Faculty of Electronics & Computer Technology and Engineering

DEVELOPMENT OF ANTENNA FOR WI-FI SIGNAL ENERGY HARVESTING USING CST

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Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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DEVELOPMENT OF ANTENNA FOR WI-FI SIGNAL ENERGY HARVESTING USING CST

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A project report submitted
in partial fulfillment of the requirements for the degree of
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UNIVERSITI TEKNIKAL MALAYSIA MELAKA
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I declare that this project report entitled “DEVELOPMENT OF ANTENNA FOR WI-FI SIGNAL ENERGY HARVESTING USING CST” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology (Telecommunications) with Honours.

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DEDICATION

Special dedication to my wonderful family,

Your love and unwavering support have been my greatest treasures throughout this journey. Mom, Dad, and my amazing siblings, your sacrifices and encouragement have fuelled my determination. This achievement is as much yours as it is mine.

I also extend my heartfelt thanks to my supervisor, Nurulhalim bin Hassim for their guidance and mentorship. Your support has been instrumental in shaping my path and realizing my potential.

This work is dedicated to my family and my supervisor, whose belief in me has been the driving force behind my success.

ABSTRACT

The "Development of Antenna for Wi-Fi Signal Energy Harvesting using CST" project is all about designing, simulating, and improving an antenna system for producing electricity from Wi-Fi signals. Using CST (Computer Simulation Technology) software, the project will come up with a good antenna setup that can pick up Wi-Fi signals and turn them into useful electricity. The project involves designing and analysing different kinds of antennas, taking into account things like antenna shape, size, and material qualities. Through CST models, the project checks how well the antenna system works, looking at things like its radiation pattern, gain, impedance matching, and how well it gathers energy. The goal is to make an antenna design that gets the most energy out of Wi-Fi signals, so that power can be converted and sent to linked devices or energy storage systems as efficiently as possible. The project also looks at how the performance of the energy harvesting device is affected by things like signal strength and interference in the environment. The project's expected results include figuring out the best way to set up an antenna to collect energy from Wi-Fi signals, learning how design parameters affect how well energy harvesting works, and making guidelines for how to do it in real life. The results of CST simulations will be used to build and test the antenna system, which will help Wi-Fi signal energy harvesting systems move forward. In conclusion, the "Development of Antenna for Wi-Fi Signal Energy Harvesting using CST" project aims to use the capabilities of CST software to create an efficient antenna system for getting electricity from Wi-Fi signals. The project helps find ways to make wireless technologies more sustainable and self-powered. It could help power low-power devices and make them less reliant on standard energy sources.

ABSTRAK

Projek "Pembangunan Antena untuk Pemungutan Tenaga Isyarat Wi-Fi menggunakan CST" adalah berkaitan dengan reka bentuk, simulasi, dan peningkatan sistem antena untuk menhasilkan tenaga elektrik dari isyarat Wi-Fi. Dengan menggunakan perisian CST (Computer Simulation Technology), projek ini akan mencipta satu susunan antena yang baik untuk menangkap isyarat Wi-Fi dan mengubahnya menjadi tenaga elektrik yang berguna. Projek ini melibatkan reka bentuk dan analisis antena yang berbeza, dengan mengambil kira perkara seperti bentuk, saiz, dan sifat bahan antena. Melalui model-model CST, projek ini menyemak sejauh mana sistem antena berfungsi dengan baik, termasuk corak penyebaran radiasi, keuntungan, penyesuaian impedans, dan keberkesanan pemungutan tenaga. Matlamatnya adalah untuk membuat reka bentuk antena yang mendapatkan tenaga paling banyak dari isyarat Wi-Fi, supaya kuasa dapat diubah dan dihantar ke peranti yang disambungkan atau sistem penyimpanan tenaga dengan efisyen sebanyak mungkin. Projek ini juga mengkaji bagaimana prestasi peranti pemungutan tenaga terjejas oleh perkara seperti kekuatan isyarat dan gangguan dalam persekitaran. Hasil yang dijangka dari projek ini termasuk mencari cara terbaik untuk menyusun antena untuk mengumpul tenaga dari isyarat Wi-Fi, memahami bagaimana parameter reka bentuk mempengaruhi keberkesanan pemungutan tenaga, dan membuat panduan tentang bagaimana melakukannya dalam kehidupan sebenar. Keputusan simulasi CST akan digunakan untuk membina dan menguji sistem antena, yang akan membantu pemajuan sistem pemungutan tenaga isyarat Wi-Fi. Kesimpulannya, projek "Pembangunan Antena untuk Pemungutan Tenaga Isyarat Wi-Fi menggunakan CST" bertujuan untuk menggunakan keupayaan perisian CST untuk mencipta satu sistem antena yang cekap untuk mendapatkan tenaga dari isyarat Wi-Fi. Projek ini membantu mencari cara untuk menjadikan teknologi tanpa wayar lebih lestari dan berkuasa sendiri. Ia boleh membantu memberi kuasa kepada peranti dengan kuasa rendah dan mengurangkan kebergantungan mereka pada sumber tenaga piawai.

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CHAPTER 1

INTRODUCTION

1.1 Background

As wireless communication technologies have grown quickly, Wi-Fi networks have become an important part of our daily lives. They make it easy and safe to connect to the internet. But, because Wi-Fi signals are everywhere, they also offer an unused source of energy that can be used to make power. This is called "harvesting" Wi-Fi signals. This new field focuses on capturing and turning the energy that Wi-Fi waves carry into electricity that can be used. Wi-Fi signal energy gathering has a lot of potential as a source of renewable energy for many different uses. It could be used to run low-power electronics, sensors, and wireless systems without the need for wired power sources or batteries that need to be changed often. By getting energy from the Wi-Fi waves around it, this technology makes it possible for wireless devices to run on their own power and helps save energy and the environment.

The idea behind harvesting energy from Wi-Fi signals is to take the electromagnetic energy that Wi-Fi signals carry and turn it into electricity. This can be done in a number of ways, such as by making antennas that are better at picking up signals[1]. The collected energy can then be used to run a wide range of devices and applications. There are many good things about getting energy from Wi-Fi signals. First, it gives us a source of energy that is always there and doesn't run out, since Wi-Fi waves are always around us. Second, it gets rid of the need for batteries or wired power connections, which reduces waste and upkeep costs and is better for the environment. Third, it makes wireless devices more flexible and mobile by letting them work without external power sources and letting them power themselves.

This opening sets the stage for looking into how Wi-Fi signal energy harvesting could be used as a way to get power that doesn't harm the environment. By using the energy carried by Wi-Fi signals, this technology offers an interesting way to power wireless devices and move forward the development of wireless systems that use less energy and can run on their own.

1.2 Problem Statement

Wi-Fi signal energy harvesting is hard because it is hard to capture and turn the energy that Wi-Fi signals carry into electrical power in an efficient way. Even though Wi-Fi signals are all around us, most of their energy is still not being used. To use this energy source effectively, there are a few key problems that need to be fixed.

Firstly, low power density. Most Wi-Fi signals have a low power density, which makes it hard to get enough energy from them for useful uses. The problem is coming up with energy harvesting methods that can catch and turn this low-density energy into power that can be used by different devices and systems.

Secondly, limited range and coverage. Wi-Fi signals have a limited range and area of service, which makes it harder to get energy from them. The problem is to find ways to increase the range and coverage of Wi-Fi signals or to come up with energy-harvesting methods that work well even with the limits that are already in place.

Last but not least, efficiency and convertion rate. Wi-Fi signal energy harvesting systems need to be able to convert energy well. The problem is to create and improve energy harvesting circuits and methods that can convert Wi-Fi signals into as much usable power as possible and do so as efficiently as possible.

Getting rid of these problems in Wi-Fi signal energy harvesting is important if we want to use this green energy source to its fullest. By solving these problems, we can pave the way for wireless devices that can power themselves, reduce our reliance on traditional power sources, and help build wireless communication systems that are sustainable and use less energy.

1.3 Project Objective

The objective of the project is to use CST (Computer Simulation Technology) to build, simulate, and develop an antenna system for efficient Wi-Fi signal energy harvesting. This objective is directly related to the problem statement that low power density and the need for effective energy harvesting methods were found to be a problem. Specifically, the objectives are as follows:

a) To design and implement an antenna for energy harvesting that can efficiently capture and store energy from Wi-Fi signals which is at 2.45GHz and 5.83GHz and use this energy to power low- power devices such as sensors or small wireless devices.

b) To optimize the performance of the antenna so that it can operate reliably under varying Wi-Fi signal conditions and can effectively harvest energy without significantly impacting the performance of the Wi-Fi network.

c) To evaluate the effectiveness and efficiency of the antenna that has been designed for energy harvesting through testing and experimentation and identify areas for improvement and optimization in order to increase the system's overall performance and energy output.

1.4 Scope of Project

The scope of this project are as follows:

a) The design process of antenna size, shape, material selection, and impedance matching.
   - Frequency range
   - Bandwidth
   - VSWR
   - S11 Return loss
   - Directivity
   - Total efficiency

b) The project extensively utilizes CST software for electromagnetic simulation and analysis of the antenna system.

c) Optimize the antenna system for enhanced energy harvesting performance.

d) Fabrication and testing of a prototype antenna based on the optimized design.
   - FR-4 Substrate
     i. Thickness
     ii. Dielectric constant

e) Documenting the design process, simulation results, optimization techniques, and validation outcomes.

1.5 Report Outline

The report is made up of five chapters: an opening, a review of the literature, a section on how the research was done, preliminary results, and a conclusion. Chapter 1 gives background information about the project, facts about the problem, goals, the project's scope and limitations, and a plan for the thesis.

Literature reviews are presented in Chapter 2. In Chapter 2, the literature review looks at previous case studies, theories, and publications on this subject. The method used in this part is to read a previous case study, thesis, or journal. It will start with a newly made metal matrix composite and end by mentioning the title of the study.

In the third part, methods are presented. After that, the methodology was used, which explains the steps that were taken for this study. It also showed and explained in detail how the study was done. Aside from that, Chapter 3 will have a flowchart that shows how the study went in general.

All the information was gathered and looked at. After that, the result is presented, and a conclusion is drawn from the data analysis. In this study, the suggestions for how to improve will be briefly explained.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This could be the body part of the whole content. It gives an overview of the theory, the most important thing we know now, and what other researchers have found. But this is the reason why more study needs to be done in the area. In this part, there are references that are up-to-date and useful. This is important because it shows if the system is working right and if it can fix the problem.

2.2 Radio Frequency (RF) Energy Harvesting

Radio frequency (RF) energy transfer and harvesting (RF-EH) is a possible system that uses electromagnetic waves to gather energy from radio waves. This new technology can provide wireless power for gadgets that don't need batteries. This makes it a possible alternative energy source for future applications. RF-EH technology is helpful because it allows wireless devices to automatically recharge their energy and offers a wide range of energy sources that are good for the environment. It is also helpful because it makes it easier to use quality-of-service apps. Figure 2.1 below shows a block diagram of an RF energy harvesting system.

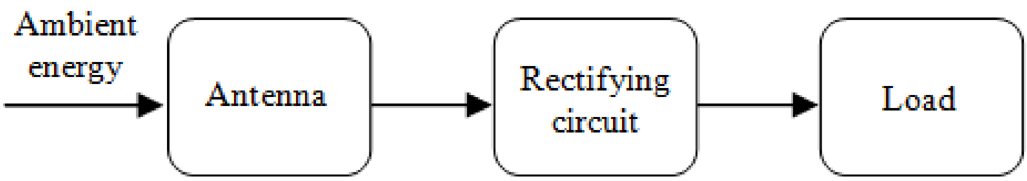


Figure 2.1: Block diagram of an RF energy harvesting system

[2]This review talks about the many sources of RF-EH in the area, such as close cell phones, Wi-Fi, wireless local area networks, broadcast TV signals or DTS, and FM/AM radio signals. On the other hand, the energy is picked up by a receiving antenna and turned into a direct current power that can be used.

This review also gives an overview of how powerful RF-EH technology is, which could be used as a guide for making RF-EH units. Energy gathering circuits use cutting-edge electrical technology to work well, since they are made to work with a very small amount of current and voltage. So, the study goes into detail about the pros and cons of different RF designs and how they work. Finally, the most recent uses of RF-EH are shown.

The collection of radio frequency (RF) energy has a bright future as a method for producing a negligible amount of electrical power that can be used to operate partial circuits in electronic devices that are capable of wireless communication. [3]In this study, the effects of frequency shift keying modulation on RF energy harvesting charging times were studied and looked into in depth. An advanced system for taking measurements was set up. This system used an RF energy gathering circuit, a signal generator, patch antennas, and other tools. The signal generator made the modified signal with an output power of 14 dBm. Then, the RF energy gathering circuit with a 6 dBi patch antenna was used to get the energy made by the signal generator from 20 cm to 60 cm at 5 cm intervals. Based on the measurements, the fastest time to charge was found to be 1 s at a distance of 20 cm. Also, the most time it took to charge was determined to be 7 s at a distance of 60 cm. It was found that the RF energy harvesting took less time to charge as the distance between the signal source and the RF energy harvesting circuit got smaller

The Internet of Things and wireless sensor networks are getting smarter control units thanks to recent improvements in how much power they use. Because of similar improvements in battery technology, these devices can now run on their own. But this method is not good enough for modern apps. Another way to power these sensors is to use energy from their surroundings, such as heat, light, mechanical movements, or radio waves. But sensors are often put in places where there isn't a lot of power.

[4]This study compares getting energy from radio waves to getting it from other places. After showing that energy could be collected over a wide frequency range, a statistical study was done to find out how much RF power is in cities and how much is in rural places. Multi-band RF harvester systems were made to take energy from more than one frequency band to show when there are more than one source of RF energy. When the system is made to work over a wide range of frequencies, the amount of energy that can be collected can be raised. In this study, Advanced Design Software (ADS) is used to make a multiband RF energy harvester that can power wireless devices. The suggested energy harvesting scheme works better on the GSM900 and GSM1800 bands, according to the design results. Figure 2.2 shows the ambient energy harvesting system.

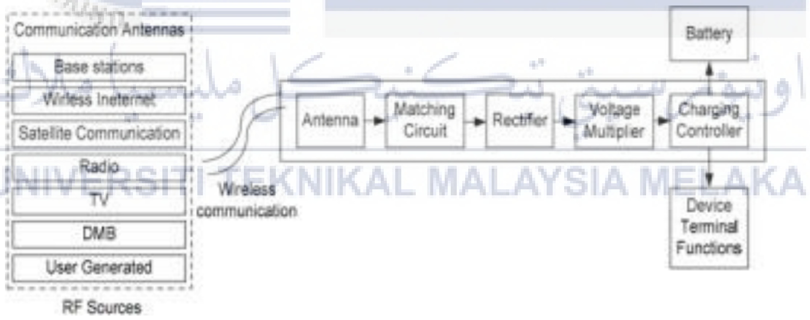


Figure 2.2: The ambient energy harvesting system

In present days, technology have been emerging with significant importance especially in wireless local area network. Energy harvesting is one of the most important parts of this. The RF Energy harvesting is the collection of small amounts of ambient energy to power wireless devices, especially, radio frequency (RF) energy has interesting key characteristics that make it very attractive for lowpower consumer electronics and wireless sensor networks (WSNs).

Commercial RF transmitting stations like Wi-Fi, or radar signals may provide ambient RF energy. [5]Throughout this paper, a specific emphasis is on RFEH, as a green technology that is suitable for solving power supply to WLAN node-related problems throughout difficult environments or locations that cannot be reached. For RF harvesting, antennas are used to get RF signals. In this work to extract RF energy from 2.4GHz an array of rectangular microstrip patch antenna is designed.1×8 array provides gain of 15.04dB with a bandwidth of 2% at WLAN frequencies. Figure 2.3 shows a microstrip patch antenna.

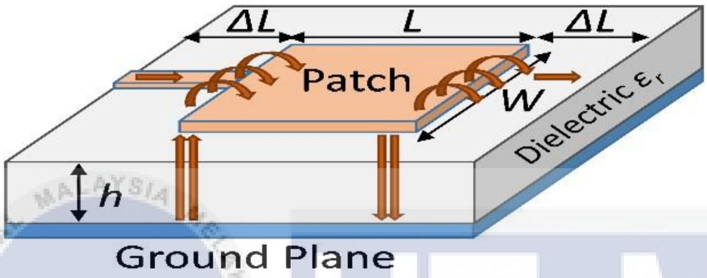


Figure 2.3: Microstrip patch antenna

On the other side, RF energy harvesting is an important tool because it could provide power forever. It is a green technology that can be used for many wireless uses, such as RFID tags, electronic devices that can be implanted, and wireless sensor networks. [6]In this paper, a new receiving antenna for RF energy harvesting systems that can work on two bands is suggested. There is a two-band device with a wide bandwidth that covers Wi-Fi bands. In this study, we focus on the radio frequency energy from commercial broadcasting stations that is available in the environment. Our goal is to create a system that uses RF energy harvesting and a new type of receiving antenna.

Several antenna designs have been suggested for use in RF energy harvesting systems. A good receiving antenna design is very important because the antenna's features can affect how much energy is collected. The suggested antenna is meant to make energy harvesting a lot more efficient on the 2.45GHz and 5GHz Wi-Fi bands according to MCMC standard[7]. Figure 2.4 below shows radio spectrum allocation in Malaysia according to MCMC.

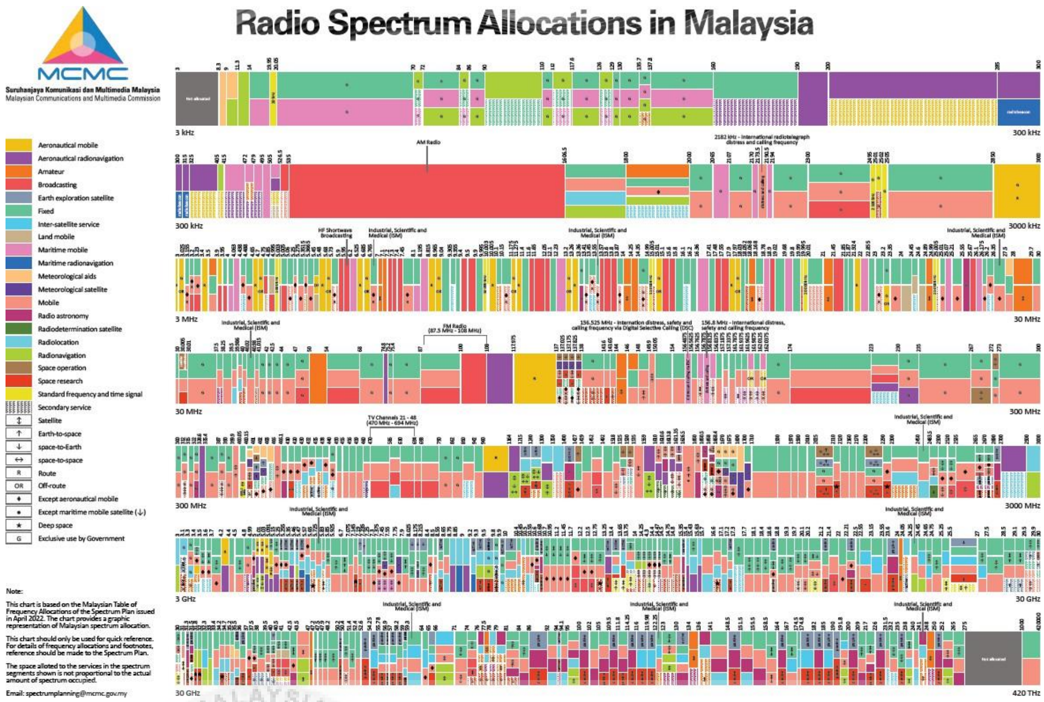


Figure 2.4: Radio Spectrum Allocation in Malaysia according to MCMC.

This is a potential alternative energy source that could be used to power sensors in harsh or remote places where other energy sources wouldn't work.The dual-band antenna is easy to put on the same circuit board as the RF energy collecting system. Simulations and measurements were used to find out how well the antennas worked and how different design factors affected how well they worked.The receiving antenna has a peak gain of more than 4 dBi across the working band and meets the requirements for bandwidth.

2.3 Wi-Fi Signal Propagation

802.11 networks, also called wireless fidelity (Wi-Fi) networks, have been the major way for homes and buildings to connect to the internet wirelessly. In addition to where the access points are placed, the way a building is built also helps the Wi-Fi signal spread. Even though putting Wi-Fi in buildings is becoming more common, building designs still don't take Wi-Fi compatibility into account. Access point location, location-based services, and home automation are the topics of current building and Wi-Fi study. In fact, the 802.11-based wireless system works better the more Wi-Fi-friendly the building is. [8]This paper defines the term "Wi-Fi-friendly building" by looking at how signals travel and how obstacles affect them. It also suggests a "ornament-attached reflector" and a "hole-in-the-wall" structure to improve the way Wi-Fi signals travel through a building. The results of an experiment show that materials made of concrete block Wi-Fi signals the most, followed by materials made of metal and wood. Materials that reflect can boost the amount of the signal that is received. For example, the ornament-attached reflector can boost the received signal by up to 6.56 dBm. The hole-in-the-wall structure is also able to boost the Wi-Fi signal by up to 2.3 dBm.

Furthermore, signal transmission is a term used to describe what happens to radio waves as they move from one place to another. The propagation process is an important thing to think about when a signal moves from one place to another. Propagation happens when there is a path between the access point (AP) and the mobile antenna (MA) other than the line-of-sight path. Multipath signal transmission is the name for this kind of spreading. Examining how signals travel at a frequency of 2.4 gigahertz (GHz) is the focus of this line of investigation. [9]This frequency is reserved for the ISM band, which is frequently utilized in wireless local area networks (Wi-Fi and HyperLAN). There are three distinct environments that could play a role in the spread of the infection: interior propagation, outdoor propagation, and the spread between buildings. The British Malaysian Institute at the University of Kuala Lumpur is where the measuring of the propagation is carried out. The Log Distance Model is used to do an analysis on the measured path loss signal and make comparisons. The outcomes of the simulations that were obtained from this investigation were consistent with what was anticipated.

The outcomes that are obtained via simulation and those that are derived from measured data are, as a result, the same and are related to one another. In addition, the new route loss coefficient factor, n, which is applicable for frequencies at 2.4GHz and is derived through this research, is generated from the Log Distance Model itself. Given that it is used to represent the various types of obstructions that the signals must go through, the n value plays a vital part in the process of predicting route loss.

Researchers have proposed the cohabitation of LTE and Wi-Fi technologies in unlicensed bands that operate at 5 GHz. This is in response to the growing needs for mobile traffic in cellular networks. Because of this, learning how to make effective use of the spectrum at 5 GHz becomes an increasingly important topic. Both the current LTE Unlicensed (LTE-U) technology and the License-Assisted Access (LAA) technology introduce the duty cycle of LTE in order to minimize channel access conflicts. On the other hand, the LBT mechanism is introduced by the License-Assisted Access (LAA) technology. Figure 2.5 shows an architecture of LTE and Wi-Fi coexisting network in 5GHz band and Figure 2.6 shows a Multigraph model of LTE and Wi-Fi coexisting network in 5GHz.

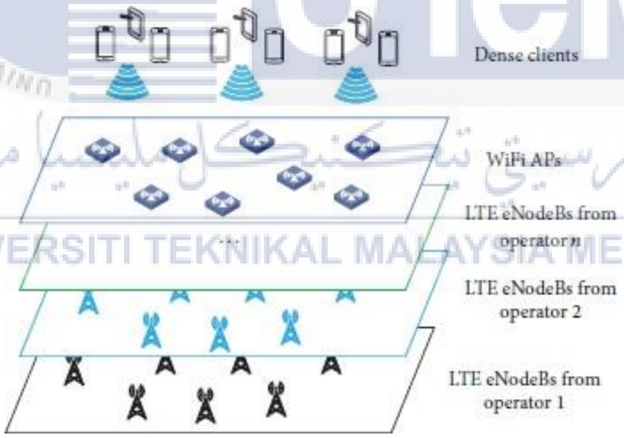


Figure 2.5: Architecture of LTE and WiFi coexisting network in 5GHz band

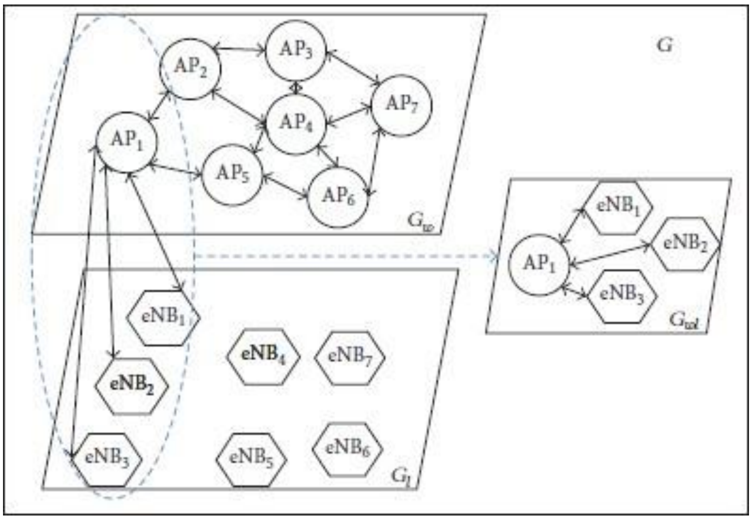


Figure 2.6: Multigraph model of LTE and WiFi coexisting network in 5GHz

Although both of these technologies enhance spectrum use by utilizing time division access schemes, we believe that even greater improvements in spectrum consumption are possible by enabling simultaneous transmissions from LTE and Wi-Fi. This would allow for a more effective use of the available spectrum. [10]Both simulation and measurements are used to explore the propagation of radio waves inside of a building that is representative of a university. The situations of propagation known as Line of sight (LOS) and Obstructed Line of sight (OLOS) were taken into consideration. The received power from a WLAN access point that was running at 2.45GHz was calculated using simulations and tests carried out in a variety of placements, orientations, and heights for both the transmitting and receiving antennas. The obtained simulation and measurement findings of the received power fluctuation with distance were utilized in order to make an estimate of the path loss exponents. The values for the route loss exponent that were obtained ranged between 1.15 and 1.63 for LOS propagation and between 2.14 and 2.55 for OLOS propagation. Figure 2.7 shows a Line-of-sight process diagram.

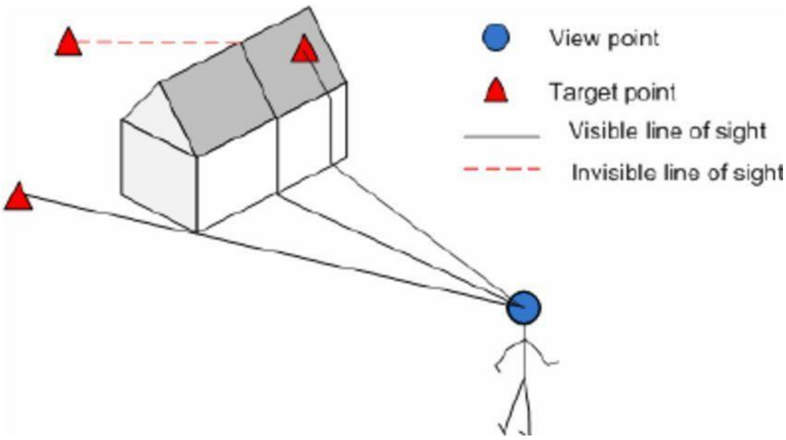


Figure 2.7: Line of sight process diagram

Wi-Fi energy harvesting is a potential way to power microsensors and microsystems by capturing electromagnetic (EM) energies that are all around us. [11]We came up with a metamaterial-inspired antenna (MIA) based on the resonant magnetic dipole that works in the Wi-Fi bands to gather EM energy. In the broadside coupled arrangement, the MIA is made up of two metal split-ring resonators (SRRs) that are separated by a FR4 dielectric layer.

Due to near-field coupling, the EM waves that hit the SRRs cause surface currents to flow, and the energy moves back and forth between them. By changing how far apart the two SRRs are in the vertical direction, we can match their resistance without having to use complicated matching networks. At the end of the connection coil, a rectifier circuit can change the EM energy into DC voltages. The results of measurements show that the proposed MIA may have a deep-subwavelength form factor (14 mm x 14 mm x 1.6 mm) and resonate at 2.4 GHz. The proposed MIA with an embedded one-stage Dickson voltage multiplier has also been tested to see if it can collect WiFi energy. When the MIA is 2 cm away from the WiFi send antenna and 9 dBm of power is being sent, the rectified DC voltage is about 500 mV. The compact MIA that is presented in this paper is very important for powering the distributed microsystems of the future.

2.4 Log Spiral Antenna

Since log spiral antennas can send signals in all directions and over a wide frequency range, they have been studied and used in many ways. In recent years, experts have thought of ways to improve the performance of log spiral antennas by adding more structures.[12]In this paper, we came up with an idea for a multi-band RF energy harvesting device that uses a modified log periodic spiral antenna with two optimized Slots Ring Resonators (SRR).

The proposed antenna was made to work in the range of 0.7 GHz to 1 GHz, 1.1 GHz to 1.4 GHz, and 1.5 GHz to 3 GHz, which is good for a number of wireless transmission systems. The SRRs were put around the log spiral antenna to make it wider at low frequencies without making it bigger at the start. Using SRRs made it possible for the antenna to work on multiple bands and have an average gain of 4 dBi, which is a big step up from standard log spiral antennas. The suggested antenna was built on a cheap and easy-to-find glass epoxy FR-4 substrate, which makes it a cost-effective way to harvest RF energy. Simulations showed that the suggested antenna has good impedance matching across all operating bands and has radiation patterns that go in all directions. The suggested antenna's performance was also checked by measuring it, which showed that the simulation results were correct. This modified log periodic spiral antenna has a clever design that could be used to collect RF energy from the environment. It could be paired with a multi-band amplifier to turn the collected RF energy into usable DC power. Figure 2.8 below shows the geometry of proposed antenna and figure 2.9 showing the illustration of the spiral antenna.

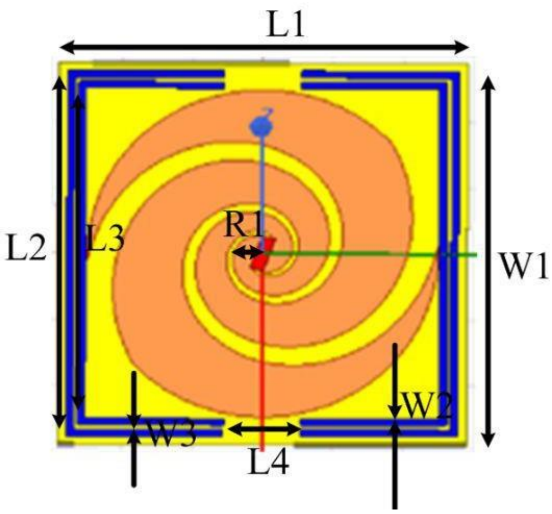


Figure 2.8: Geometry of proposed antenna

Figure 2.9: Illustration of the spiral antenna

Other than that, energy harvesting is the process of using the energy that is already in the world and turning it into something useful, like electricity. This study is about turning radio frequency (RF) electromagnetic waves into direct current (DC) electricity. Most of the time, this is done by converting the alternating current (AC) RF wave into direct current (DC). Antenna design is a big part of how well RF energy can be used, and equiangular spiral antennas are being looked at as a way to receive and use RF energy successfully. The equiangular spiral antenna has a unique logarithmic spiral shape that lets it cover a wide range of frequencies and give off good energy.

For ultra-wideband direction-finding applications, [13]this paper presents a dual arm conical logarithmic spiral antenna design. A gradient printed balun is used to provide power to the antenna. Because of this, the back cavity design is chosen, and the absorbing materials are loaded onto the inner wall of the cavity in order to optimise the standing wave, beam width, and circular polarisation axis ratio. Complete optimisation allows for the acquisition of a frequency bandwidth that is greater than ten times its original value. The rotary arm may be produced using the radium engraving plating technique on the thin medium substrate, and the measured results verify the design quite successfully. In this study, to find out how well equiangular spiral antennas work, we suggest two different antenna designs. CST MWS software is used to model and analyze how the antennas work, predict their radiation patterns, measure how well they work, and figure out how to make them work best for energy harvesting uses. We will show a number of simulations and results from CST MWS to show how well and how well-suited these antennas are for energy recovery uses. The simulations gave us valuable information that will help us build and use equiangular spiral antennas in real energy harvesting systems. Figure 2.10 below shows a Wideband balun design.

Figure 2.10: Wideband balun design

The logarithmic spiral antenna is a small and effective way to use a wide range of frequencies. By using the shape of a logarithmic spiral, the antenna can cover a wide range of frequencies while still being small. The antenna is made up of a spiral wire that grows outward from the center in a logarithmic way. This gives the antenna even coverage over the desired frequency range.

[14]In this transmission, a conical log spiral antenna with a wide frequency range is suggested. The antenna is made up of two arms that are wrapped around each other in a log-periodic way. It is powered by a printed microstrip feed on the other side of the base that has a dielectric constant of 2.65 and a thickness of 1mm. This is called a balun because it matches the impedance of the two arms of the antenna. A parametric study is done to give practical directions for design. Based on the results of the modelling, the impedance bandwidth for VSWR 2.0 is from 3.2GHz to 7GHz. Between the working frequencies, the radiation pattern stays stable and has a wide beam width. A flexible frame is also created to make the antenna smaller. Compared to the standard helical antenna, this antenna has a wide band and a wide beamwidth. The results show that the electric properties of the antenna meet the working frequency needs of the application. Figure 2.11 shows simulation model of antenna in HFSS.

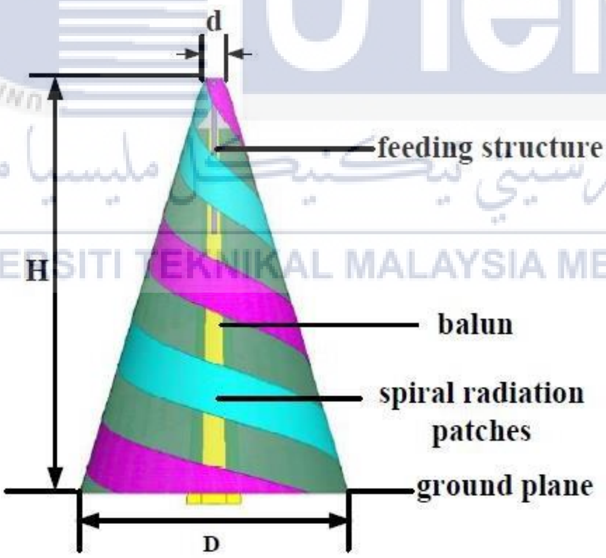


Figure 2.11: Simulation model of antenna in HFSS

2.4.1 Microstrip Patch antenna

Antennas are parts of metal structures that are used to send messages over radio waves. Antennas come in different shapes now, based on what they are used for and how strong the signal is. The bowl-shaped structure of antennas used for space and large-scale communications helps to focus the signals on a single place. [15]Some antennas are made to move both horizontally and vertically so that they can send signals in both ways. Microstrip patch antennas are very small and are a type of printed antenna. Microstrip patch antennas are used a lot in medical devices and cell phone communications. In recent years, the performance of microstrip patch antennas has been getting better, and the goal of this review is to figure out how that happened. In the same way, this work looks at the pros and cons of the new methods that have been made to improve the performance of microstrip patch antennas.

2.4.2 Patch

In a microstrip antenna, electromagnetic waves are sent into the air by using a patch. It is put on top of the base sheet and has a certain shape. Copper or gold are examples of materials that can be used to make a patch.

During modelling, the length and width of the emitting patch of a slotted microstrip antenna are tuned and slotted to make the frequency band bigger. Here are the numbers that are used to make this antenna:

$$W = \frac{C}{2f}\sqrt{\frac{2}{(\epsilon r+1)}}$$

Where W = width of patch, c = light speed, f = resonance frequency.

$$L = L_{eff} - 2\,\Delta\,\mathrm{L}$$

Where L = patch length, L_{eff} = effective length, Δ L = extension of length.

$$L_{eff} = \frac{c}{2f0}\sqrt{\frac{2}{\varepsilon eff}}$$

Where ε_{eff} = effective dielectric constant of substrate.

$$X_f = \sqrt{\frac{L}{\varepsilon eff}} \quad \text{and} \quad Y_f = \frac{W}{2}$$

Where X_f = input position along with X axis, $Y_f =$ = input location along with Y axis.

2.4.3 Dielectric Substrate

Substrate is a base that is used to make a microstrip patch antenna and to hold it up. It also has dielectric material in it, which could affect how well the antenna, circuit, and broadcast line work. So, the right material must be chosen in order to meet the electrical and mechanical requirements. Substrate is also used to improve electrical and mechanical safety, reduce antenna size, and improve antenna's ability to radiate. Figure 2.12 showing an example of dielectric substate.

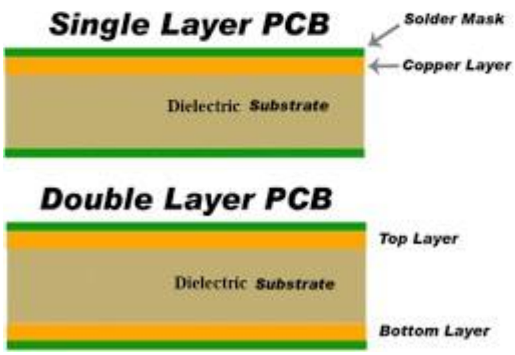


Figure 2.12: Example of dielectric substate

2.4.4 Ground Plane

The ground plane is a surface that lets electricity flow through it and is linked to the electrical ground. For the antenna, it works as a surface that radio waves can bounce off of. Radio waves are usually reflected by a flat, horizontal conducting surface that is part of an antenna. So, the radiation properties, such as gain, depended on how the ground plane was made and how big it was. Balun can be used instead if don't have a ground plane for a Log Periodic Spiral antenna.

2.4.5 VSWR

The Voltage Standing Wave Ratio (VSWR) is a way to measure how well an antenna and a transmission line that ties it to a transmitter or receiver have the same impedance. A VSWR of 1:1 means that the impedances match perfectly, while higher numbers mean that the impedances don't match as well, which can lead to less power transfer and more signal loss. The VSWR of a log spiral antenna relies on its design parameters, such as its pitch angle, number of turns, and spiral angle, as well as its operating frequency[16]. Most of the time, a well-designed log spiral antenna can have a VSWR of 2:1 or better over a wide range of frequencies. This means that the resistance is matched well and energy is transferred efficiently. The calculation for VSWR shown by equation below:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

Where Γ is reflection coefficient. In addition, the better the match between the antenna and the communication line is, the smaller the VSWR. Therefore, more power is sent to the receiver and less power is sent back from it.

2.4.6 Return Loss

Return loss is the loss of power in the signal that comes back because of a break in the transmission line. The break could not match up with the load or device at the end of the queue. Return loss is often written as a measure in decibels (dB):

$$RL(\mathrm{dB}) = 10\log_{10}\frac{P_{\mathrm{i}}}{P_{\mathrm{r}}}$$

The SWR is lower when the return loss is bigger. Therefore, if the return loss is high, the SWR and insertion loss will be low. Hence, there needs to be a high return loss.

2.4.7 Bandwidth

Depending on the type of receiver, the range of frequencies that can be used varies. It can be very narrow or very wide. If the frequency bandwidth is outside of its range, the antenna impedance will not meet with the transmission line, transmitter, or receiver. This means it will change the way the antenna radiates, which will lower its directivity. But antenna frequency bandwidth can be increased by making an antenna out of tubular elements instead of thin lines or a circular slot[17]. Since Log-Spiral antenna belong to “Frequency Independent” class antenna, it has a very large bandwidth and fractional bandwidth can be as high as 30:1. Figure 2.13 below shows the geometry of the tapered balun and impedance transformer.

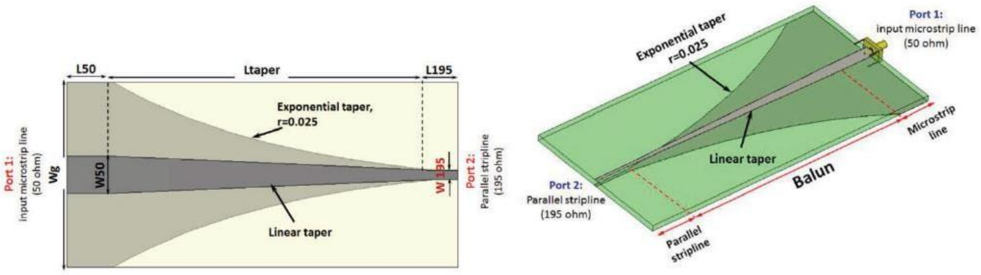


Figure 2.13: Geometry of the tapered balun and impedance transformer.

2.13.1 Radiation Pattern

The way a log spiral antenna sends out waves relies on its shape, such as the number of arms, the pitch angle, and the size of the spiral. Most of the time, a log spiral antenna's transmission pattern is very focused and circularly polarized. This means that the antenna sends out electromagnetic waves in a certain direction and that the electric field vector changes direction as the wave moves.

The directivity, which is a measure of how focused the antenna is, and the beamwidth, which is the angle between the points on the pattern where the radiation intensity drops to half its highest, are usually used to describe the radiation pattern of a log spiral antenna. With electromagnetic simulation tools like CST Studio Suite or HFSS, it is possible to simulate and study the radiation pattern of a log spiral antenna. The results of these models can be used to make sure that the antenna is best designed for certain uses. It is important to know that a log spiral antenna's radiation pattern can be changed by close objects or other electromagnetic interference, which can cause reflections and diffractions that change the pattern.

2.13.2 Directivity and Gain

An antenna's directivity gain indicates how well it can direct a signal in one direction or another. It measures how much energy is focused in one direction as opposed to being evenly dispersed in all directions, as would be the case with a perfect isotropic radiator. greater signal strength in one direction is the result of an antenna's greater directivity gain. The desired direction's power density is compared to that of an isotropic radiator to determine the antenna's directivity gain, which is commonly stated in decibels (dB). Note that directivity gain only takes into consideration the antenna's radiation pattern and not other factors like impedance matching or efficiency.

The highest value of a Log-Spiral antenna's directional gain is in a single direction, and its broadside radiation pattern has a beamwidth of only about 70 to 90 degrees at half power[18]. The characteristics of a given antenna determine its effective directional range. Antenna gain also indicates the antenna's efficiency in transforming electrical power into radio waves for transmission in a certain direction or in transforming electrical power into radio waves for reception in a certain direction. Figure 2.14 shows an example of simulated 3D-radiation pattern.

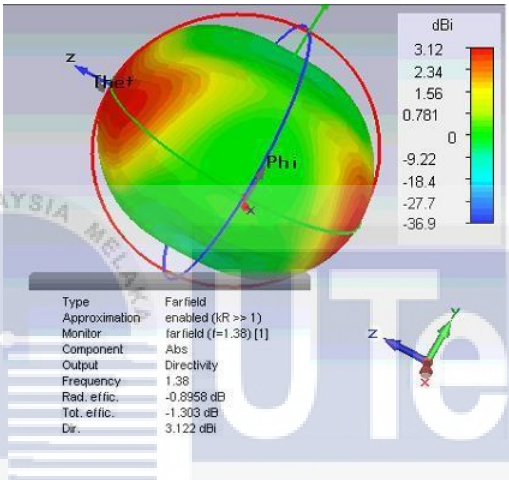


Figure 2.14: Simulated 3D-radiation pattern.

2.13.3 Polarization

When an antenna emits an electric field, that field has a polarisation. Radiation waves that are polarised and directed in a particular direction to an antenna are known as polarisation. However, if no direction is given, the strongest signal will be received in the direction of maximum polarisation. That is to say, the wave's polarisation is established by the location and orientation of the electric field relative to the surface of the planet.

2.14 Computer Simulation Technology (CST) for antenna design

Active electronically scanned arrays are used more and more as high-end antennas for things like RADAR, monitoring, and communication because they are flexible and have many benefits.

Both on the ground and in the air, technology has changed a lot in the last few years. The electromagnetic design of these devices is hard, and numerical modelling has become an important part of the design process. But the plan puts a lot of pressure on a simulation tool. This paper talks about new array design features in CST STUDIO SUITE. These features make it much easier and more powerful to build phased arrays and related planar devices like polarizers or frequency selective surfaces (FSSs), both at the cell level and for the whole array. [19]This paper shows a full design flow for a Ku band uplink satellite communications array that works in the 14-14.5 GHz frequency band and can be used in the air. One of the most important new features will be shown in the first design of the low profile antenna elements: the ability to improve the unit cell geometry at the same time for operation at multiple frequencies and multiple scan angles. In order to put an antenna on the roof of an airplane, an aerodynamic radome must be designed. This radome must be thought of as part of the transmitting structure at both the unit cell and the full array levels. A hybrid field coupling method is also used to find out what happens when the array is put in different places on the airplane.

The Complete Technology approach in CST STUDIO SUITE lets you use a number of numerical methods together to do a full analysis. For example, a FEM simulation is used to optimize the antenna at the unit cell level, a time domain approach is used to analyse the whole array, and an asymptotic shooting bouncing ray (SBR) simulation is used to predict how well the array will work when it is installed. The unit cell design concept can also be used to make sure that planar periodic structures, like polarizers and FSSs, work well for a wide range of incident angles. This is an important thing to think about when an FSS is meant to fit into a bent structure like a radome.

Antenna makers are interested in microstrip slotted patch antennas because they are light and don't take up much space. However, they also have some problems, such as low gain, narrow bandwidth, and higher VSWR (Voltage Standing Wave Ratio). Some of these problems can be lessened by the way antennas are made. [20]This study comes up with a new way to improve the bandwidth, efficiency, and VSWR of a microstrip patch antenna by putting a slotted patch next to the radiating patch. In this study, there is also the idea of using a microstrip slotted patch antenna for 5G transmission. The frame is made to work at 29.416 GHz. Using the CST studio suite (Computer Simulation Technology) software, a simulation is made of the suggested design. The VSWR is 1.0115, the return loss is -44.78 dB, and the frequency is 900 MHz. The results show that the proposed design has properties that are good for Ka-band uses. Figure 2.15 shows a 3D view of proposed microstrip slotted patch antenna in CST.

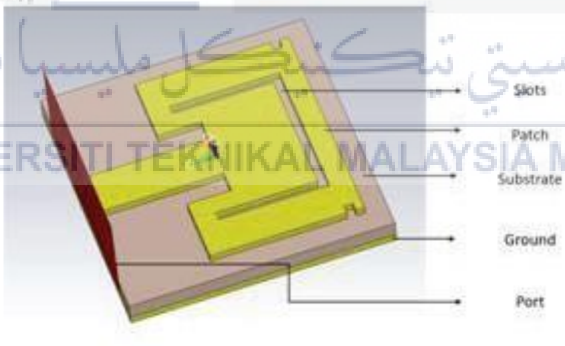


Figure 2.15: 3D view of proposed microstrip slotted patch antenna in CST.

2.15 Societal and global issues of RF energy harvesting

Next-generation wireless networks may be able to use RF energy harvesting (RFH) to proactively renew their energy supplies. Due to its predictability and on-demand nature, RFH is better suitable for supporting quality-of-service based applications than harvesting methods that are environment-dependent. Low RF-to-DC conversion efficiency and receiver sensitivity, however, mean that RFH efficiency is in short supply. [21]In this piece, we single out the cutting-edge methods of communication that make RFH possible and boost its utility. Some experimental observations on RFH and the current state of the art serve as the basis for our discussion of the difficulties inherent in the practical implementation of RFH communications, as well as the opportunities and threats presented by new lines of investigation.

2.16 Research project

A research project is a methodical inquiry into a specific topic or question. It involves collecting, analysing, and extracting conclusions from data. Researchers set goals, create hypotheses, and gather and analyse data. Experiments, surveys, interviews, and data analysis may be involved. Research projects strive to improve knowledge, fill knowledge gaps, or solve real-world problems. Critical thinking, innovation, and thorough documentation are needed. The scientific community and society benefit from research project reports, presentations, and publications. Table 2.1 below shows the comparison of Radio Frequency Energy Harvesting project.

Table 2.1: Comparison table of Radio Frequency Energy Harvesting.

Project's Name	Hardware	Frequency used	Result
Radio Frequency Energy Harvesting with Frequency Shift Keying Modulation Technique. [3]	- Patch antenna -Signal generator	-902MHz -928MHz	Charging time of the RF energy harvesting decreased as the distance between signal generator and RF energy harvesting circuit reduced.

Radio Frequency Energy Harvesting for Low Power Sensors. [4]	- GSM 900 - GSM 1800 - Rectenna - Sensor	-1.7GHz to 1.8GHz -1.9GHz to 2.2GHz	Two versions of multiband rectennas have been looked into. One is optimized to get energy from three RF bands, and the other combines different RF branches to make the system more efficient and resistant to RF bands that inactive.
Patch Antenna Array for RF Energy Harvesting Systems in 2.4 GHz WLAN Frequency Band. [5]	-Microstrip patch antenna	-2.4GHz	An array of rectangular microstrip patch antenna is designed.1×8 array provides gain of 15.04dB with a bandwidth of 2% at WLAN frequencies to reached for specific emphasis on RFEH.
A Dual-Band Antenna for RF Energy Harvesting Systems in Wireless Sensor Networks. [6]	-Dual-band antenna - Sensor	-900MHz -1.8GHz -2.4GHz	The suggested antenna works well in general at the required frequency range: the return loss is better than 20 dB, the

			impedance is close to 50, and the radiation patterns are almost omnidirectional.
Modified log periodic spiral antenna for multi-band RF energy harvesting applications. [12]	-GSM 900 -GSM 1800 -Log spiral antenna	-0.7GHz to 1GHz -1.1GHz to 1.4GHz -1.5GHz to 3GHz	The suggested antenna has good impedance matching across all operating bands and has radiation patterns that go in all directions.
This project	-Log spiral antenna - Wi-fi	-2.45GHz -5.83GHz	Wireless devices to run on their own power and helps save energy and the environment.

2.17 Summary

In the end, chapter 2 discusses how previous study has affected this project. In this chapter, the approaches and methods that other experts have used in their own work have been discussed. The researcher's study is important knowledge that can be used to compare the features of past research, which can help with the project in this journal.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The study method tells how the design is made and why. The study goals may not be accomplished right without this part. Some parts of how research is designed are talked about in this chapter. Research is the process of figuring out what parts and things a project needs to be successful. It's best to start a study as soon as possible to avoid problems down the road. The project is mostly about case studies and building a receiver to collect energy from Wi-Fi signals. CST, a popular electromagnetic modelling software, models and simulates the antenna design to accurately simulate the Wi-Fi signal environment. Simulations reveal radiation pattern, gain, directivity, and impedance matching. Energy harvesting efficiency is optimized using simulation data. The optimized design is prototyped to test the CST-based design technique, and its accuracy and efficacy is verified by comparing measured and simulated data.

3.2 Project Development

Using CST, the project plan for making an antenna that can collect energy from Wi-Fi signals involves a few key steps. A requirements analysis is done to find out what the antenna design needs to do and what its limits are. The features of the chosen antenna design are also found out. After installing and setting up the CST programme, a detailed 3D model of the antenna is made. In CST, simulation settings are set up, and electromagnetic simulations are run to look at how well the antenna works. Then comes an iterative optimization process where the design factors of the antenna are changed to make energy harvesting work better.

An actual prototype of the antenna is made, and then it is tested in the real world to find out how well it works. The antenna design that was made is judged on how well it works and whether it can be used for Wi-Fi signal energy gathering. During the whole project, the antenna selection, modelling details, simulation setup, optimization steps, fabrication methods, and experimental results are all carefully recorded and reported. In the end project report, the reasoning behind the design, the results of simulations, the results of optimization, and the experimental validation are all summed up.

3.2.1 Flowchart

Figure 3.1 below shows the flowchart of the project.

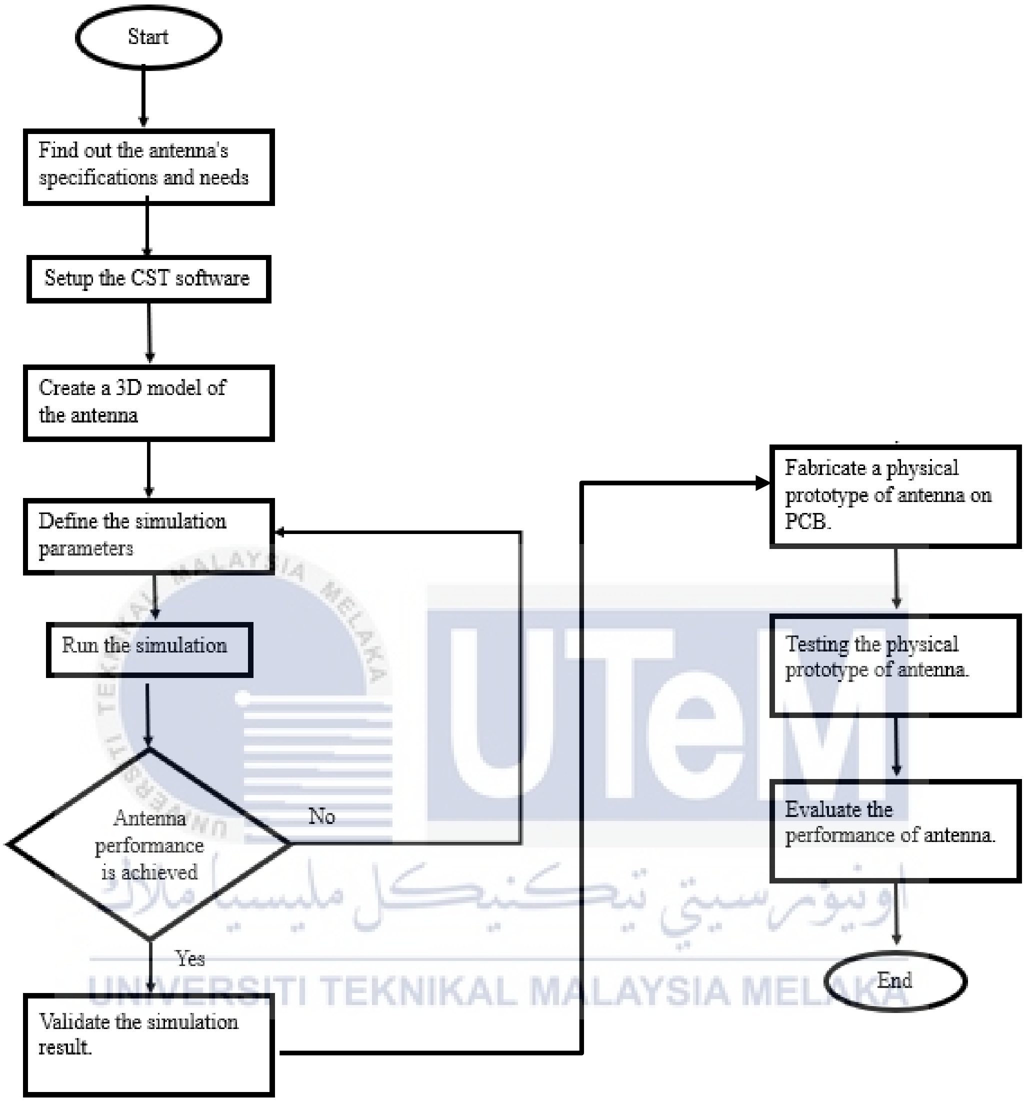


Figure 3.1: Flowchart of project.

3.2.2 Block Diagram

The project is concentrate and limited within the dotted line only. Figure 3.2 below shows the block diagram of the project.

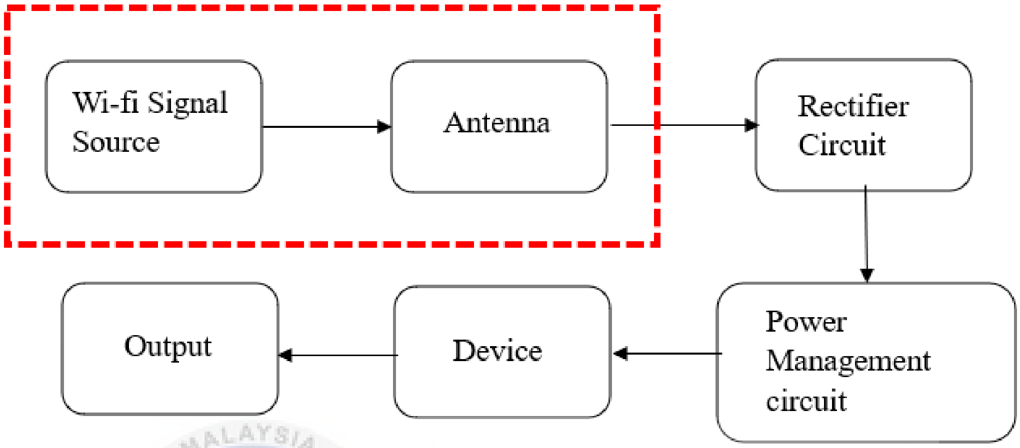


Figure 3.2: Block diagram of the project

3.2.3 Hardware

FR-4 Substrate

FR-4, or Flame Retardant-4, is a substrate material commonly used in the fabrication of printed circuit boards (PCBs). It is a laminate of glass-reinforced epoxy that offers superior electrical insulation and mechanical robustness. The designation "FR" indicates that the material has been treated with additives to reduce its flammability and retard the spread of fire. The number "4" refers to the material's grade or classification; FR-4 is the most common and extensively available grade.

FR-4 substrates consist of fiberglass material impregnated with epoxy resin. High mechanical strength, dimensional stability, and excellent thermal properties are provided by the fiberglass reinforcement. The epoxy resin serves as an insulating matrix that binds the fiberglass and provides electrical isolation between the PCB's conductive layers.

The compatibility of the FR-4 substrate with standard PCB fabrication processes makes it a popular choice for a wide variety of electronic applications. It has exceptional electrical properties, including a low dielectric constant and loss, as well as resistance to moisture, chemicals, and temperature changes. Figure 3.3 shows a FR-4 substrate.

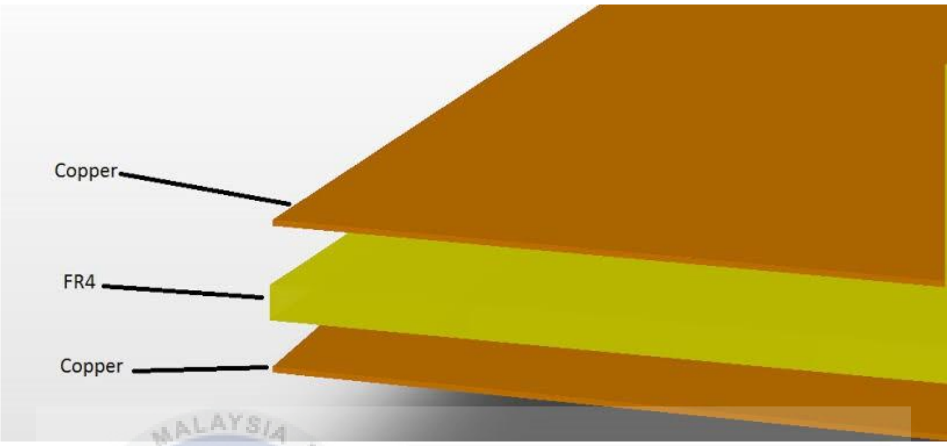


Figure 3.3: FR-4 substrate.

3.2.4 Software

Computer Simulation Technology (CST)

Computer Simulation Technology or CST, is a powerful software suite that is widely used in the area of electromagnetic simulation. It has different modules for different uses, such as CST Studio Suite for general electromagnetic modelling, CST Microwave Studio for high-frequency and microwave analysis, and CST PCB Studio for designing printed circuit boards. CST uses numerical methods like the finite-difference time-domain (FDTD) or the finite element method (FEM) to solve Maxwell's equations and model how electromagnetic fields behave. It has an easy-to-use interface that lets users build and change geometries, set up simulation parameters, define material properties, and see simulation results. It has advanced features for antenna design, optimisation, and performance analysis, such as radiation pattern analysis, input impedance calculation, and electromagnetic compatibility (EMC) evaluations.

CST has been used in many fields, such as telecommunications, aerospace, automobiles, electronics, medical products, and more. It helps with the creation and optimisation of antennas, microwave circuits, radar systems, wireless communication systems, electromagnetic shielding, and more. . Figure 3.4 shows a logo of Computer Simulation Technology (CST) and figure 3.5 shows the interface of CST Studio Suite 2021 software.

Figure 3.4: Logo of Computer Simulation Technology (CST)

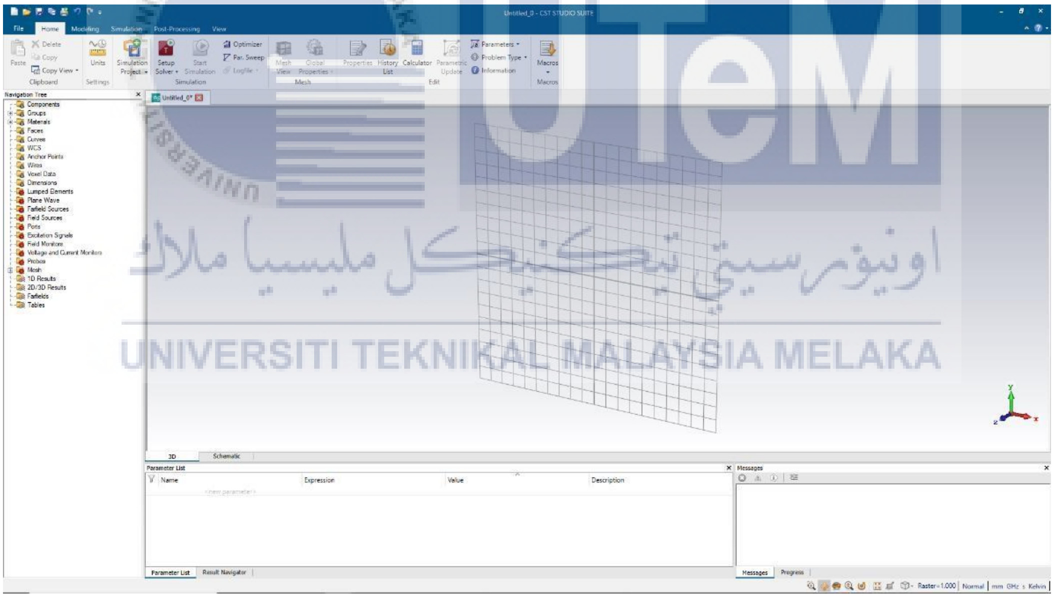


Figure 3.5: Interface of CST Studio Suite 2021 software

3.3 Antenna Parameter

To design Planar Log Spiral antenna, a parameters need to be calculated to determine the antenna dimension such as inner radius, r1 and initial radius, Ro. Furthermore, a parameter such as thickness, number of turns, initial radius, Alpha, Phi-increment and Delta need to be listed before designing a Planar Log Spiral antenna as constant variable. These are the formulas that being used to determine the parameters:

$$\text{Inner Radius, } r1 = ke^{\alpha\varphi}$$

$$\text{Outer Radius, } r2 = ke^{\alpha(\varphi-\delta)}$$

Where initial radius = k, alpha = α, phi-increment = φ, delta = δ.

3.4 Designing Antenna patch, substrate and ground

To make a full Planar Log Spiral antenna, you have to do a few things. Figures will be used to explain these steps.

Step 1: How to design arm for Planar Log Spiral antenna.

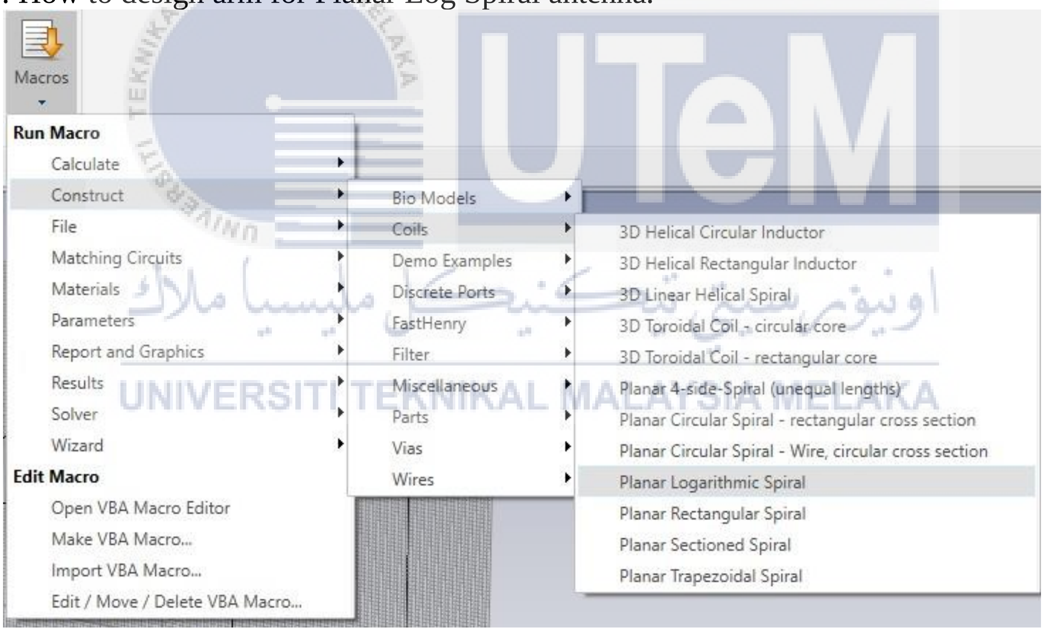


Figure 3.6: How to design arm for planar log spiral antenna.

Figure 3.6 shows how to design spiral-coil of the log spiral antenna by using CST software.

Step 2: Insert the calculated parameters values.

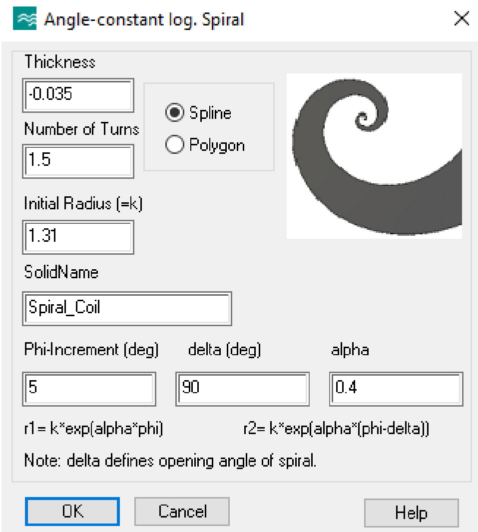


Figure 3.7: Parameter values for spiral-coil.

Figure 3.7 shows parameter values for spiral-coil.

Step 3: Designing a pair of arms for Planar Log Spiral antenna.

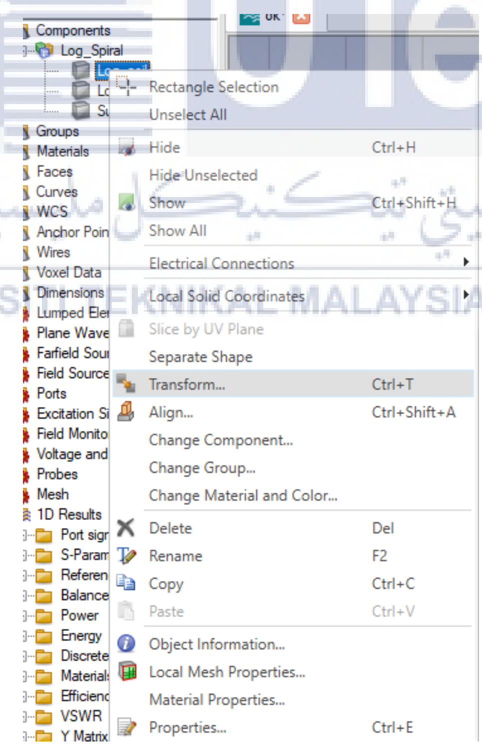


Figure 3.8: Setting for pair of arms of planar log spiral antenna.

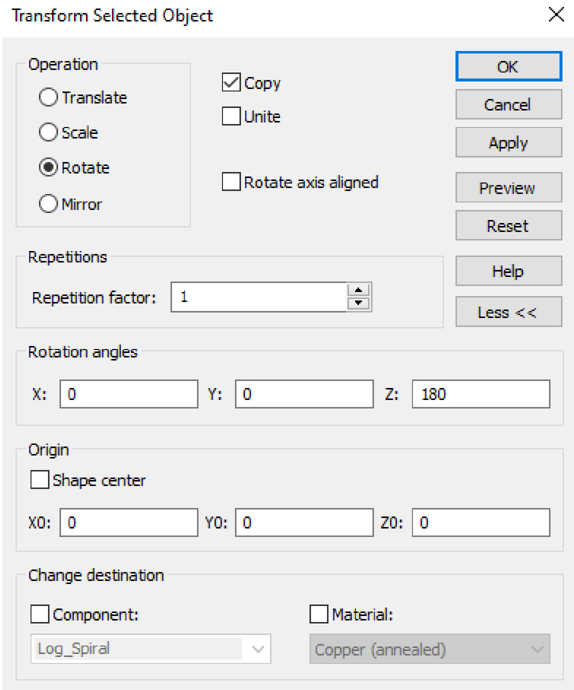


Figure 3.9: Setting for pair of arms of planar log spiral antenna.

Figure 3.8 and figure 3.9 shows the setting for pair of arms of planar log spiral antenna.

Step 4: Designing a substrate for Planar Log Spiral antenna.

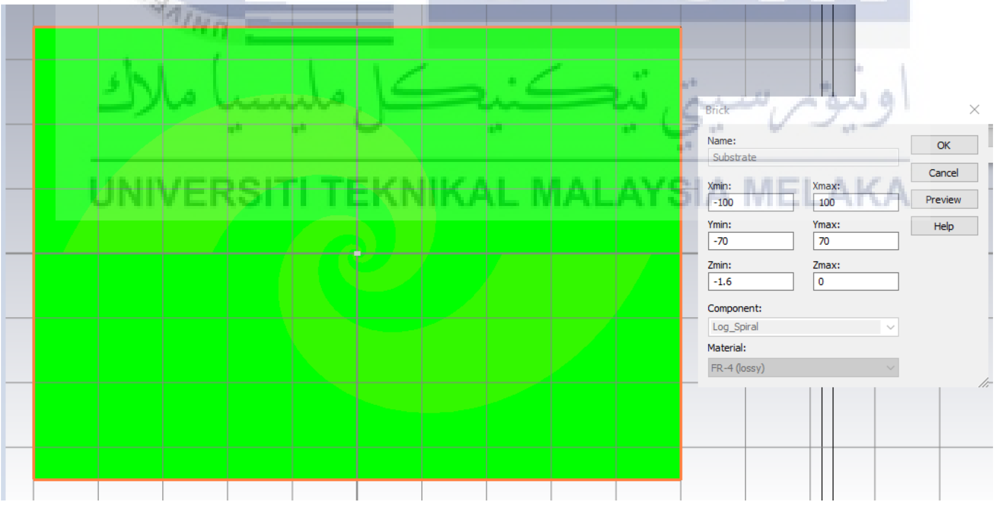


Figure 3.10: Designed substrate for planar log spiral antenna.

Figure 3.10 showing how to design a substrate with specific dimension of thickness, width and length.

Step 5: Discrete Port

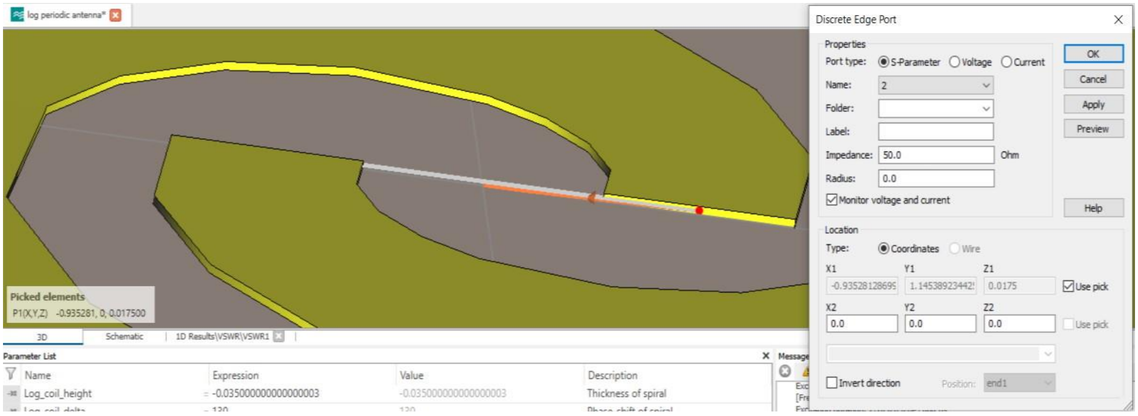


Figure 3.11: First coordinate for Port.

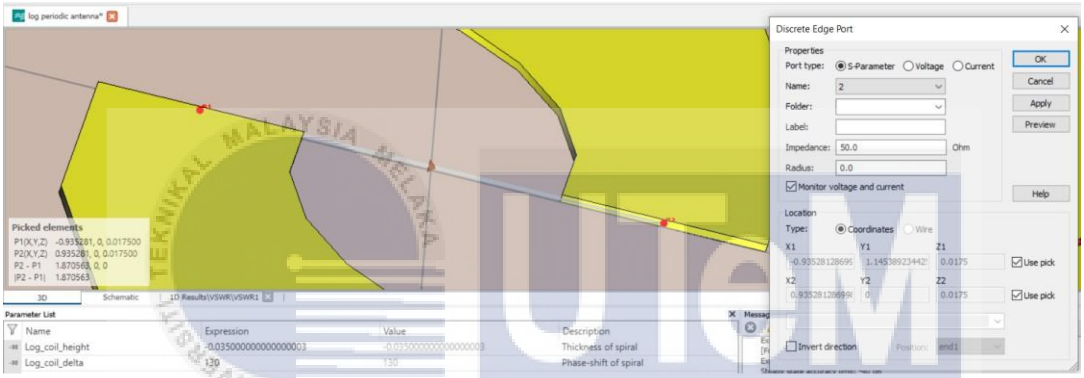


Figure 3.12: Second coordinate for Port.

Figure 3.11 and figure 3.12 show how to create a discrete port for log spiral antenna by using CST software.

3.5 Simulation

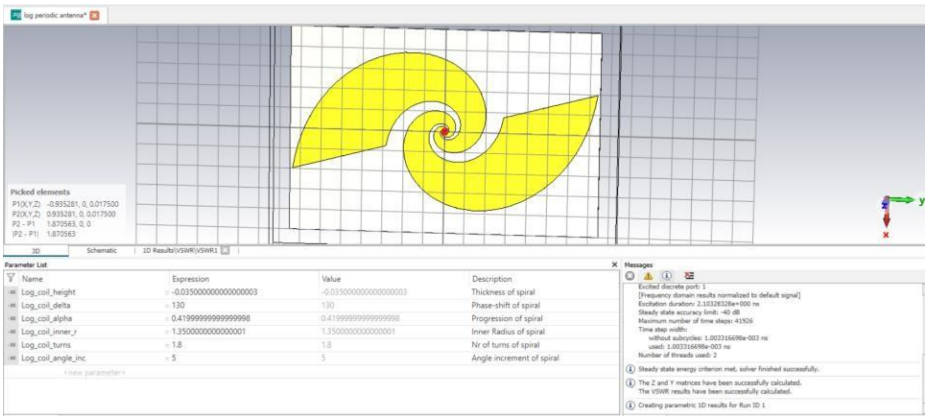


Figure 3.13: Simulation for designed Planar Log Spiral Antenna.

A successful simulation for designed antenna must not have errors in messages box at the right bottom side of CST software window. However, a warning that appears in message box can be ignored as shown in Figure 3.13.

3.6 Fabrication Process

The production process starts after the simulation results have verified an ideal response and satisfied the required parameters. Eight standard steps are involved in the fabrication of a printed circuit board (PCB): printing the circuit layout; cleaning the substrate; removing the protective layer; applying a mask of transparency; exposing the board; developing the board; etching the board with ferric chloride; drilling holes for components; and soldering the probes and components. The physical layout of the circuit, created in the Corel Draw program, is then transformed into an electromagnetic (EM) structure within the EM simulator software.

The EM structures are printed onto a transparency sheet using a laser jet printer. After that, the substrate is carefully cleaned to get rid of any dirt, oils, or other impurities that might have accumulated on the board's surface. After removing the protective covering sticker, carefully attach the printed layout circuit from the transparency sheet to the board. After removing the artwork circuit from the transparency sheet, the board is exposed and the circuit is transferred to the top using a UV machine. The artwork is only slightly visible on the board's surface after it has been exposed. To allow it to develop, the board will be immersed in a developing tank and inspected on a regular basis. Figure 3.14 shows the process of fabrication of an antenna

Figure 3.14: Fabrication process.

3.7 Limitation of proposed methodology

Each system or project requires a defined set of constraints based on the suggested methodology. The proposed approach may have some restrictions that have an impact on the designed system or project. The results may not be as trustworthy as they seem because of the project's reliance on the CST simulation software, which itself relies on a number of elements and assumptions. Validation against independent, external measurements is essential for reliability. Making the leap from a virtual antenna design to a real prototype may be difficult due to constraints in materials and production methods. It is also important to think about the frequency dependence of the suggested design, as its optimal performance may change at frequencies beyond the specified range. In addition, the power levels harvested from Wi-Fi signals are often low, thus the methodology should investigate ways to boost energy conversion efficiency. Interference and signal blockages are just two examples of real-world environmental issues that need to be considered. For real-world use, it's crucial to think about scalability and compatibility with current devices and networks. The proposed method can be improved and optimised for efficient harvesting of energy from Wi-Fi signals if those limitations and constraints are addressed.

3.8 Summary

In the end, chapter 3 discusses the methods used to make this project, including the project flow chart and the software and hardware that were used. At the same time, the results of all these discussions about methodology help people understand how the process works and how to plan and carry out projects the right way.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results of this project and how it was done. As stated in Chapter 3 about how the project was made, the results and analysis need to be made after the hardware has been described. Get the results by taking the data as it has been written. Therefore, the results are very necessary to know whether the results will be the same when the project is fully completed. In this chapter, the results of a CST simulation that used the factors will be figured out. Return Loss (S11), Voltage Standing Wave Ratio (VSWR), E-field and H-field are the findings that need to be found.

4.2 Results and Analysis

4.2.1 Simulation Result

The FR4 substrate (white) must as close as possible to copper patch (yellow) for better antenna result as shown in Figure 4.1

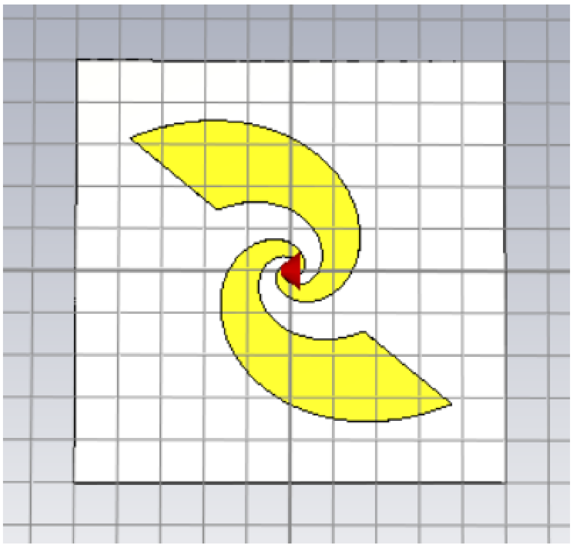


Figure 4.1: Designed antenna.

The parameter not only will change antenna size but also antenna result. Thus, a detailed calculation is needed in designing an antenna. Figure 4.2 below shows the parameter of antenna.

Parameter List

Name	Expression	Value	Description
Log_coil_height	= -0.035000000000000003	-0.035000000000000003	Thickness of spiral
Log_coil_delta	= 90	90	Phase-shift of spiral
Log_coil_alpha	= 0.5	0.5	Progression of spiral
Log_coil_inner_r	= 0.624	0.624	Inner Radius of spiral
Log_coil_turns	= 1.3999999999999999	1.3999999999999999	Nr of turns of spiral
Log_coil_angle_inc	= 5	5	Angle increment of spiral

Figure 4.2: Antenna parameter.

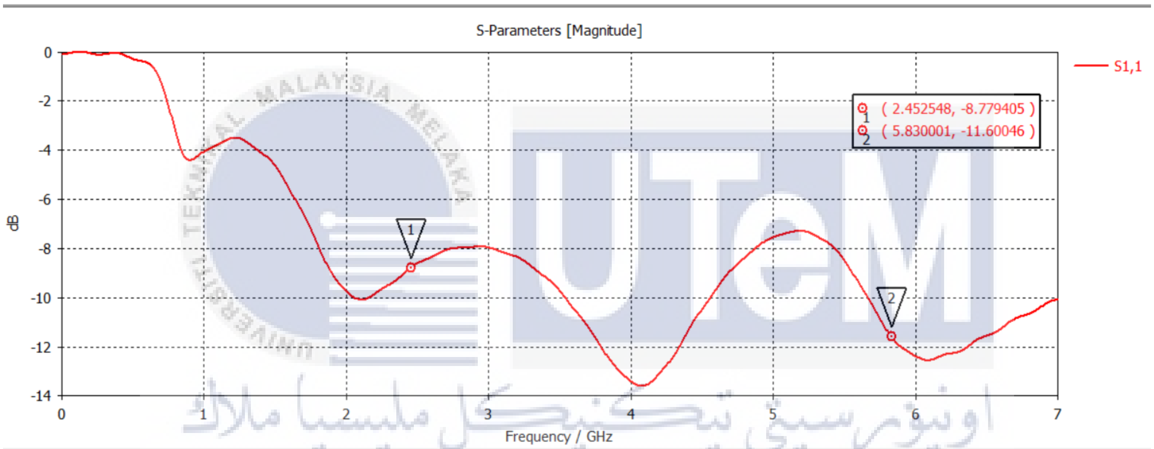


Figure 4.3: S11 graph.

Return loss is a measurement of how well an antenna or other system component matches the impedance of the devices or transmission line to which it is attached. A lower return loss suggests improved impedance matching and reduced signal reflection. Figure 4.3 shows the return loss of 2.45GHz and 5.83GHz.

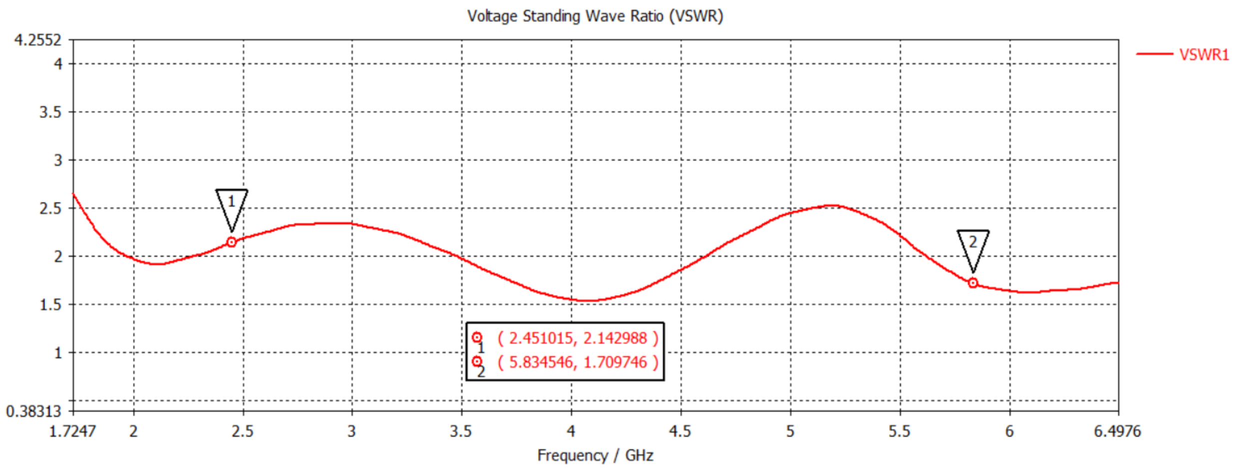


Figure 4.4: VSWR graph.

Figure 4.4 above shows the graph of VSWR. When an antenna's Voltage Standing Wave Ratio (VSWR) is less than 2, it means that the connected devices are well matched, resulting in effective power transfer with minimal reflections. In many applications, this range is regarded as "good" or "ideal" for antenna performance because it minimizes power loss and guarantees efficient communication. It shows that the VSWR of 2.45GHz is slightly above 2 and it still acceptable, while the VSWR of 5.83GHz is below 2 is considered good.

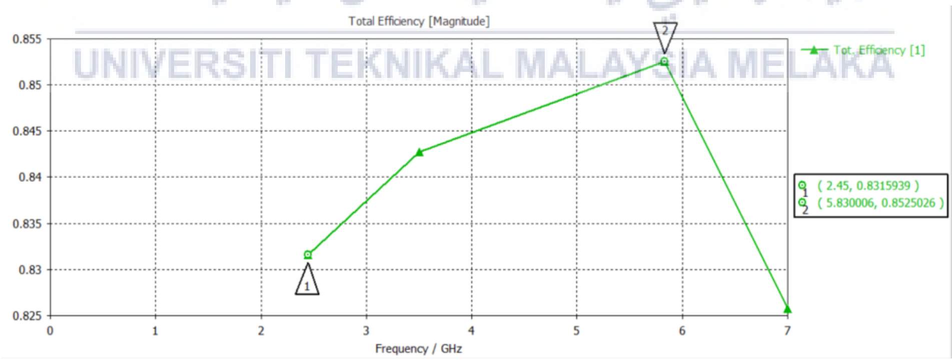


Figure 4.5: Total efficiency graph.

Figure 4.5 shows the total efficiency graph of the antenna. It shows that the frequency of 2.45GHz and 5.83GHz is efficient with the value of efficiency is 0.832 and 0.852.

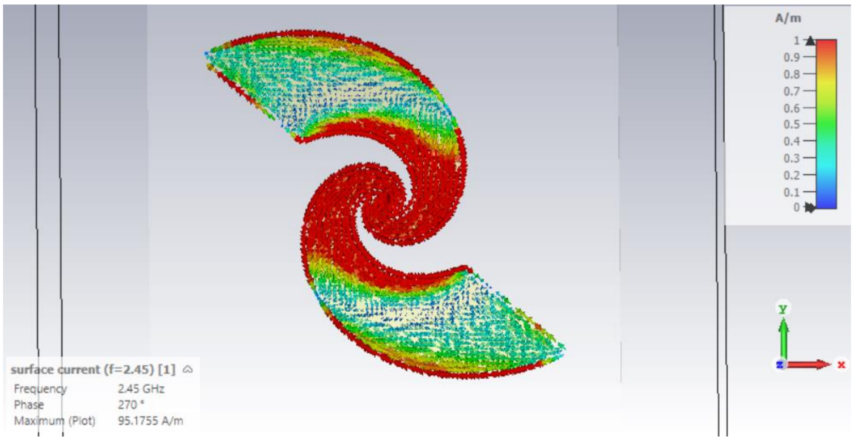


Figure 4.6: Surface current at 2.45GHz.

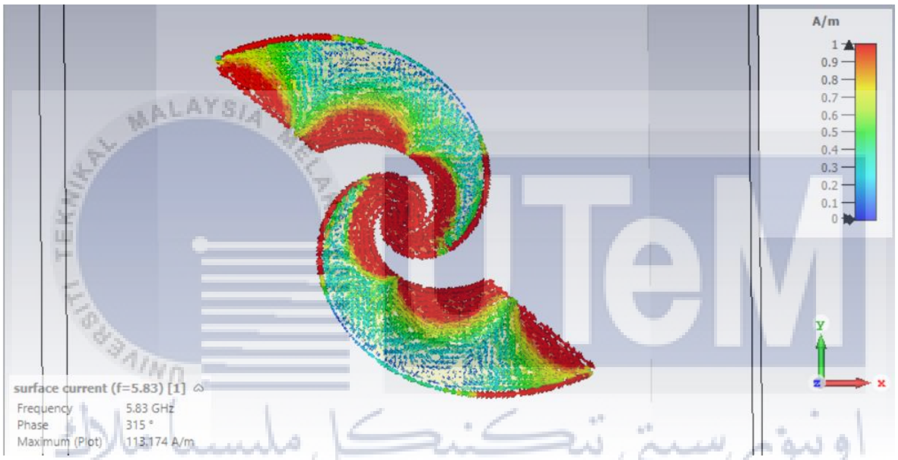
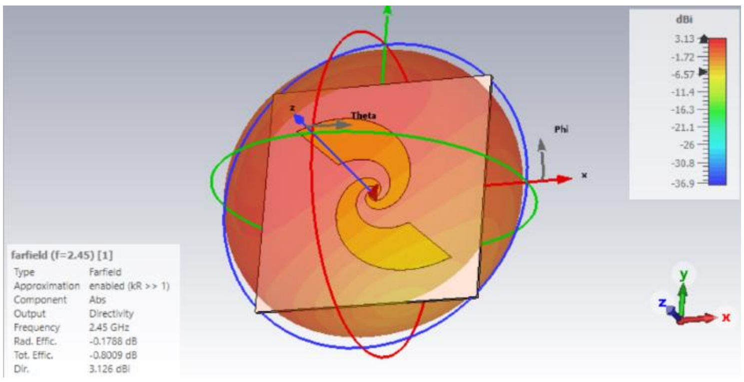
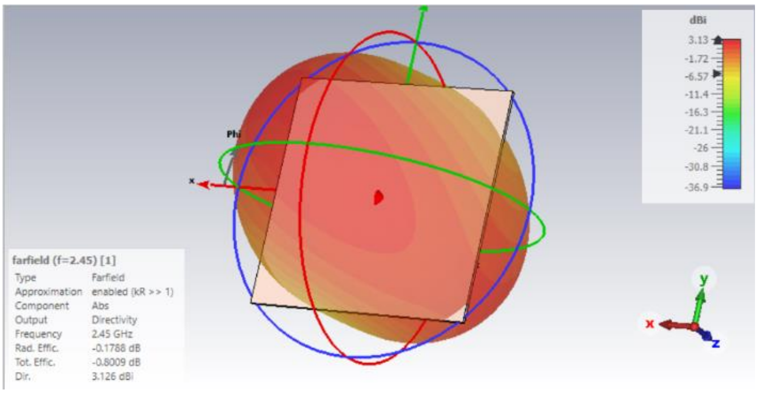


Figure 4.7: Surface current at 5.83GHz.

Figure 4.6 and Figure 4.7 above shows the current flow or surface current at 2.45GHz and 5.83GHz.

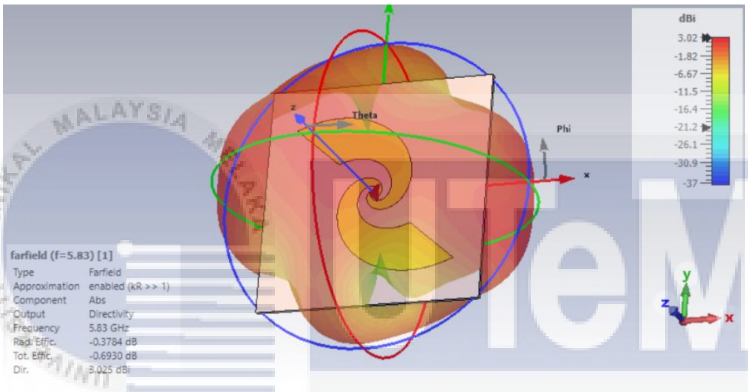


(a)

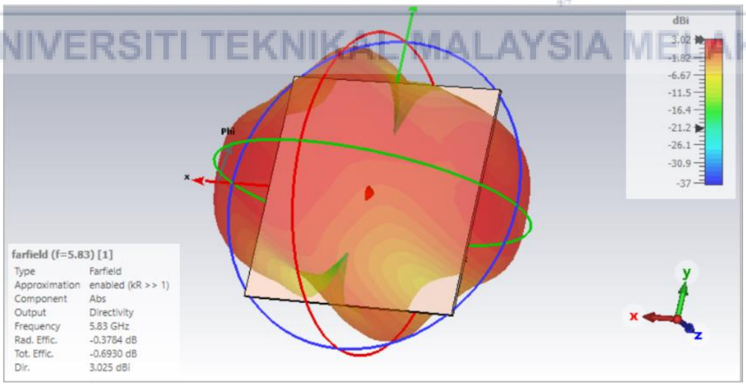


(b)

Figure 4.8: Far field of directivity of 2.45GHz (a)top (b)bottom.

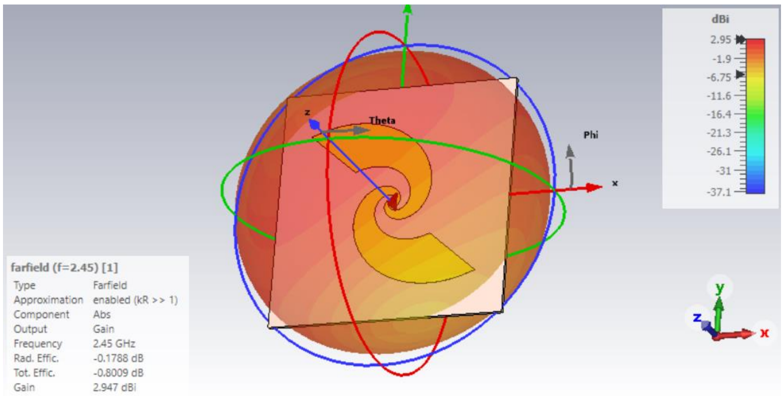


(a)

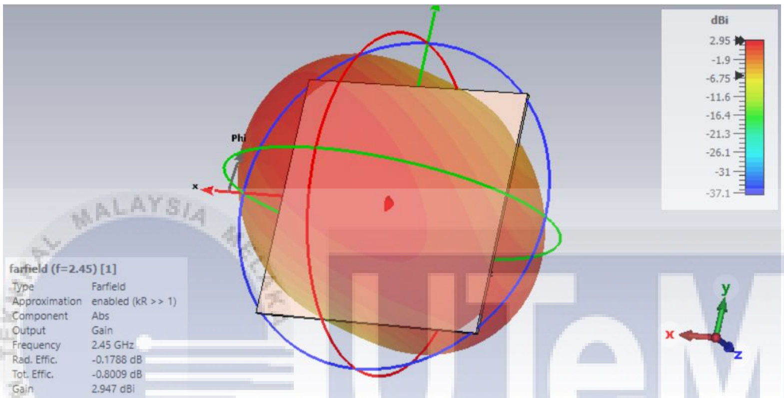


(b)

Figure 4.9: Far field of directivity of 5.83GHz (a)top (b)bottom.

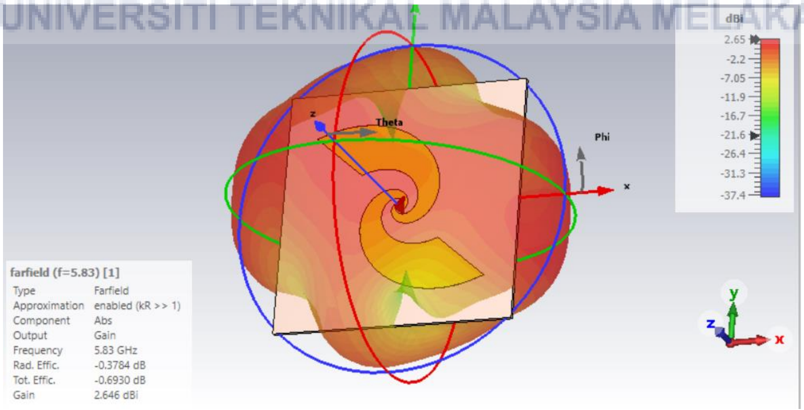


(a)

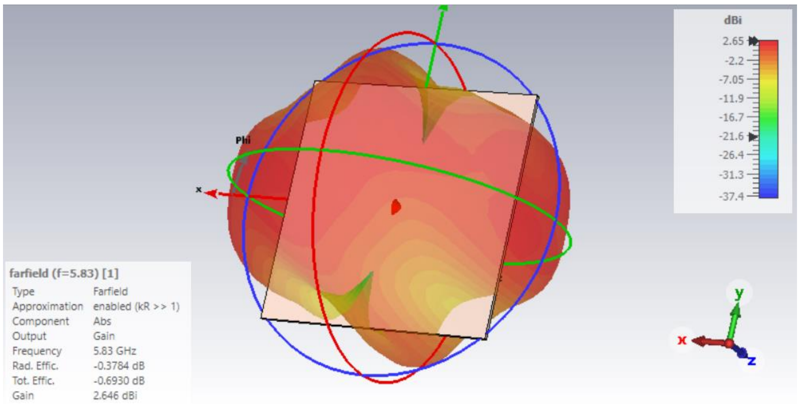


(b)

Figure 4.10: Far field of gain of 2.45GHz (a)top (b)bottom.



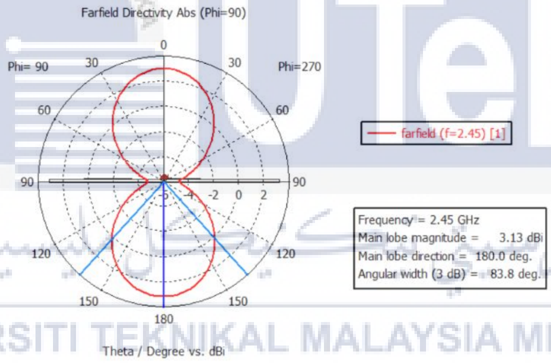
(a)



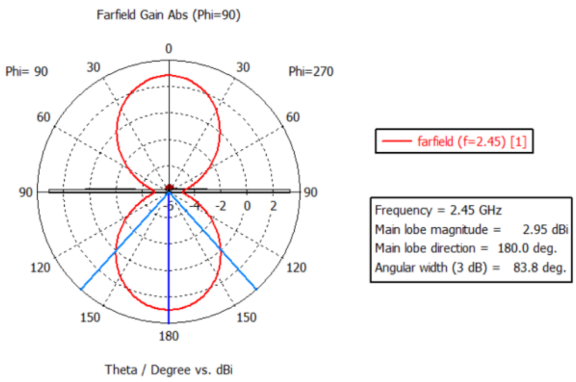
(b)

Figure 4.11: Far field of gain of 5.83GHz (a)top (b)bottom.

Figure 4.8 to Figure 4.11 shows the far field of directivity and gain from the top view and bottom.

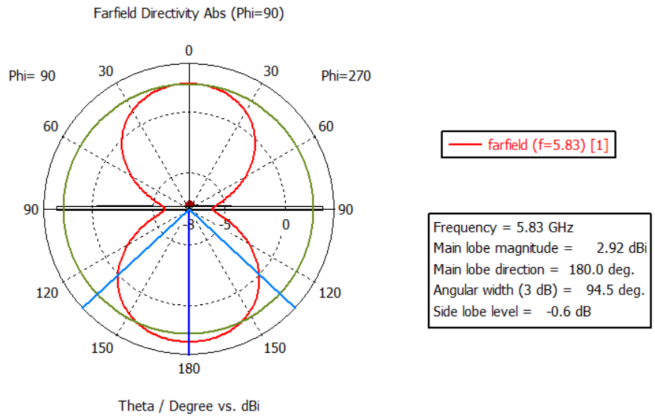


(a)

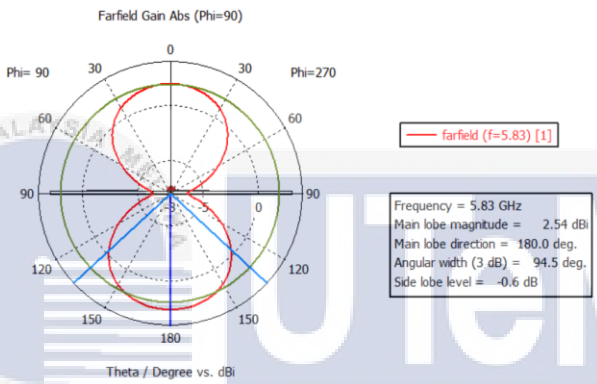


(b)

Figure 4.12: Far field of (a)directivity and (b)gain at Phi=90 for 2.45GHz.



(a)



(b)

Figure 4.13: Far field of (a)directivity and (b)gain at Phi=90 for 5.83GHz.

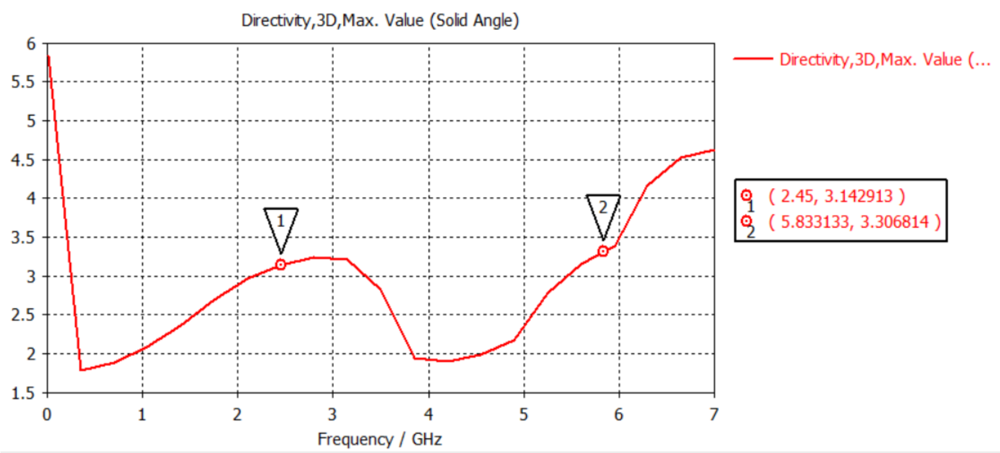


Figure 4.14: Graph of directivity.

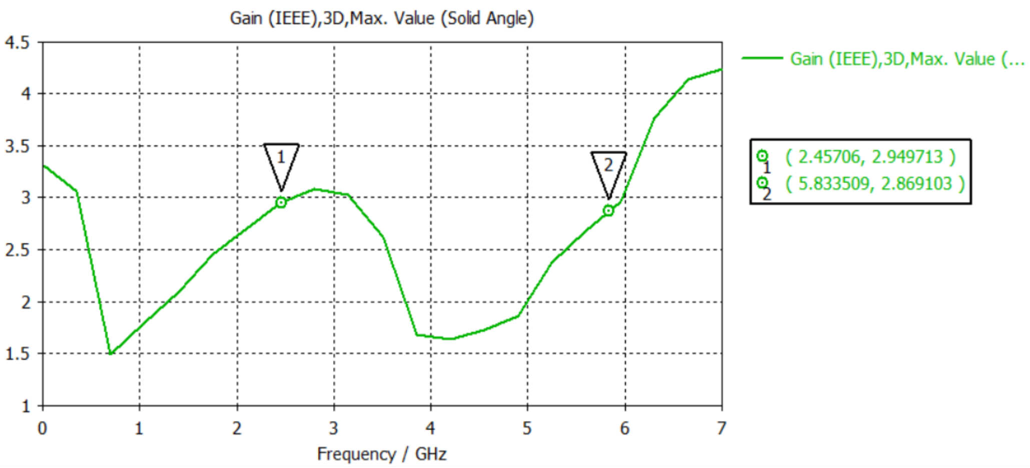


Figure 4.15: Graph of gain.

Figure 4.12 to Figure 4.15 shows the simulation result of directivity and gain in CST. The output of directivity is 3.143 dB and 3.307 dB for both 2.45GHz and 5.83GHz. While the output of gain for 2.45GHz and 5.83GHz is 2.949 dB and 2.869 dB. The higher the directivity of the antenna, the higher the effectiveness in transmit or receive the signal in a specific direction.

Table 4.1: Result parameter of the antenna in CST simulation.

Frequency	**2.45 GHz**	**5.83 GHz**
VSWR	2.143	1.709
Return Loss	-8.779 dB	-11.600 dB
Gain	2.949 dB	2.869 dB
Directivity	3.143 dB	3.307 dB

4.2.2 Measured Result

This antenna's measured results offer important information about its performance characteristics. Usually, parameters like gain, radiation pattern, efficiency, and S11 are included in these results. By examining these measurements, it is possible to evaluate how well the antenna satisfies design requirements and operates under actual circumstances, guaranteeing the best possible signal reception and communication.

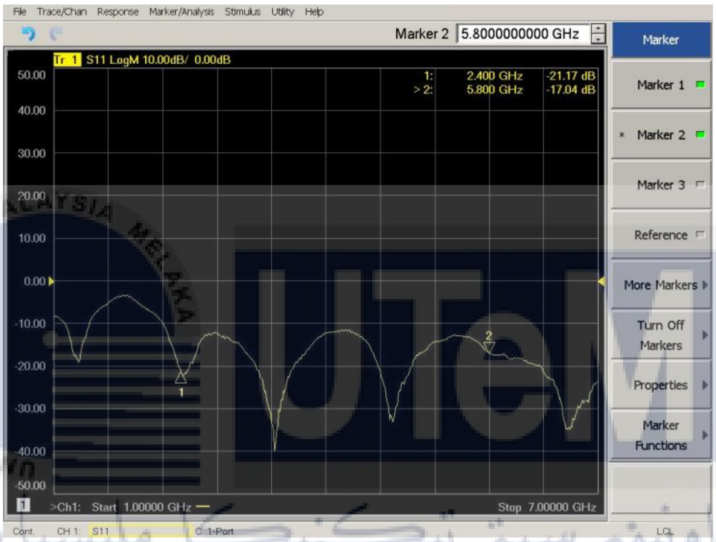


Figure 4.16: Return loss measurement on VNA

Figure 4.16 above shows the measurement of return loss using Vector Network Analyzer (VNA). The outcomes show that the simulation and measurements produce values for the return loss that are reasonable and maintain a minimum of -10 dB for efficient operation. Only 10% of the incident power is reflected back to the source when the return loss is -10 dB, indicating efficient transmission. When the rate is higher than -10 dB (ranging from 0 dB to -10 dB), it indicates that the antenna has either a high RF efficiency or a low return loss.

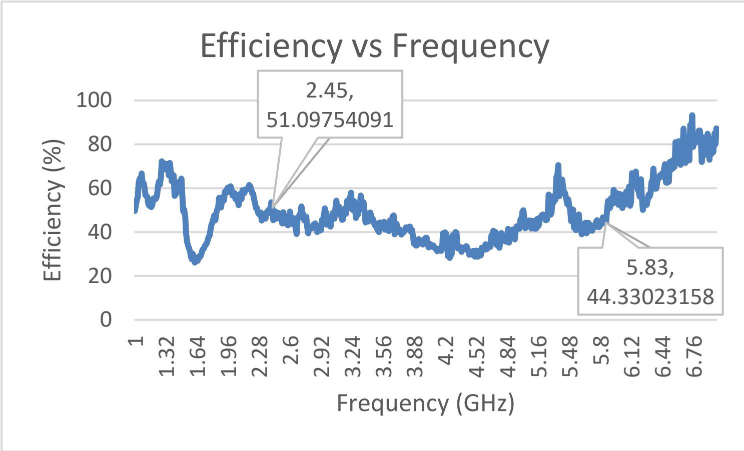


Figure 4.17: Measured result of efficiency.

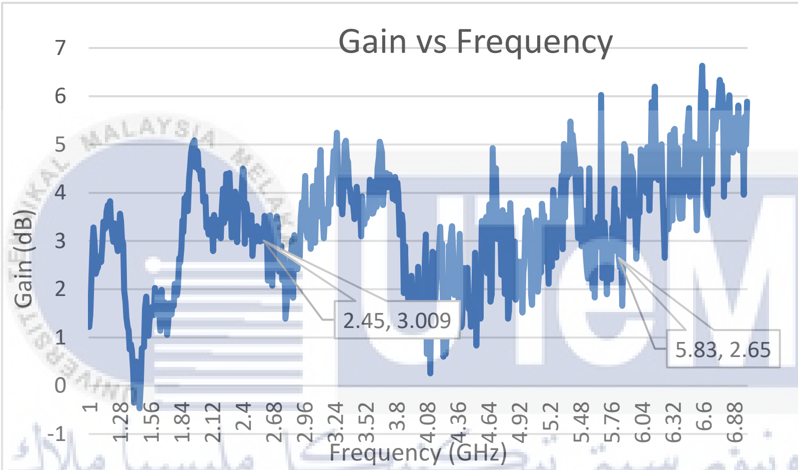


Figure 4.18: Measured result of gain.

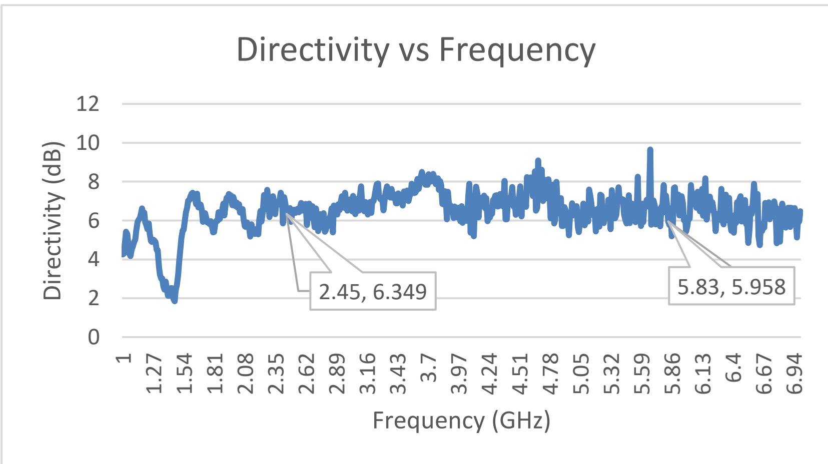


Figure 4.19: Measured result of directivity.

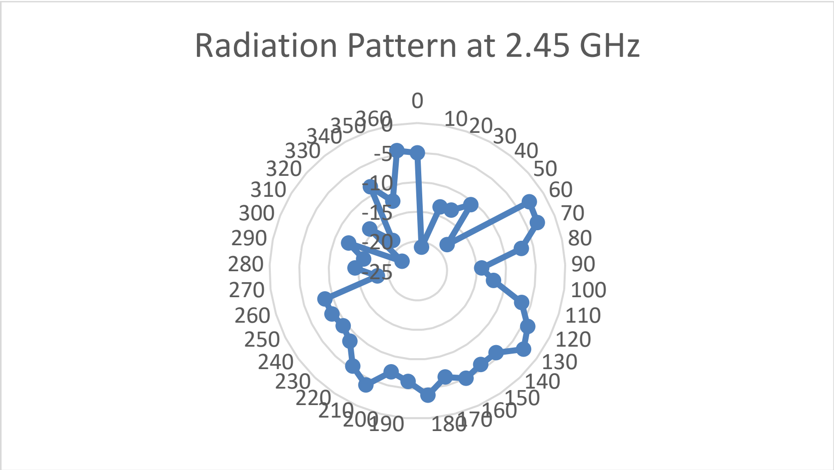


Figure 4.20: Measured result of radiation pattern at 2.45 GHz.

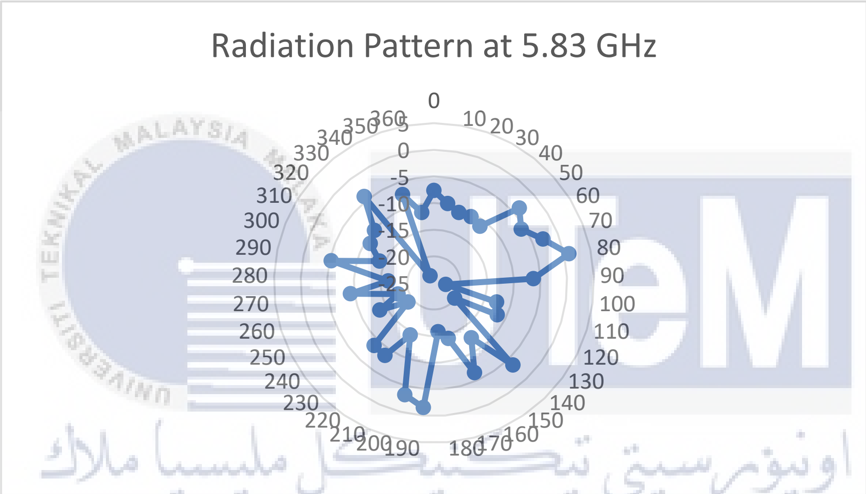


Figure 4.21: Measured result of radiation pattern at 5.83 GHz.

Figure 4.16 to Figure 4.21 shows the result of efficiency, gain, directivity and radiation pattern at 2.45 GHz and 5.83 GHz that have been measure in the chamber.

Table 4.2: Measured result's parameter of the antenna

	Simulated	Measured
Frequency	2.45 GHz	2.45 GHz
Return Loss	-8.779 dB	-21.17 dB
VSWR	2.143	1.192
Efficiency	83.16 %	51.09 %
Gain	2.949 dB	3.009 dB
Directivity	3.143 dB	6.349 dB

Table 4.3: Measured result's parameter of the antenna

	Simulated	Measured
Frequency	5.83 GHz	5.83 GHz
Return Loss	-11.600 dB	-17.04 dB
VSWR	1.709	1.327
Efficiency	82.52 %	44.33 %
Gain	2.869 dB	2.65 dB
Directivity	3.307 dB	5.958 dB

From the above experimental result, the return loss for simulated at 2.45GHz and 5.83GHz was recorded with -8.779 dB and -11.600 dB, while for the measured result -21.17 dB and -17.04 dB. The Voltage Standing Wave Ratio fall to 2.143 for 2.45 GHz which is slightly higher than 2 and for 5.83 GHz, the value is 1.709, which consider a very ideal result. For measured VSWR, the value recorded at 2.45 GHz is 1.192 and for 5.83 GHz the value is 1.327. The far-field directivity for the simulated antenna recorded 3.612 dB at 2.45 GHz and 3.025 dB for 5.83 GHz, while for measured value is 6.349 dB and 5.958 dB Overall, the simulated antenna achieves a gain of 2.949 dB and 2.869 dB, while for the measured result recorded at 3.009 dB and 2.65 dB. Hence, the overall measured antenna is better than the simulated antenna while the only disadvantage for measured antenna is the poor efficiency compared with simulated antenna. Table 4.2 and Table 4.3 shows the measured result's parameter of the antenna for 2.45 GHz and 5.83 GHz frequency.

4.3 Summary

In the end, Chapter 4 of this thesis or research paper is all about the study's analysis and findings. Building on what was said in Chapter 3 about the research method, all of the parts and methods described there have been put into place and built in Chapter 4. This chapter shows how the study can be used in the real world by giving a detailed account of how the experiment was set up, how data was collected, and how it was analyzed.

CHAPTER 5

CONCLUSION

5.1 Conclusion

This final year project, "Development of Antenna for Wi-fi Signal Energy Harvesting using CST," involved extensive research and experimentation to determine the viability and efficiency of the suggested antenna design. Numerous factors and performance measures have been investigated, and significant findings have been made. These results demonstrate the antenna's potential as an effective way for electronic devices to harvest energy.

In order to determine the best strategy and method to obtain the best outcome in comparison to the study conducted by another researcher, early design and simulation were conducted. In order to design the antenna, the project decided to simulate it using CST Studio Suite software.

The creation of a fabrication process for the antenna constitutes the second contribution. FR-4 is a precise substrate, thus creating an antenna with it requires careful material selection, manufacturing processes, and design. The structural stability and performance of the antenna are enhanced by the FR-4 substrate. In order to achieve the best possible signal reception and transmission in a variety of applications, meticulous attention to detail is maintained throughout the fabrication process.

Finally, this study presents an innovative log spiral antenna design specifically for wireless communication systems. The theoretical, simulation, and experimental approaches successfully explain the concepts. Log spiral antennas are advantageous in wireless sensor networks due to their high conversion efficiency and resilience to ambient RF energy sources. Further research is needed to validate the method's reliability and address emerging challenges in log spiral antenna development.

5.2 Future Work

Based on the results of this research, the following recommendations for further work may be made. The next steps in the development of log spiral antennas should concentrate on improving the manufacturing processes for greater dependability and efficiency, as well as refining the use of new materials. It would also be helpful to look into ways to increase the antenna's bandwidth and flexibility to operate at different frequencies. Investigating ways to reduce size without sacrificing functionality might lead to more adaptable and small-sized uses. Its practical deployment would also benefit from evaluating the antenna's performance in real-world settings and resolving interference and environmental condition-related issues. For seamless connectivity, ongoing research should also look into improvements in impedance matching methods and integration with wireless communication systems.

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APPENDICES

Appendix A Gantt Chart

PROJECT ACTIVITY	WEEK													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
PSM 2 Briefing	X													
Research Project	X	X												
Preparation for material		X	X	X										
Identify component			X	X										
Fabrication printing for design				X	X	X								
Data measurement					X	X	X							
Result & analysis						X	X	X		X				
Review report								X		X	X	X		
Submit 1st PSM 2 draft report to supervisor for review												X		
Submit report													X	
Presentation														X