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

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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
ACKNOWLEDGEMENT

In the Name of Allah, Most Gracious, Most Merciful

Assalamualaikum…..

First and foremost, I would like to thank ALLAH for giving me strength to complete the final year project from September 2012 until June 2013. Who gave me an opportunity, courage and patience to carry out this work. I feel privileged to glory His name in the sincerest way through this small accomplishment. I seek His mercy, favor and forgiveness.

I would like to express my deepest gratitude to my Supervisor, Dr.Zahriladha bin Zakaria for his constant patience, support and constructive guidance for this project. Special thanks also to Dean and Deputy Dean of FKEKK, all the Lecturers who taught me throughout my course. I would also like to thank the technician at LAB for his cooperation and support.

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.

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.
## CONTENT

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TITLE PROJECT</td>
<td>i</td>
</tr>
<tr>
<td></td>
<td>DECRALATION</td>
<td>ii</td>
</tr>
<tr>
<td></td>
<td>DECRALATION</td>
<td>iii</td>
</tr>
<tr>
<td></td>
<td>SUPERVISOR DECRALATION</td>
<td>iv</td>
</tr>
<tr>
<td></td>
<td>DEDICATION</td>
<td>v</td>
</tr>
<tr>
<td></td>
<td>ACKNOWLEDGEMENT</td>
<td>vi</td>
</tr>
<tr>
<td></td>
<td>ABSTRACT</td>
<td>vii</td>
</tr>
<tr>
<td></td>
<td>ABSTRAK</td>
<td>viii</td>
</tr>
<tr>
<td></td>
<td>CONTENT</td>
<td>ix</td>
</tr>
<tr>
<td></td>
<td>LIST OF TABLE</td>
<td>xii</td>
</tr>
<tr>
<td></td>
<td>LIST OF FIGURE</td>
<td>xiii</td>
</tr>
<tr>
<td></td>
<td>LIST OF ABBREVIATIONS</td>
<td>xvi</td>
</tr>
</tbody>
</table>

### I INTRODUCTION

1.1 Introduction 1  
1.2 Project Objective 2  
1.3 Problem Statement 2  
1.4 Scope of Work 3  
1.5 Methodology 4  
1.6 Chapter Review 6
II  LITERATURE REVIEW

2.1 Introduction  7
2.2 RF Energy Harvesting System  7
2.3 Operating Frequency  11
2.4 Introduction of Antenna  12
2.5 Microstrip Patch Antenna  12
2.5.1 Bandwidth Improvement  14
2.5.2 Circular Patch Antenna  15
2.6 Feeding Method  16
2.7 RF-DC Conversion  17

III  METHODOLOGY

3.1 Introduction  19
3.2 Antenna Design Specification  21
3.3 Antenna Design  22
3.3.1 Rectangular Microstrip Patch Antenna  22
3.3.2 Rectangular Patch Antenna with Notch  23
3.3.3 Circular Patch Antenna Design  24
3.4 Rectifier Circuit Design  27
3.4.1 Transmission Line and Microstrip Line Conversion  31
3.4.2 Generate Microstrip Layout  33
3.5 Antenna Measurement Process  35
3.5.1 Parameter Measurement  35
3.5.2 Radiation Pattern Measurement  35

IV  RESULT AND DISCUSSION

4.1 Introduction  37
4.2 Simulation Result  37
4.3 Circular  37
4.3.1 Basic Circular Patch Antenna Design 38
4.1.2 Circular Patch Antenna Design with Notch 40
4.4 Rectangular Patch Antenna Design and
Practical Implementation 45
4.4.1 Rectangular Patch Antenna Design 46
4.4.2 Rectangular Patch Antenna with Notch Design 48
4.5 Rectifier Circuit Design 52
4.5.1 Single Stage Rectifier Circuit 52
4.5.2 Effect of Load in Rectifier Circuit 57
4.6 Antenna Connecting With Rectifier Circuit Measurement 59
4.6.1 Circular Patch-Circular Patch Antenna Measurement 59
4.6.2 Horn Antenna-Circular Patch Antenna Measurement 61
4.6.3 Rectangular -Rectangular Patch Antenna Measurement 63
4.6.4 Horn Antenna-Rectangular Patch Antenna Measurement 64

V CONCLUSION

5.1 Introduction 68
5.2 Conclusion 68
5.3 Future Work 69

REFERENCES 70
## LIST OF TABLES

<table>
<thead>
<tr>
<th>NO</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Summary of Literature Study</td>
<td>9</td>
</tr>
<tr>
<td>2.2</td>
<td>Frequency Allocation of Cellular Mobile (MCMC)</td>
<td>11</td>
</tr>
<tr>
<td>2.3</td>
<td>Operating Frequency for Celcom</td>
<td>11</td>
</tr>
<tr>
<td>3.1</td>
<td>Design Specification of Patch Antenna</td>
<td>21</td>
</tr>
<tr>
<td>3.2</td>
<td>Design Material of Microstrip Patch Antenna</td>
<td>21</td>
</tr>
<tr>
<td>3.3</td>
<td>Probe Feed Dimension</td>
<td>26</td>
</tr>
<tr>
<td>3.4</td>
<td>Interdigital Capacitor Basic Structure</td>
<td>29</td>
</tr>
<tr>
<td>4.1</td>
<td>Circular Patch Design Parameter</td>
<td>39</td>
</tr>
<tr>
<td>4.2</td>
<td>Circular Patch with Notched Design Parameter</td>
<td>41</td>
</tr>
<tr>
<td>4.3</td>
<td>Single Mode and Dual Mode Comparison</td>
<td>43</td>
</tr>
<tr>
<td>4.4</td>
<td>Measurement and Simulation Result Comparison</td>
<td>44</td>
</tr>
<tr>
<td>4.5</td>
<td>Parameter of the Material</td>
<td>46</td>
</tr>
<tr>
<td>4.6</td>
<td>Antenna Design Parameter Value</td>
<td>46</td>
</tr>
<tr>
<td>4.7</td>
<td>Rectangular Patch Antenna Design Parameter</td>
<td>49</td>
</tr>
<tr>
<td>4.8</td>
<td>Measurement and Simulation Result Comparison</td>
<td>52</td>
</tr>
<tr>
<td>4.9</td>
<td>Rectifier Measurement Result</td>
<td>55</td>
</tr>
<tr>
<td>4.10</td>
<td>Effect of Load</td>
<td>58</td>
</tr>
<tr>
<td>4.11</td>
<td>Measurement result</td>
<td>60</td>
</tr>
<tr>
<td>4.12</td>
<td>Effect of antenna distance</td>
<td>62</td>
</tr>
<tr>
<td>4.13</td>
<td>Measurement result</td>
<td>63</td>
</tr>
<tr>
<td>4.14</td>
<td>Measurement Result By using Horn Antenna as Transmitter</td>
<td>65</td>
</tr>
<tr>
<td>4.15</td>
<td>Rectangular and Circular Antenna Performance Comparison</td>
<td>67</td>
</tr>
</tbody>
</table>
# LIST OF FIGURE

<table>
<thead>
<tr>
<th>No</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>RF energy harvesting block diagram</td>
<td>1</td>
</tr>
<tr>
<td>1.2</td>
<td>Project flow chart</td>
<td>5</td>
</tr>
<tr>
<td>2.1</td>
<td>RF Energy Harvesting System Conceptual Views</td>
<td>8</td>
</tr>
<tr>
<td>2.2</td>
<td>Microstrip patch elements shape example</td>
<td>13</td>
</tr>
<tr>
<td>2.3</td>
<td>Rectangular Patch Antenna Physical Structure</td>
<td>14</td>
</tr>
<tr>
<td>2.4</td>
<td>Notch introducing</td>
<td>15</td>
</tr>
<tr>
<td>2.5</td>
<td>Circular Patch Antenna Geometry</td>
<td>15</td>
</tr>
<tr>
<td>2.6</td>
<td>Feeding method (a) Inset Feed (b) Probe Feed (c) Proximity Coupling</td>
<td>16</td>
</tr>
<tr>
<td>2.7</td>
<td>Single stage voltage multiplier circuits</td>
<td>17</td>
</tr>
<tr>
<td>3.1</td>
<td>Project Methodology</td>
<td>20</td>
</tr>
<tr>
<td>3.2</td>
<td>Antenna Design Parameter</td>
<td>23</td>
</tr>
<tr>
<td>3.3</td>
<td>Antenna Design Structure</td>
<td>23</td>
</tr>
<tr>
<td>3.4</td>
<td>Rectangular Patch Antenna with Notch</td>
<td>24</td>
</tr>
<tr>
<td>3.5</td>
<td>Circular Patch Design Parameter</td>
<td>25</td>
</tr>
<tr>
<td>3.6</td>
<td>Circular Patch Antenna with Notch</td>
<td>25</td>
</tr>
<tr>
<td>3.7</td>
<td>Probe Feed Connector Structure</td>
<td>26</td>
</tr>
<tr>
<td>3.8</td>
<td>Antenna Design Structure (a) front view (b) back view</td>
<td>26</td>
</tr>
<tr>
<td>3.9</td>
<td>Single Stage Villard Voltage Multiplier</td>
<td>27</td>
</tr>
<tr>
<td>3.10</td>
<td>Lumped Element Circuit</td>
<td>27</td>
</tr>
<tr>
<td>3.11</td>
<td>Interdigital capacitor</td>
<td>28</td>
</tr>
<tr>
<td>3.12</td>
<td>Introducing of Interdigital Capacitor and Open Circuit Stub</td>
<td>29</td>
</tr>
<tr>
<td>3.13</td>
<td>Characteristic Impedance</td>
<td>29</td>
</tr>
<tr>
<td>3.14</td>
<td>LineCalc Tools In ADS</td>
<td>31</td>
</tr>
<tr>
<td>3.15</td>
<td>Transmission Line Stage</td>
<td>31</td>
</tr>
</tbody>
</table>
3.16 Transmission line Tuning Process 32
3.17 Comparison Result after Tuning Process 32
3.18 Microstrip line Stage 33
3.19 Adding Port Into The Circuit 33
3.20 Microstrip Layout 34
3.21 Microstrip Layout in Symbol Form 34
3.32 S-Parameter Measurement Setup 35
3.33 Radiation pattern Measurement Setup 36
4.1 Basic Circular Patch antenna (a) front view (b) perspective view 39
4.2 Return Loss Result 39
4.3 (a) Antenna gain (b) Antenna directivity 40
4.4 Antenna Structure 41
4.5 Return loss 42
4.6 (a) Antenna gain (b) Antenna directivity 42
4.7 Return loss dual mode antenna 1.84GHz 43
4.8 In lab test measurement result for 1.84GHz antenna 43
4.9 Fabricated Antenna 44
4.10 Measurement and Simulation Result Comparison (S-parameter) 44
4.11 Rectangular Patch Antenna at 1.84GHz (a) front (b) perspective view 47
4.12 Antenna Return loss result 47
4.13 Antenna Result (a) gain (b) directivity 48
4.14 S-Parameter Result 49
4.15 Antenna Gain and Directivity 50
4.16 Fabricated Antenna 50
4.17 Measurement S-Parameter Result 51
4.18 Measurement and Simulation Comparison for S-parameter Result 51
4.19 Single Stage Villard Voltage Multiplier (Lumped Element) Design 53
4.20 Replacing Capacitor into Interdigital Capacitor & Stub 53
4.21 Simulation Result 53
4.22 (a) Microstrip Layout in ADS, (b) Fabricate Circuit 54
4.23 Measurement Process 54
4.24 Output Graph for Measurement Result 56
4.25 Effect of Load in Rectifier Simulation Process 57
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.26</td>
<td>Effect of Load To The Rectifier Performance</td>
<td>58</td>
</tr>
<tr>
<td>4.27</td>
<td>Measurement Process</td>
<td>59</td>
</tr>
<tr>
<td>4.28</td>
<td>Measurement Result</td>
<td>60</td>
</tr>
<tr>
<td>4.29</td>
<td>Horn Antenna as a Transmitter</td>
<td>61</td>
</tr>
<tr>
<td>4.30</td>
<td>Antenna Distance vs Output Voltage Graph</td>
<td>62</td>
</tr>
<tr>
<td>4.31</td>
<td>Rectangular patch antenna Input Signal vs Output Voltage graph</td>
<td>64</td>
</tr>
<tr>
<td>4.32</td>
<td>Horn –Rectangular Patch Antenna Measurement Process</td>
<td>64</td>
</tr>
<tr>
<td>4.33</td>
<td>Distance vs Output Voltage Result for Horn-Rectangular Patch antenna</td>
<td>66</td>
</tr>
<tr>
<td>3.34</td>
<td>Rectangular vs Circular Output Voltage Produce</td>
<td>67</td>
</tr>
</tbody>
</table>
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Alternative Current</td>
</tr>
<tr>
<td>ADS</td>
<td>Advanced Design System</td>
</tr>
<tr>
<td>CST</td>
<td>Computer Simulation Technology</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile Communication</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
</tbody>
</table>
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](image)
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

Start

Define specification of antenna and rectifying circuit for energy harvesting system

Design and simulation antenna

Design and simulation of the integrated between antenna and rectifying circuit

OK

Fabrication / Manufacturing
[Measurement / Testing]

OK

End

NO

YES

NO

YES

OK

NO
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.
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.