DEVELOPMENT OF COMPACT, HIGHLY EFFICIENT RECTENNA FOR WIRELESS POWER HARVESTING OF 2.45 GHz FOR LIGHTLY POWERED WIRELESS TAGS

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This report is submitted in Partial Fulfillment of Requirement for Award of Bachelor of Electronic Engineering (Wireless Communication) With Honours

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Universiti Teknikal Malaysia Melaka

JUNE 2015

UNIVERSTI TEKNIKAL MALAYSIA MELAKA

FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN

PROJEK SARJANA MUDA II

Tajuk Projek : DEVELOPMENT OF COMPACT, HIGHLY EFFICIENT RECTENNA FOR WIRELESS POWER HARVESTING OF 2.45 GHz FOR LIGHTLY POWERED WIRELESS TAGS

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For my dearest mother, Rahmah bt Ahmad,family, beloved lecturers and friends.

ACKNOWLEDGEMENT

First of all, I am thankful to Allah S.W.T for giving me guidance and strength internally and externally to enable me to finish my final year project successfully. I would like to convey my greatest gratitude to my dearest supervisor Dr. Mohamed Saeed Jawad for his guidance, brilliant ideas and his expertise in this field are sincerely appreciated.

I also want to express my special thanks for my lovely dad and my lovely family because they always support me and their advice become an inspiration and strength to me in completing this research successfully. Lastly, I dedicate a valuable thankful to my classmates, friends and colleagues at this university who always support me directly or indirectly.

ABSTRACT

Power source in battery nowadays have become part of human life. The short lifetime of battery sometime can be a problem. Even though nowadays, there are many others technique of energy harvesting such as solar panel, wind energy and other renewable source, but it is not convenient to use large power source to power up low power level application such as sensors and wireless tags. Therefore solution of other energy harvesting that is small yet efficient must be achieved. Rectenna is a solution to create small energy harvesting tools that can be applied to low power level application. Rectanna is basically a device that used to capture and convert signal into DC power and used as receiving terminal. Rectenna is combining of rectifying circuit and antenna. Both of rectifying circuit and antenna design will determine the overall performance of rectenna. Proposal of this project is to harvest enough energy that can power up low level application such as wireless tags at 2.45 GHz. Rectenna will be design using CST studio software and fabricated on FR4 board. RF Schootky diode will be used to construct rectifying circuit. The matching of the Schootky diode will be in stub matching form which will be design on FR4 board. The horn antenna will be used as a transmitter that resonate at 2.45 GHz for the input power level at -20dBm to 20dBm. Rectenna then will be used to convert the signal into DC voltage.

ABSTRAK

Pada masa kini, sumber kuasa di dalam bateri menjadi sebahagian daripada kehidupan manusia. Jangka hayat yang pendek kadang-kadang boleh menjadi masalah. Walaupun begitu, terdapat banyak lagi teknik penuaian tenaga seperti panel solar, tenaga angin dan sumber yang boleh diperbaharui yang lain, namun ia tidak mudah untuk meningkatkan aplikasi tahap kuasa yang rendah seperti sensor dan tag tanpa wayar dengan menggunakan sumber kuasa yang besar. Oleh itu, penyelesaian penuaian tenaga lain yang kecil tetapi berkesan haruslah dicapai. Rectenna adalah penyelesaian untuk mewujudkan alat penuaian bertenaga kecil yang boleh digunakan untuk aplikasi kuasa tahap rendah. Rectenna pada dasarnya adalah alat yang digunakan untuk menangkap dan menukar isyarat ke dalam kuasa DC dan digunakan sebagai pangkalan penerima. Rectenna adalah gabungan daripada litar penerus dan antenna. Kedua-dua litar penerus dan reka bentuk antenna akan menentukan keseluruhan prestasi rectenna. Cadangan projek ini adalah untuk menuai tenaga yang cukup untuk meningkatkan aplikasi tahap rendah contohnya tag tanpa wayar pada 2.45GHz. Rectenna akan di hasilkan dengan menggunakan CST Studio Software dan fabrikasi pada papan FR4. Diod jenis Schottky akan digunakan untuk membina litar penerus. Padanan daripada diod Schootky akan berada dalam bentuk puntung (stub), yang hampir sama yang akan direka bentuk di papan FR4. Horn antenna akan digunakan sebagai pemancar yang bergema di 2.45GHz pada tahap kuasa input di 2dBm hingga 20dBm. Rectenna kemudiannya akan digunakan untuk menukar isyarat kepada voltan DC.

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RECTENNA	-	Rectifying antenna
PCB	-	Printed circuit board
VHF	-	Very high frequency
GSM	-	Global system for mobile
RFID	-	Radio Frequency Identification
ISM	-	Industrial, Scientific and Medical
IEEE	-	Institute of Electrical and Electronics Engineering
FR-4	-	Flame retardant
ADS	-	Advance Design System

LIST OF SYMBOLS

λ	-	Wavelength
Ω	-	Ohms
ε_{eff}	-	Effective permitivity
ε_r	-	Effective dieletric constant
Z	-	Impedance
f	-	Frequency
c	-	Speed of light; 3×10^8

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CHAPTER 1

INTRODUCTION

This chapter will give an overview about the project as project background, project objectives, project scope, project methodology and summary of the project. This chapter will explain briefly about project details.

1.1 Project introduction

Nowadays, there are many items which can be used to harvest energy as a source including RF signal and microwave. In most area, wireless signal such as microwave and RF signal is mostly used for internet surfing, but these signal can be converted to DC voltage using proper tools and technique.

There is an active research in investigating several methods significantly extracting ambient energy from surrounding and convert it into electrical energy [1] for energizing low power wireless sensors which can get the required power from rectenna circuit. Indeed, RF energy scavenging from the ambient will become more beneficial at future of microelectronic which will be flexible of green electronics devices due to self-powered wireless sensor and energy autonomous [2]. In fact, there are many energy from external sources such as solar power, magnetic, vibration and RF energy. The advantage harvested RF energy from the ambient because the energy is feely available in space. Thus, RF energy is captured by a receiving antenna and rectified into a usable DC voltage.

The application of project is to use rectenna to convert wireless signal into DC (direct current) and power up low power application such as wireless tags. Rectenna received/captured signal which is transmitted from the transmitter using horn antenna at a frequency of 2.45 GHz. This project is carry out to develop and design a compact and high efficiency rectenna for wireless power harvesting of 2.45 GHz for lightly powered wireless tags.

RF energy harvesting system is made up of microwave antenna, prerectification filter, rectifying circuit and DC pass filter that rectifies incoming electromagnetic waves into DC current. The rectifying circuit can be in any types like full-wave bridge rectifier or as a single shunt full-wave rectifier [5][6].

In order to obtain an optimum power transfer, a low pass filter between the antenna and rectifier will be used. The purpose of using this filter is to achieve impedance matching between them. Then, after signal is rectified, a DC low pass filter will be used to smooth the output DC voltage and current by attenuating the high frequencies harmonics that present in the RF signals or generated by the highly nonlinear rectifying process itself. The best is collecting the maximum power before deliver it to the rectifying

diode, and then to suppress the harmonics generated by the diode that reradiate from the antenna as the power lost [6].

Rectenna with DC power conversion could provide a new revelation for power source technology. Generally, communication devices have omni-directional radiation pattern of antennas that propagate RF energy in most direction thus maximizes the coverage for mobile applications. The energy harvesting system design promotes a promising future in low power consumer of electronics devices and wireless sensor networks.

1.1.1 Overview of Rectenna

The rectenna has been advancing in recent years, as the microwave integrated circuit and monolithic microware integrated technologies become more mature allowing for high level integration. The rectenna term is actually a combining of an antenna and a non-linear rectifying circuit where these two element integrated into one single circuit. Rectenna is capable to receive and detect microwave power and convert the signal into dc voltage at high frequencies [1]. Rectenna which can capture and convert electromagnetic power to electric power plays an important role in free space wireless power transmission(WPT).This feature is an attractive solution to supply a node in wireless sensor network(WSN) or the electronic circuit of the wireless tags such as radio frequency identification (RFID) tags. The development of rectenna focused on its efficiency for great power reception and conversion [2].

The crucial factor of the rectenna is antenna itself. The frequency selected for antenna is 2.45 GHz which means antenna is able to work in that frequency. Frequency 2.45 GHz is selected as operating frequency as to get high frequency. Rectifying circuit design and the diode use also affect the performance of the rectenna. Rectifying circuit consisted Schootky diode and the load resistor for power measurement.

1.2 Objectives

The objective of this project is to design a highly efficient rectenna as small size and relatively high gain enough to power up wireless tags from received signal energy. Another objectives is to evaluate the performance of the proposed rectenna in software simulation as well as experimented analysis and testing of the rectenna. This rectenna design will convert captured signal into DC power which is use to power a low power level device such as wireless tags and sensor. Rectenna also can contribute in in reduction of waste (in this case: battery) and can be develop as a green technology. Due to the green technology that highly demands these days, the project can be used to generated new power and rectenna can be used as alternative power source in future.

1.3 Problem statement

The research regarding rectenna had been done long time ago, but there are certain problem that can be improve for better performance. For example , Rakesh Kumar Yadev and etc in their journal stated that broadband and large arrays antenna enables to receive high signal however a mismatch of polarization arises between antenna size and radiation gain. S. Riviere, F. Alicalapa, and etc in their journal of compact rectenna only achieved efficiency of 34% using simple aperture coupled patch antenna at low power level of -10dBm and to find a correct match between antenna and the rectifying circuit is an issue. It is clearly find that still need for improvement on the size of antenna, efficiency and the mismatch of the circuit

The problem of this research can be stated as to develop a compact but have high efficiency. Other problem of the research is ambient frequency of 2.45 GHz must have enough power to produce high output DC yet small size rectenna. This project is

undertaken as a solution for wireless energy harvesting without other source. This project is also undertaken as a solution for problem reported in related journal about designing a good antenna.

1.4 Project Scope

The scope of this project is to find a solution to convert the energy from wireless signal to DC power and to increase the efficiency of power conversion. This project is a forecast on the wireless harvesting for low level application device. Frequency of interest is at 2.45 GHz. This project involve in designing antenna and rectifying circuit component of proposed rectenna. The implementation of this work is first implemented in software as simulation in CST studio.

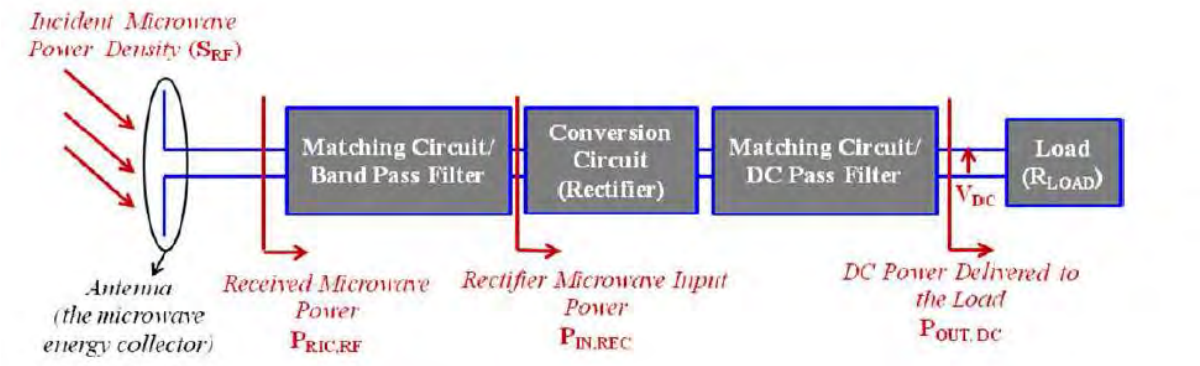

Figure 1.0 shows rectenna basic component in block diagram

The antenna is used to capture the input incoming signal and delivered to the rectifier circuit. The rectifier circuit which consist filter and Schottky diode is use to convert the voltage that in form of AC to DC. The properties of diode determine the overall performance.

The Schottky diode is chosen for rectifying circuit because that diode have lower built-in voltage that would realized a higher rectifying efficiency. The function of filter in

rectifier circuit is to block any harmonic generated by diode and antenna. The filter is also used to make the output smoother. However this project only involve in wireless energy harvesting to power up low power level device such as wireless tags.

Antenna used in this project is microstrip patch antenna and rectifier circuit that is used in this project is two stage Dickson charge pump voltage doubler circuit.

1.5 project Significance

This project gives high commercial values since the active research motivated for the search for an alternative source of energy to power wireless sensor network especially at 2.45GHz frequency band (Industrial, Scientific and Medical) application that requires sensors to be installed for a long duration where battery replacement is not practical. The antenna design at this frequency band is important to work in for many applications. The microstrip patch antenna design at different frequency band between [9] and [10] is compare which is the operating frequency is at 5.25GHz and 2.4GHz in term of method that they used. Researcher in [9] design microstrip patch antenna without slot whereby researcher in [10], introduced additional slots to rectangular patch in order to achieve single band functionality.

Then, the performances of antenna gain which same operating frequency of antenna at 2.45GHz is analyzed between [23], [24], [25]. In [23], researcher proposed four planar dipole elements placed in two parallel lines whereas in [24], a compact wideband microstrip thinned array antenna using EBG substrate is designed. Then, researcher in [25] proposed 2x1 linear antenna array , 4-element microstrip linear array antenna with Butler matrix beamforming network is designed, analyzed and implemented using microstrip technology in completely planar structure. The gain of antenna design by researcher in [23], [24], and [25] is 7.5dBi, 8.2dBi, 9.186dBi for 2x1 linear antenna array.