sistem penghasilan. Projek ini bertujuan untuk mereka bentuk antena yang boleh memberikan dapatan yang tinggi supaya voltan keluaran DC bertambah. 4x1 dan 2x2 jajaran antenna telah direkabentuk dalam CST studio Suite Software. Pengoptimuman untuk reka bentuk jajaran antena dalam perisian CST hendaklah dilakukan sebelum proses fabrikasi yang akan dijalankan di makmal. Setelah proses simulasi dan fabrikasi selesai, perbandingan prestasi antenna dilakukan, ini adalah untuk mengambil kira dari segi antena parameter bagi dapatan, kehilangan pulangan, jalur lebar dan corak radiasi. Antena jajaran direka untuk aplikasi WLAN yang boleh beroperasi pada frekuensi 2.45 GHz dengan kehilangan pulangan kurang daripada -20 dB dan lebar jalur luas sekitar 80 MHz. Voltan DC yang terhasil dari sistem penghasilan tenaga RF boleh digunakan untuk memberi kuasa terhadap peranti kuasa rendah seperti telefon bimbit dan sensor di bawah laut. Oleh itu, bateri tidak perlu kerap digantikan dan ini sekaligus dapat menyelamatkan alam sekitar daripada lebihan sisa buangan bateri dan turut menjimatkan wang yang banyak dari perbelanjaan untuk menggantikan peranti bateri kuasa rendah juga.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Energy harvesting is the process of capturing energy that is available from different source such as RF source, solar energy or piezoelectric [1]. Radio frequency (RF) energy scavenging is the process of capturing around RF signal where the signal is in the form of electromagnetic energy in the air and convert this signal into an appropriate DC power. This system is a combination of an integrated antenna receiver, and an efficient rectifier circuit to convert RF energy into DC signal. The basic system consists of scavenging RF microwave antenna, impedance matching network, rectifier circuit, the next stage low pass filter for DC route and load resistance. Figure 1.1 shows the basic block diagram of RF energy harvesting system.

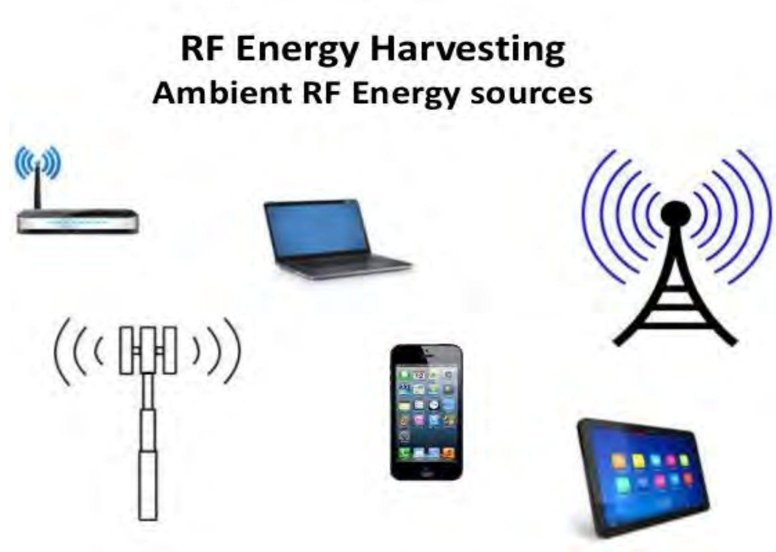

Figure 1.1: RF Energy Harvesting Applications.

In the RF signal transmission system generated, amplified, modulated and applied to the antenna. In the meantime, the receive antenna system to collect electromagnetic waves through the antenna and induce alternating Currents is used by the receiver. The antenna capability to transfer energy from the atmosphere to the 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 a DC signal by a diode-based rectifier circuit or a voltage multiplier. This project will represent the design of antenna to use for rectifying circuit based on a concept of RF energy scavenging system. The CST Studio Suite software will be used for the antenna design.

1.1 Objective

The objective of this project is to design an antenna for RF energy harvesting system operates at a frequency of 2.45 GHz. This antenna design is able to provide a high gain and directivity. The antenna design is used with Rectifier circuit to achieve high efficiency of the RF-DC conversion of maximum power transfer.

1.2 Problem Statement

The main problem in the RF energy scavenging system is that the amount of energy captured from the around the RF source is very low. This effect may be due to low levels of RF power levels and antenna mismatch to the rectifier. To capture the maximum power, the receiving antenna should be well designed, taking into consideration the many factors to achieve impedance matching between antenna and rectifier at the operating frequency and to obtain maximum power transfer and minimize transmission loss from the effects of PCBs. Hence, to convert more of the antenna surface incident RF power to DC power, high efficiency RF to DC conversion required by correcting circuit.

There has been a rapid increase in the use of wireless devices in applications such as mobile phones and sensor networks. These devices are powered by a portable device, and limited energy of battery. This means an increase in the use of the application will result in the battery being used has also increased and these batteries need to be replaced often. These batteries contain heavy metals, which if we are not properly disposed of it can leak it contains into the environment pollution increases. Consequently, the use of green technologies such as RF power system is one of the solutions to overcome this problem for developing wireless broadcasting and communications systems generated the free energy.

1.3 Scope of Work

This project will focus on the design and analysis, testing and measurement of microstrip patch antenna that captures electromagnetic energy from the RF signal being transmitted by the communication system at frequency of the WLAN band (2.45 GHz). Computer Simulation Technology or CST Studio Suite will be used for the antenna simulation process. The type of antenna will be designed that is a rectangular patch array antenna. After the complete design process, the next procedure is to do fabrication, testing and measurement. Then, the results will be compared with the measurement results and the actual results. Other antenna parameters such as return loss level, gain, and radiation pattern will also be look at as to know performance of the antenna design. Although this antenna will be used for FR energy harvesting system application, it will only focus on particular frequency which is 2.45 GHz.

1.4 Methodology

This project will begin by 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, 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. When all the specification meets the requirement, the fabrication process of the antenna will be carried out. Next the testing and measurement of the fabricated antenna 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.

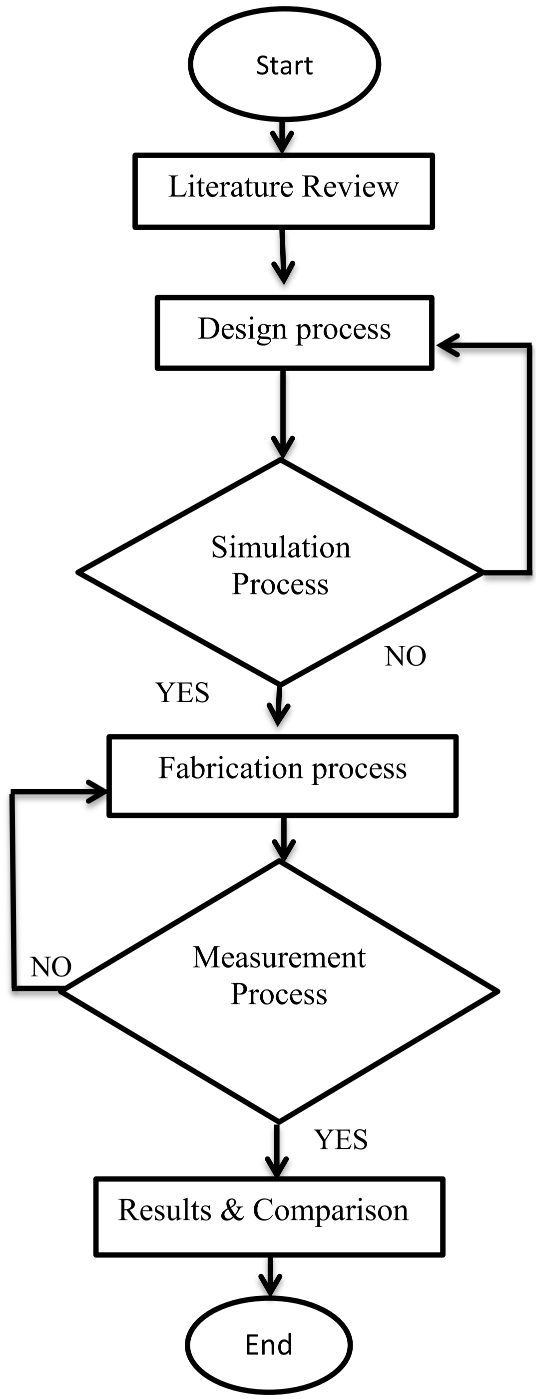

Figure 1.2: The flow chart of project

1.5 Contribution of Project

Nowadays, a variety of low-power devices can be operated and charged with use of RF energy is around us. To use short-distance for a low-power transmitter, energy scavenging system can be used to trickle charge a number of devices for example GPS or RLTS tracking tags, medical sensor, and consumer electronics devices such as mobile phones. For long-distance, this system can replace the battery or battery-free sensors known as to control Heating, Ventilation and Air Conditioning also known as HVAC, structural monitoring, and industrial control. Energy scavenging system depends on the power requirements and operations for power can be transmitted continuously, scheduled, or on request. Efforts to eliminate future maintenance to replace the battery can be done using large-scale sensor to reduce labour costs.

RF energy is suitable Candidates to recharge wirelessly on a single set of batteries, in which the device will operate normally for a week, a month, or a year. In certain applications, Energy harvesting can be used as a wireless power enhancer to increase the battery life or offsetting during sleep microcontroller.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter present the researched journals that were reviewed about antenna deigns at frequency of 2.45 GHz with a high gain. After correcting the desired journals, Comparisons were carried among them. In addition this chapter covers a detail theory about an antenna and its parameters that determine its performance.

2.2 Critical Literature review

The literature review was performed on a journal to collect related information and facts that can be used in the design process of this project prior to Design process; research was carried out by performing a review of the literature in several journals related to research the topic of RF energy harvesting system.

Table 2.1 summarizes the sample literature of reviewed journals.

Table 2.1: Summary of journals for literature review

Journal	Application	Method	Improvement
[2]	2.45 GHz & 5.2 GHz (ISM & Bluetooth Band)	Adjust two different multiplying factor and setting the gaps between the two patches.	The expected result achieved for return loss and radiation pattern
[3]	2.45 GHz (ISM band)	Design a 10mm microstrip antenna by using shorting pin technique and common PCB	Enhance the impedance bandwidth and gain of the microstrip antenna
[4]	5.8 GHz (RFID Application)	This design using the orthogonal ports, both Transmit and receive functions can be implemented on the same antenna.	Slot length affects the resonant frequency and produce high isolation, good cross-polarization and radiation levels are high waist with 9.3dBi gain.
[5]	2.4 GHz (WLAN Band)	This antenna design by using Electromagnetic Band Gap (EBG)	Reduce coupling losses with two patch antenna layer and wider bandwidth also increases the directivity.
[6]	2.45 GHz (ISM Band)	This system developed by using miniaturize 2nd iteration koch fractal patch antenna and two stage Dickson charge pump voltage-doubler rectifier circuit	Rectenna harvests enough energy from a commercial RFID interrogator 3.1 meters away (4W EIRP at 2.45 GHz ISM band) to power up a 1.6 V LED

2.3 Antenna Theory

An antenna is an electrical device which converts electric currents into radio wave or radio wave into electric currents. Antenna usually used with a radio transmitter or radio receiver. In transmission, radio transmitter applies an oscillating radio frequency electric current to the antenna‟s terminals and the antennas radiate the energy from the current as electromagnetic waves. Antennas that excite an electrical field are referred to as electrical antennas; antennas exciting a magnetic field are called magnetic antennas. The oscillating electrical or magnetic field generates an electromagnetic wave that propagates with the velocity of light, c. In reception, an antenna intercepts some of the power of electromagnetic waves in order to produce tiny voltage at its terminals. An antenna can be used for both transmitting and receiving. In other words, an antenna only converts an electromagnetic signal to an electrical signal at receiver or transmitter. If there is 100 % of efficiency, they radiate no more power than is delivered to their input terminal. This is because all the energy of the signal is absorbed.

2.4 Antenna Properties

There are many of basic properties that are used to describe the performance of the antenna. There are including impedance, return loss, VSWR, bandwidth, radiation pattern, 3 dB bandwidth, gain and polarization.

2.4.1 Impedance

Impedance of antenna relates the voltage and current at the input to the antenna. In order to achieve maximum energy transfer between a coaxial transmission line and an antenna, the input impedance of antenna must identically match the characteristic impedance of the transmission line.

Reflected waves will be generated at the antenna terminal and travel back towards the energy source if it does not match.

2.4.2 Return Loss

Return loss is a convenient way to characterize the input and output signals Sources. Return loss can be defined in dB as in the following equation (2.1);

$$RL\ (\text{dB}) = -20 \log_{10} |\Gamma| \quad (2.1)$$

Where;

RL = return loss

Γ = reflection coefficient

For perfect matching between the transmitter and the antenna, = 0 and RL = ∞ which means no power would be reflected back, whereas a = 1 has a RL = 0 dB, which implies that all incident power is reflected.

2.4.3 VSWR (Voltage Standing Wave Ratio)

VSWR of an antenna stands for how efficiently the measured of a radio-frequency power is transmitted from a power source through a transmission line into a load [2]. VSWR also can be defined as the ratio between the maximum voltage and the minimum voltage along the transmission line which indicates how closely or efficiently an antenna‟s terminal input impedance is matched to the characteristic impedance of the transmission line. In other words, VSWR is a real number that is always greater than or equal to 1. A VSWR of 1 indicates no mismatch loss (antenna is perfectly matched to the transmission line). Higher value of VSWR indicates more mismatch loss.