HYBRID RF AND SOLAR PV ENERGY HARVESTER

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HYBRID RF AND SOLAR PV
ENERGY HARVESTER

by

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LIST OF ABBREVIATION AND SYMBOL

fr	Frequency of Mesh
C	Speed of Light
G_{DUT}	Gain of Device Under Test
G_{DUT}	Gain of Device Under Test
h	Thickness of FR4
L	Length of microstrip
P_{DUT}	Power of Device Under Test
Pn	Neutralization Power
Pr	Received Power
W	Width of microstrip
Ɛr	Dielectric Constant
$Ɛr_{eff}$	The Effective Dielectric Constant

ABBREVIATIONS

ADS	Advanced Design System
CST	Computer Simulation Technology
dB	Decibel
dBm	Decibel-mill watts
Hz	Hertz
IoT	Internet of Things
PCB	Printed Circuit Board
SMA	Subminiature Version A
TEG	Thermoelectric Generator
RF	Radio Frequency

ABSTRAK

Penuaian tenaga telah wujud untuk masa yang sangat lama. Pada masa itu, tenaga telah dituai pada awal revolusi elektrik dengan meletakkan penjana di sungai yang telah dikuasakan oleh air yang mengalir untuk menjana tenaga elektrik. Tenaga yang paling kerap digunakan adalah tenaga matahari yang merupakan item yang paling penting dalam menghasilkan tenaga. Konsep pengeluaran tenaga dari alam semula jadi, yang boleh digunakan untuk menggantikan sumber kuasa konvensional. Penuai tenaga perlu ditukar ke voltan untuk kuasa sistem. Salah satu cara untuk menggunakan penuaian tenaga dengan menggunakan sumber-sumber hibrid. Sumber hibrid boleh dibentuk dengan menggunakan tiga jenis sumber iaitu Termoelektrik Generator (TEG) yang varians suhu sekitar dan haba. Kedua, sumber getaran yang digunakan seperti motor dan peranti getaran, Frekuensi Radio (RF) yang menghasilkan kuasa pancaran. Selain daripada itu, penuaian tenaga adalah pelaksanaan dunia sebenar pertama berskala bateri tanpa wayar platform pengesan untuk kualiti hidup dan Internet Perkara permohonan (IOT). Tenaga yang biasa digunakan ialah teknologi tenaga matahari. Walau bagaimanapun, peranti kini perlu menggunakan elektrik secara berterusan tetapi tenaga matahari mempunyai had. Ini kebimbangan tesis mengenai siasatan terhadap tenaga penuaian untuk tenaga RF dengan menggunakan panel solar. Kedua-dua tenaga RF dan tenaga solar boleh diserap melalui panel solar. Dalam kata lain, panel solar juga bertindak sebagai antena untuk menerima isyarat dan menukar kepada tenaga RF. Analisis akan dibuat untuk menganalisis sama ada tenaga RF boleh didapati dari panel solar. Antena patch telah direka dan dibina. Panel solar telah diuji dengan peralatan RF untuk mengukur parameter prestasi panel solar dan dibandingkan dengan patch antena. Untuk kekuatan isyarat, panel solar menunjukkan prestasi yang baik

berbanding dengan antena patch dimana panel solar adalah -32.67dBm di 2.5GHz manakala patch antena adalah -38.88dB di 2GHz. Sebaliknya, tenaga ambien menunjukkan sedikit perbezaan dari segi penerimaan kuasa tetapi untuk frekuensi, kekerapan yang diterima adalah dalam julat ± 1.8GHz. Selain itu, gandaan untuk panel solar adalah 2.31dB dan ia adalah lebih rendah daripada gandaan patch antena 4.73dB kerana toleransi dalam proses pembuatan PCB. Kesimpulannya, frekuensi dominan untuk panel solar adalah 1.8GHz ± dimana kegunaan untuk frekuensi ini digunakan di dalam GSM.

ABSTRACT

Energy harvesting has been around for a very long time. At that time, energy was harvested in the early days of the electrical revolution by putting generators on river mills that were powered by running water to generate electricity. The most common energy is solar energy which is most important item in energy harvesting. The concept of energy extraction from nature, which can be used to replace the conventional power source. The energy harvester needs to be convert to voltage or current to power the system. One of the ways to use energy harvesting by using the hybrid sources. Hybrid sources can be formed by using three types of sources which are Thermoelectric Generator(TEG) that the variance of temperature between the surrounding and the heat. Secondly, the vibration sources that are used the vibration sources such as motor and the shaking device, the Radio Frequency(RF) that are produced radiated power. Other than that, energy harvesting is the first real-world implementation of scalable battery-less stand-alone wireless sensor platforms for quality of life and the Internet of Things (IoT) application. The energy that commonly used are solar energy technologies. However, the devices currently need to use electricity frequently but solar energy have it limitations. This thesis concerns on the investigation on harvesting energy for RF energy by using the solar panel. Both energy which are RF energy and solar energy can get from the solar panel. In the other words, the solar panel also act as the antenna for receiving the signal and convert to RF energy. The analysis will be made to analyze whether the RF energy can be got from solar panel. The patch antenna was designed and fabricated. The solar panel was tested with RF equipment to measure the solar panel performance parameters and compared with patch antenna. For the signal strength solar panel showed a good performance compared to patch antenna

which for solar panel was -32.67dBm at 2.5GHz while patch antenna was -38.88dB at 2GHz. On the other hand, the ambient energy showed slightly difference in terms of receiving power but for the frequency, the frequency received was in range ±1.8GHz. Moreover, the gain for solar panel was 2.31dB and it was lower than patch antenna gains of 4.73dB due to the tolerance in PCB manufacturing process. In conclusion, the dominant frequency for solar panel is ±1.8GHz which the application for this frequency is in GSM.

CHAPTER 1

INTRODUCTION

1.1 Overview

Energy harvesting has been around for a very long time. At that time, energy was harvested in the early days of the electrical revolution by putting generators on river mills that were powered by running water to generate electricity. The most common energy is solar energy which is a most important item in energy harvesting. The concept of energy extraction from nature, which can be used to replace the conventional power source. The energy harvester needs to be converted to voltage or current to power the system. One of the ways to use energy harvesting by using the hybrid sources. Hybrid sources can be formed by using three types of sources which are Thermoelectric Generator(TEG) that the variance of temperature between the surrounding and the heat. Secondly, the vibration sources that are used the vibration sources such as motor and the shaking device, the Radio Frequency(RF) that are produced radiated power. Other than that, energy harvesting is the first real-world implementation of scalable battery-less stand-alone wireless sensor platforms for the quality of life and the Internet of Things (IoT) application. The energy that commonly used is solar energy technologies. However, the devices currently need to use electricity frequently and solar energy has its limitations. This study will highlight on the investigation on harvesting energy for RF energy by using the solar panel. Both energies which are RF energy and solar energy can get from the solar panel. In the other words, the solar panel also acts as the antenna for receiving the signal and convert to RF energy. The analysis will be made to analyze whether the RF energy can be got from solar panel RF energy is one of the hybrid sources for energy harvesting. The RF energy is made of an antenna, capacitor and voltage multiplier. RF energy also can enhance the life time of sensor nodes for wireless sensor network [2] and as low power voltage boosting [3]. Besides that, RF energy has been converted to direct current (DC) [4] and its design for low the cost of electricity [5].

Solar PV which is photovoltaic energy also one of the energy harvestings. Solar PV is one of the largest sources for the energy harvester [6]. There are some properties to harvest energy from the solar PV such as the spectral composition, incident angle, and intensity of the energy. Plus, the common properties that need to be considered are the size, sensitivity, temperature and the type of the PV cell [6].

1.2 Problem Statement

The solar energy is commonly used by most of the countries in the world. The solar energy harvest by using solar PV panel which will occupy the space. Therefore, the research need to carry out on possible harvest RF energy by using a solar PV panel. Also, the development combination of RF energy and solar energy are made a success. This research can replace the conventional power source and can prove that the solar panel can also be used to produce energy not only for solar energy.

The low-profile and small antenna is really recommended for any communication system. For example, a rectenna which a hybrid energy harvesting that combining a solar panel and a rectenna to produce RF energy [5]. This research is to analyze either solar panel and antenna can share the same area leading to a compact structure. But, the cost for the development is quite high to produce it. Plus, the time spends to complete the system are much longer compared to common one. Other than that, the rectenna also used to obtain a compact implementation and to minimize the sensitivity of rectifier circuit variations in the received RF power level [4]. The previous research only does the analyzing process but does not compare with any references antenna. Last but not least, there are many solutions to overcome the problems in the next future for a communication system.

1.3 Aim

The aim of the project is to investigate and analyze Hybrid RF and Solar PV energy harvesting. Also, to test the solar panel either it can propagate and radiate at certain frequencies.

1.4 Objectives

The objectives of this project are:

I. To investigate Hybrid RF and Solar PV energy harvester

II. To analyze RF energy from Solar PV panel

1.5 Scope of Limitation of the research

In this research, Hybrid RF and Solar PV are proposed. The solar panel operating at certain frequencies. This research will focus on the testing process of the solar panel. The performance of the solar panel including the gain, return loss, bandwidth and signal strength will be measured using laboratory RF equipment. The scope of this study is in line with the objectives which are investigating, analyzing and comparing. The other scopes are:

I. Analyze the bandwidth

II. Analyze the receive signal level energy

1.6 Thesis Organization

Chapter 2 summarizes the research information from previous research that is related to energy harvesting. It explains the types of energy harvesting used and introduction to solar PV and RF energy applications. The basic concept of the solar panel used as the antenna will be explained here.

Chapter 3 provides the discussion of methods being applied on this project. The flow chart, block diagram, design procedure of solar panel and measurement procedure will be explained in this chapter.

Chapter 4 focuses on the results and analyses. This chapter will show the simulated and measured results from simulation tool and laboratory RF equipment respectively and comparison between simulated and measured results of the solar panel.

Chapter 5 concludes the project from the beginning stage until the stage of implementation. The limitations of the solar panel and future works will be discussed and suggested here.

CHAPTER 2

Literature Review

2.1 Introduction

This chapter discusses the studies and researches done previously about the development of energy harvesting. The review is to gain more information, ideas, and concept which has been conducted previously. The studies on energy harvesting technologies are to make this research to be more effective and efficient.

2.2 Energy Harvesting Technologies

Energy harvesting is the first real-world implementations for battery-less and wire-less platforms for the quality of life and the Internet of Things (IoT) applications [1,14]. Besides that, energy extraction is to obtain significant advantages over conventional power source. These technologies can change non-rechargeable battery to rechargeable battery which is replacing conventional power source. The conventional sources have some disadvantages such as creates a lot of greenhouses gases and some other carcinogenic gases that lead to global warming. This system already reaching a point of equilibrium which is low-cost. Besides that, a small size of harvester can power up very low energy consumption [6].

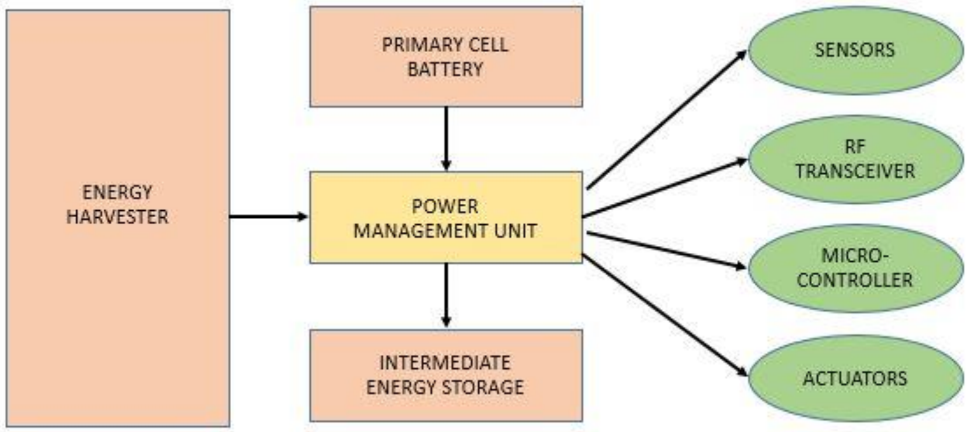

Figure 2.1. Energy harvesting system setup [6]

Figure 2.1 shows the normal energy harvesting process for a wireless environmental sensor. Temperature, humidity or different gases can be sensed by using this sensor. Energy harvesting can be applied to many other applications such as industrial applications for security and surveillance camera. Other than that, home healthcare applications and wireless patient monitoring have a need to run without battery life. Furthermore, energy harvesting can act as a consumer for electronic devices such as portable and wearable devices.

There are several types of sources such as solar, thermal, vibration, and RF. Basically, solar and thermal sources need to be converted form AC to DC which is DC is the output source while kinetic and RF sources are generated changing or AC voltages [2-6].

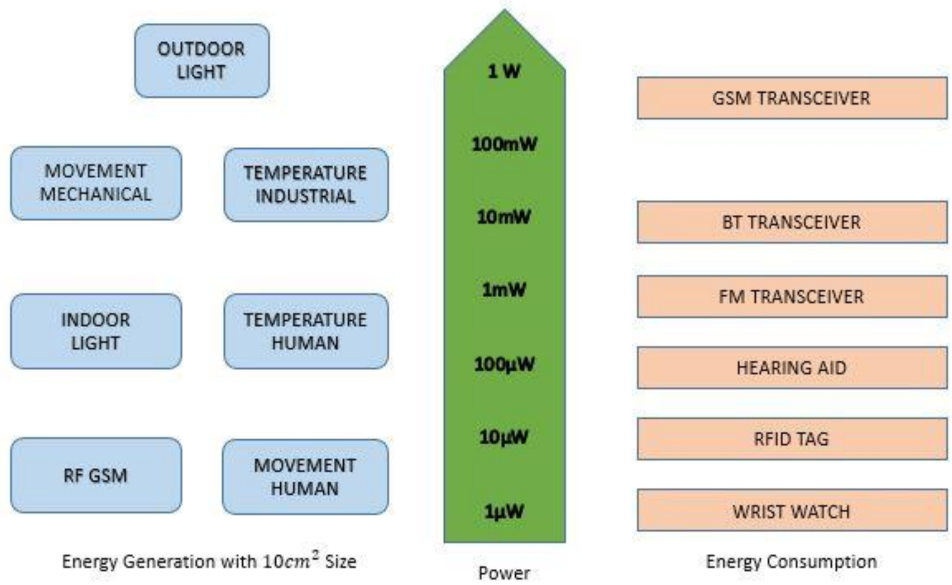

Figure 2.2. Different sources of energy and the required energy requirements of different applications [6].

In the research investigated by Frederik (2015), Figure 2.2 shows the harvester size of 10 centimeters square that can roughly be generated. At the center of the figure shows the power of the unit of Watts. While on the right side shows the energy generation and the left side shows energy consumption. Feasibility can be interpreting by using this figure and this figure easily show the energy that is harvested either enough power or not.

2.2.1 Solar

For wireless sensor networks, one of the best and mature sources is solar energy [2]. The solar system is made up of photovoltaic(PV) and the cell is made from crystalline silicon (c-Si). Other than that, to make Photovoltaic cells (PV) some of the silicon types are used such as mono-crystal, multi-crystal, micro-crystal and amorphous [2]. PV methods are consisting of photons that it negative and positive layer are fabricated at each of solar cell. The electrons move freely and move through the wires to generate electricity. This produced by the absorption of photons in the cells. Besides that, solar energy is clean and renewable energy and its very environmental-friendly [7]. Solar has the long list of applications where as at any home or workplace, there must be at least one solar-panel calculator. It has a small panel photovoltaic (PV) cell to top it up [2].

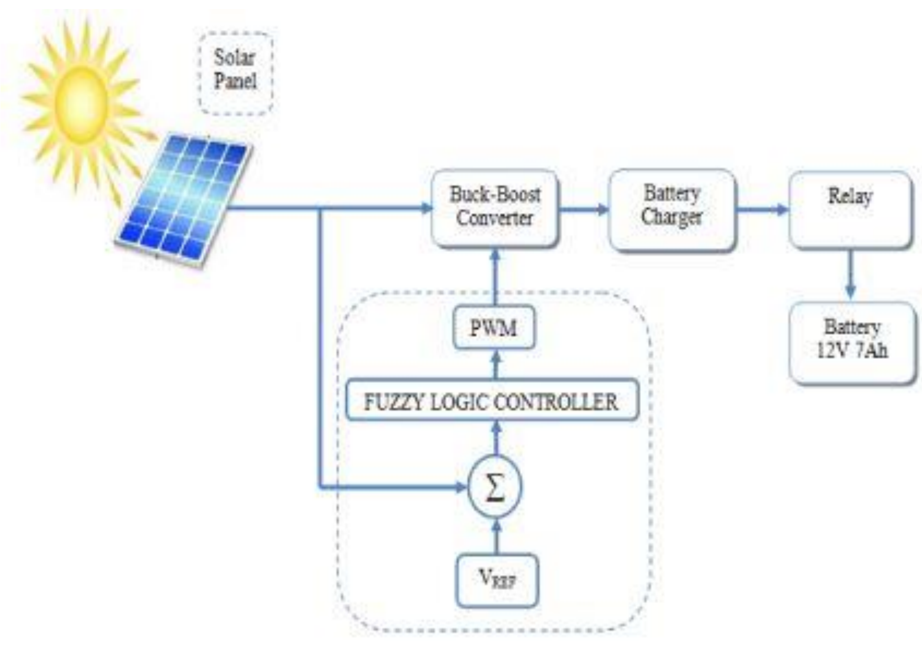

Figure 2.3. Block diagram of Buck-Boost Converter using Fuzzy Logic Controller [15]

Chetan P. Ugale et al. (2017) in their recent paper describe the Buck-Boost Converter using Fuzzy Logic Controller. Figure 2.3 show that the entire flow of the method starts with the solar panel. At first, the sun is converted to electrical energy by using photovoltaic effect. Then, depending on the temperature and solar irradiation, the output of the solar panel is low voltage. In the morning, solar irradiation and temperature are very low while at the noon time, it is varied. To solve this problem, they are using Buck-Boost Converter which is the output depends on time for which MOSFET is ON. Other than that, the duty cycle needs to be changed depending on the variable solar panel voltage that applied to the buck-boost converter, so that the output voltage become constant. Lastly, fuzzy logic is used to obtain the variable duty cycle.

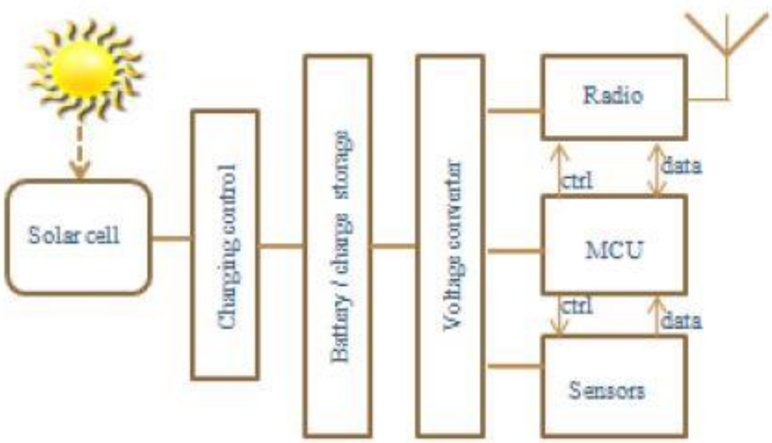

Figure 2.4. Block diagram of a typical WSN nodes [16]

Jakob Gakkestad et al. (2011) successfully powered up the wireless sensor nodes (WSN) using the solar panel. Figure 2.4 show the typical WSN nodes that started with the solar panel. While using the solar cell, a battery is needed to store surplus energy for the time when the sun irradiation is low or absent. The function of the MCU is to control the biasing of the sensor so that the power consumption in sleep periods is reduced. Next, if the sensor is analog, the internal A/D in the microcontroller are used to convert the measured data. If the sensor is digital, it will be controlled by the MCU and must be in sleep modes or low power modes.

2.2.2 RF

RF energy that transfers power with radio wave by propagated RF energy. Plus, either in time or weather RF energy will not be effected [3]. To convert RF signal to DC voltage one of the method used to harvest RF energy is the efficiency of an antenna. The efficiency of an antenna along with the impedance accuracy matching of an antenna with a voltage multiplier. The power that is harvested is small due to the RF-to-DC low energy conversion efficiency.

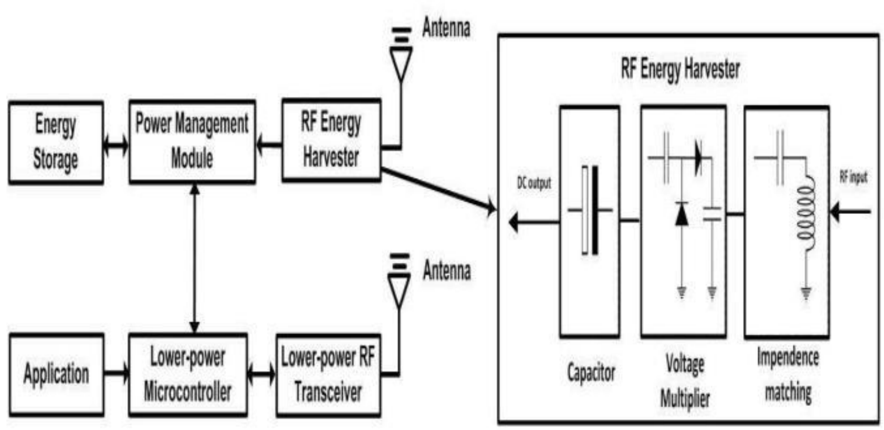

Figure 2.5. The architecture of RF energy harvesting device [2].

According to Faisal Ahmad et al. (2015), the architecture of Radio Frequency Energy Harvesting (RFEH) has three major components which are information gateways, the RF energy sources, and the network devices. Figure 2.5 show the block diagram of RF energy harvesting device that consists of few components such as application, a low-power microcontroller, a low-power RF transceiver, an energy harvester, composed of an RF antenna, a capacitor, and a voltage multiplier and convert them into electricity, a power management module and energy storage device. Based on the efficiency of the antenna and the matching of impedance, they can harvest the RF energy. After receiving RF energy, the energy needs to convert to DC voltage but the RF power is small due to the converting process that produces low energy conversion efficiency.

2.2.3 Wind

There is various type of energy harvesting, one of the energy harvestings that is non-pollution is wind energy. There are some techniques used which are using piezoelectric material and cantilever beams. But mostly used for energy harvesting is piezoelectric [19]. As we know, main wind energy mechanism is wind turbines. The wind turbines convert the kinetic energy to mechanical power. Then from the mechanical power, convert to electricity [2].

According to Giuseppe Acciani et al. (2015), by optimizing the shape of the cantilever beam for wind energy harvesting can provide us comparison from the original turbines. By choosing suitable shapes, they can find the best values of electrical potential under wind stress, in the fixed analyzed configuration. This research came out with the best shape for the cantilever beam which is a trapezoidal beam. This is because it has the largest width for clamped side and maximum height [19].

2.2.4 Thermal

With the difference of temperature between thermoelectric materials and heat, the carrier will produce thermoelectric effect [22]. Based on Seebeck and Peltier effects, the thermal energy is exploited [2]. Seebeck effect means that's possible to harvest energy from heat by using thermoelectricity generator due to its heat energy harvesting capabilities [2-3]. Then, convert thermal energy into electrical power. By using thermoelectricity generator (TEG), electricity can be obtained with difference temperature. Because of TEG are nil emission, compactness, few moving parts, high reliability, low noise, cleanness and no fuel consumption, the TEG is one of desirable energy harvester [3].

In the research by Priya V et al. (2016), an 11mV single stage thermal energy harvesting regulator with the effective control scheme for extended peak load. By controlling the input voltage, the system is able to support a maximum load of 1.5mW at the 1V output voltage. Also at 11mW, the peak efficiency is 68% obtained. This shows that the system can be used for low energy power applications.

2.3 Related Works

2.3.1 Solar/RF Energy Harvesting and Wireless Power Transmission

According to Kyriaki Niotaki et al. (2014) [4], the research is focused on solar and RF energy harvesting only. This is because both energies are eco-friendly and the level of energy are not predictable. As to start the research, they are using solar antenna where the solar panel shares the same area as the radiating element which is RF element. By designing the Resistance Compression Network (RCN)-based dual band with the frequency of

915MHz and 2.45GHz rectifier. The used of RCN is to minimize the load sensitivity of the rectifier.

The rectifier is designed to be matched with the 50Ω source which is the circuit is designed by using the harmonic balance (HB) and the large signal scattering parameter (LSSP) I the Agilent ADS software. To achieve the impedance matching and to maximize the RF-dc conversion efficiency of the circuit which is imposed the optimizing goals. The designed rectifiers are compared to the conventional rectifier and the observation obtained by comparing fewer variations in the efficiency versus load and the input power variations. The rectifier shows a good simulated and measured with an input power of -15dBm and output load of 1kΩ. Furthermore, to power the frequency generation circuits, solar energy is used so that RF energy can be synthesized and used as wireless power transmitters.

2.3.2 Hybrid Solar and RF Energy Harvesting Rectenna

By the research from Ana Collado, Apostolos Georgiadis (2012) [5], the solar panel and antenna element has been presented. One method is used to optimize the RF energy harvester that allows a joint simulation of the radiating element and the rectifier circuit using reciprocity theory.

Table 2.1. Matching Network Parameters

Rectifier Design	Lg (nH)	L (nH)	C (pF)	R_L (KOhm)
800 MHz to 2.5 GHz	N/A	20	20	3.1
GSM-850 / GSM-1900	5.6	12	100	2.2
GSM-850 / ISM 2.45GHz	N/A	12	100	2.2

By comparing three designs, the GSM-850 and GSM-1900 were selected as the highest RF-to-DC conversion efficiency. Other than that, to evaluate the performance of the RF energy harvester with and without the integration of the solar cell, the solar/RF hybrid energy harvester implemented was placed in the anechoic chamber. With the distance of 3.45m, the RF signal is transmitted toward the hybrid harvester and the results show that the output voltage is low. This is due to the low power density arriving at the rectenna which is less than -20dBm.

Furthermore, the result shows that the performance of the RF energy harvester is the same either with a solar cell or not. By testing the effect of the bending of the structure, they are using 2 difference curvature R, R= 7 cm, and R= 10 cm. the performance of the RF energy harvester only slightly effected by the bending of the system showing a robust structure. The performance of the simultaneous operation of the rectenna and the solar cell is evaluated. It is showed that the current under irradiation conditions does not show any varies while the available RF power at the antenna input is varied from -25dBm to -10dBm. Plus, RF power presented at the antenna does not affect the output of solar cell DC.

At the frequencies of 850 MHz and 1850 MHz, the signal is corresponding to the two frequency bands where the rectenna efficiency is optimized. Besides that, due to larger propagation loss, the DC output is less even though the frequency is at the higher range. The output signal from each of DC source is recorded separately while the solar cell and rectenna circuits shared the same DC ground reference. In the future, it is the object to design forming a complete energy harvesting solution powering a rechargeable battery or super-capacitor. Lastly, the final implementation of the optimum hybrid harvester design has been done successfully show the good results.

2.3.3 Photovoltaic Enhanced UHF RFID Tag Antennas for Dual Purpose Energy Harvesting.

According to Alanson P. Sample et al. (2011) [7], they had argued that the most challenging obstacle to improving passive RFID tag performance is the limited amount of power that can be rectified from the signal transmitted by the RFID reader. They are using a power supply, harvests RF energy, communicates with the RFID reader and harvest solar energy has been used to argue this research. Using HFSS the prototype is simulated after built a prototype of the solar-enhanced RFID antenna.

The effective read range of the tag by at least a factor of six under normal indoor office due to the dual-harvesting antenna has been increased. Plus, sensing and data logging has enough power even while away from a RFID reader. Because of the used of dual energy harvesting, it can enhance the red rate of the RFID tags. Other than that, it also provides increased power for more demanding workloads and allows sensing, data logging, and computing operations even while away from RFID readers.

With using low cost but high volume production processes, the tag architecture is compatible. Besides that, hybrid RF-solar is compatible with the RFID IC footprints and without extensive modification, it can be integrated the photovoltaic and RFID manufacturing processes. It can be simplified that, the tags are similar in cost with the recent tag used but it has been improved in performance and additional capabilities enabled by the additional power source.

Table 2.2. Comparison between the system research

Author	Method	No of operational bands	Antenna design	Results
Kyriaki Niotaki, Ana Collado, Apostolos Geogiadis, Sangkil Kim, Manos M. Tentzeris	Solar & EM energy harvesting	Dual band	RCN-based (915MHz/2.45GHz)	EM energy can be synthesized & minimize the sensitivity to input power and load variations
Ana Collado, Apostolos Georgiadis	Solar & EM energy harvesting using reciprocity theory	Dual band	GSM-850 & GSM-1900	The design is optimized
Alanson P. Sample, Jeff Braun, Aaron Parks, Joshua R. Smith	Solar & RF energy harvesting	Dual band	Not reported	Same as the normal design but improved in performance

2.4 Summary

Some of the investigation on energy harvesting with 4 techniques were described to give difference insights to design the system. A number of frequencies that can be used and suitable for the system. Hybrid RF and solar PV as known as eco-friendly, compatible with low cost and high volume production process. Therefore, RF and Solar energy will be selected as the proposed design.

Other than that, the topology and various techniques related to RF and solar energy were studied and discussed. The solar panel is a good participant as it has potential to convert the solar energy to the RF energy. Moreover, it can be easy to get it from the supplier and the fabrication process is very easy as it only uses for DC blocking. Despite that, many techniques are also discussed to improve the return loss, power radiation and transmitted. Last but not least, the hybrid RF and solar PV energy harvesting will be analyzing and the analysis methodology will be explained in the next chapter.

CHAPTER 3

Methodology

3.1 Introduction

This chapter will describe the methods and steps used in analyzing a hybrid RF and solar PV energy harvesting that is suitable for search and rescue operations. Basically, there are three main milestones in this research. (1) investigating; (2) analyzing and (3) comparing. Other than that, there are four sections that will explain the procedures to fulfill the objectives research. In section 3.2, this section will be covered the overall steps and procedures until the completion of the research. Then, on the next section, section 3.3 will explain about the project requirements which are software and hardware. Next, in section 3.4, will explain about the process modelling according to the project specifications. Finally, in the last section, the data analysis will explain in section 3.5.

3.2 Project Implementation Flow

In this section, it will cover the procedures to analyze the solar panel either the solar panel can receive RF energy or not. There are many solar panel with differences type and size, so the first step is by searching for available and suitable solar panel. Secondly, combine the DC blocking with solar panel. Thirdly, measure the performance of the solar panel using lab equipment. Fourthly, use design patch antenna as a reference to compare with the solar panel with the ground plane and without the ground plane. Then, the results will be compared with the measurement that has been collected. Figure 3.1 show the overall flowchart of steps and procedures.

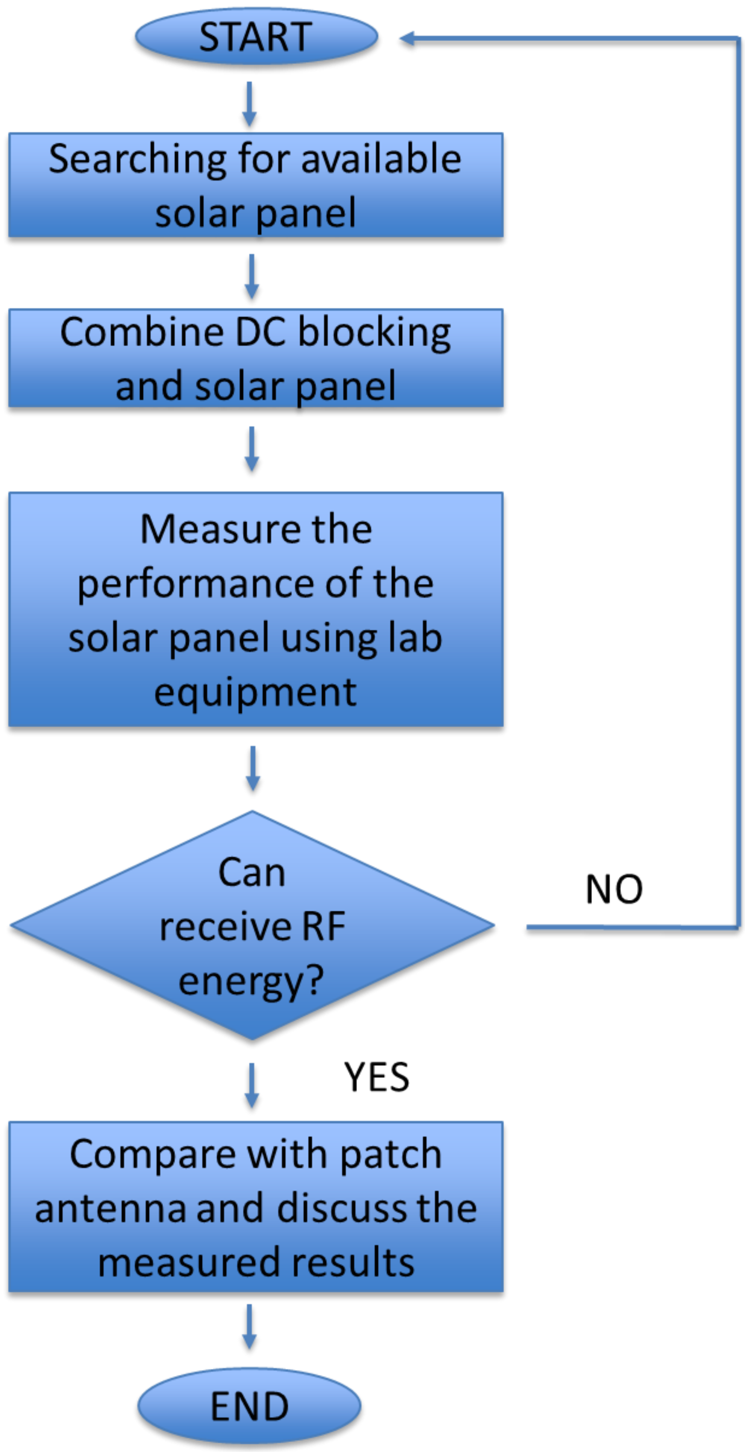

Figure 3.1. Overall methods to compare the results

3.3 Project Requirement

3.3.1 Hardware

(a) Solar panel

The solar panel is used to receive solar and RF energy. The RF energy that receives is measured to do the analysis and to determine the energies receive and interference occurs. Then the solar panel measurement will be compared with designed patch antenna.

(b) Capacitor

The capacitor is used for the DC blocking. In this research, 10pF is used to solder at the fabrication board for DC blocking.

(c) PNA-X Network Analyzer

The network analyzer is used to determine the return loss, resonant frequency and bandwidth of the solar panel and patch antenna.

(d) Agilent CXA Spectrum Analyzer

The spectrum analyzer is used to determine the ambient energy, power and frequency receive. Besides that, to determine the gain for solar panel and patch antenna.

(e) Agilent 8364B Series Swept Signal Generator

The signal generator is used to set the amplitude and the frequencies for transmitter and receiver process.

(f) Aluminum Plate

Aluminum plate is used as a ground plane for the solar panel. This ground plane is added to analyze either it will enhance the measurement or the measurement remain the same. The thickness of aluminum used is 1.70mm.

(g) Horn antenna

The horn antenna is used in the transmitter and receiver process. This process is to determine the signal strength of the solar panel. The range frequencies for the horn antenna is 2GHz to 20GHz. The horn antenna will be the transmitter while the solar panel will be the receiver. Other than that, horn antenna also used as a reference antenna in measuring gain for solar panel and patch antenna. The range frequency for the horn antenna is 0.8GHz – 8GHz.

3.3.2 Software

(a) Advanced Design System (ADS)

Using ADS to design the DC blocking for the solar panel. As mention before, current that are flow in a solar panel is in alternating current (AC). So that, need to convert to direct current (DC) using DC blocking. The DC blocking design only consists of wire and capacitor. Other than that, DC blocking is to prevent the flow of audio and direct current (DC) frequencies while offering minimum interference to RF signals.

(b) Computer Simulation Technology (CST)

Using CST to design the patch antenna with the frequency of 1.8GHz. The patch antenna is used to compare the measurement result between solar panel and patch antenna.

3.4 Project Design

3.4.1 Microstrip for DC blocking

In this section, it will cover the modelling process by using the software which is ADS software. This modelling is the process to design Direct Current (DC) blocking for the solar panel. To design the microstrip line, the parameters such as the width of microstrip and length of micro strip have to be first determined. In order to calculate the length and the width of the micro strip line, LineCalc tool is used to determine the dimensions of the microstrip line. In Figure 3.2, it shows the length and width in the unit of a millimeter that calculated with ADS. The ADS resulted values of the micro strip line will be matching with the 50Ω impedance load at 18GHz.

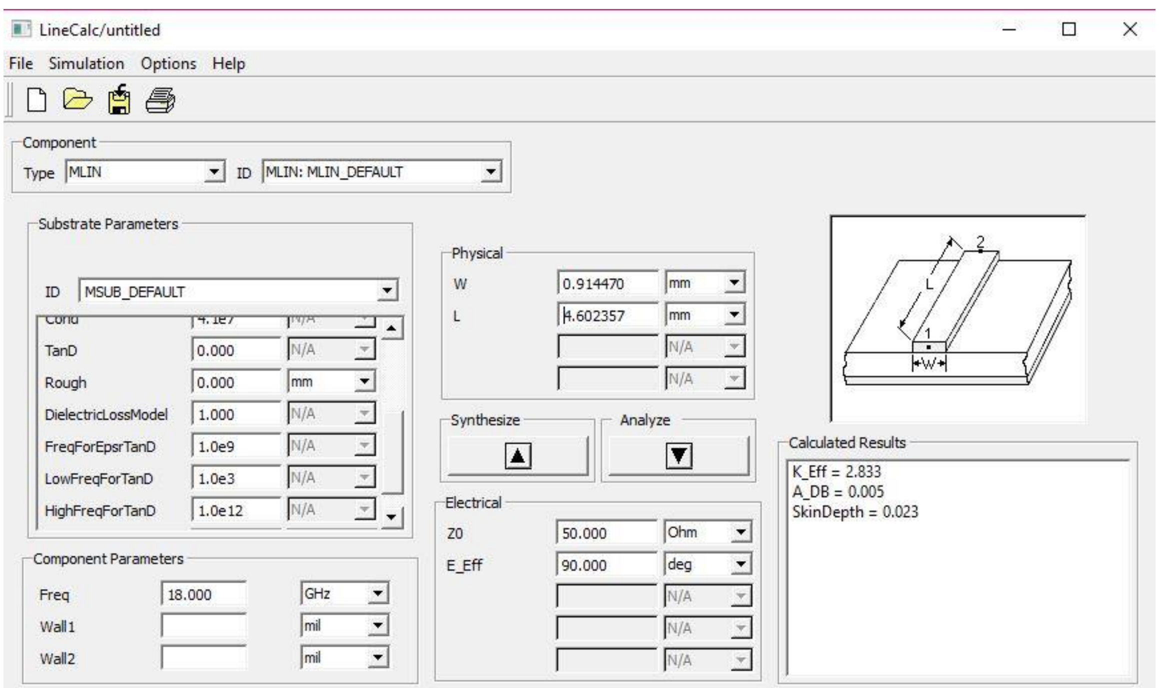

Figure 3.2: Values for Length and Width of Micro strip

Figure 3.3 shows the schematic for the micro strip line. The schematic consists of Mlin, Mcurve, and capacitor. The value for the capacitor is 10pf. Furthermore, Figure 3.4 shows the layout for the DC blocking for fabricating. The type of the plate used for fabricating is Duroid.

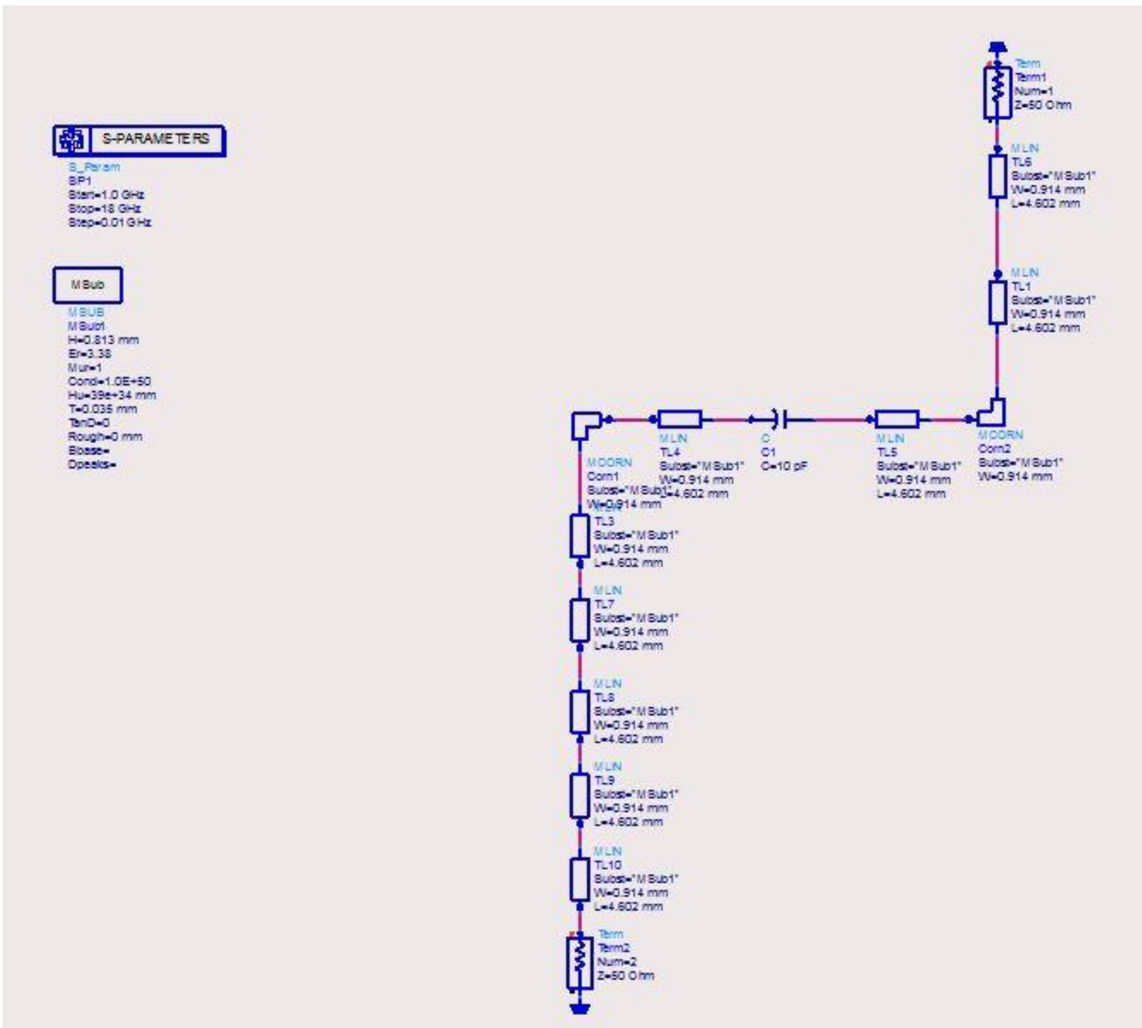

Figure 3.3. Schematic Diagram of Micro Strip Line