Faculty of Electronics and Computer Technology and Engineering

DEVELOPMENT OF WEARABLE LEATHER ANTENNA MADE FROM GRAPHENE CONDUCTIVE INK FOR ADVANCE COMMUNICATION APPLICATIONS

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Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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DEVELOPMENT OF WEARABLE LEATHER ANTENNA MADE FROM GRAPHENE CONDUCTIVE INK FOR ADVANCED COMMUNICATION APPLICATIONS.

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ABSTRACT

Leather antenna is also known as wearable antenna is a technology that is being actively developed to improve the quality of daily life for future use. The objective of this project is to design the combination of ring patch antenna and analyze antenna parameters. The features of the proposed antenna should be small, lightweight, flexible, and easily integrated into the human body. Therefore, the antenna proposed in thisproject is a microstrip antenna in the form of a combination of 5 rings that make up the olympic logo and uses fabrics material as substrate and graphene conductive ink as conductive material with resonant frequency 2.47 GHz. For the simulation, Microwave Studio Computer Simulation Technology (CST) software was used to design the proposed antenna to obtain the optimal antenna size before the fabrication process. The simulation result show that the simulated antenna achieved the return loss -31.585 dB at 2.47 GHz with bandwidth 182.64 GHz range from 2.3687 to 2.5507 GHz and VSWR at 1.054. While for the measured antenna, the return loss achieved at 2.42 GHz is -21.40 dB with bandwidth 170 GHz ranging from 2.33 to 2.4 GHz and the VSWR achieved at 2.42. The results show that the proposed antenna has good performance in terms of return loss, bandwidth and VSWR.

ABSTRAK

Antena kulit juga dikenali sebagai antena boleh pakai adalah teknologi yang sedang giat dibangunkan untuk meningkatkan kualiti kehidupan harian untuk kegunaan masa hadapan. Objektif projek ini adalah untuk mereka bentuk gabungan antena tampalan cincin dan menganalisis parameter antena. Ciri-ciri antena yang dicadangkan hendaklah kecil, ringan, fleksibel dan mudah disepadukan ke dalam tubuh manusia. Oleh itu, antena yang dicadangkan dalam projek ini adalah antena jalur mikro berupa gabungan 5 gelang yang membentuk logo olimpik dan menggunakan bahan fabrik sebagai substrat dan dakwat konduckif graphene sebagai bahan konduktif dengan frekuensi resonans 2.47 GHz. Bagi simulasi, perisian Microwave Studio Computer Simulation Technology (CST) telah digunakan untuk mereka bentuk antena yang dicadangkan bagi mendapatkan saiz antena yang optimum sebelum proses fabrikasi. Hasil simulasi menunjukkan bahawa antena simulasi mencapai kehilangan pulangan -31.585 dB pada 2.47 GHz dengan lebar jalur 182.64 GHz dari 2.3687 hingga 2.5507 GHz dan VSWR pada 1.054. Manakala bagi antena yang diukur, kerugian pulangan yang dicapai pada 2.42 GHz ialah -21.40 dB dengan lebar jalur 170 GHz antara 2.33 hingga 2.4 GHz dan VSWR dicapai pada 2.42. Keputusan menunjukkan bahawa antena yang dicadangkan mempunyai prestasi yang baik dari segi kehilangan pulangan, lebar jalur dan VSWR.

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LIST OF SYMBOLS

GHz	-	Giga Hertz
MHz	-	Mega Hertz
dBi	-	Decibel Isotropic
dB	-	Decibel
Ω	-	Ohm
U	-	Radiation Intensity
W/kg	-	Weight per kilogram
S/m	-	Siemens per meter
wt %	-	Weight percent
ºC	-	Degree Celsius
nm	-	Nanometer
g/ml	-	Gram per milliliters
mm	-	Millimeter
ppm	-	Parts per million
cm^{-2}	-	Centimeter
µm	-	Micrometer
ε	-	Permittivity
Q	-	Quality Factor
C	-	Speed of light
δ	-	Delta
θ	-	Theta
m^2/g	-	Square meter per gram
%	-	Percentage
σ	-	Sigma
ϕ	-	Electric Flux

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CHAPTER 1

INTRODUCTION

1.1 Background

An antenna, also known as an aerial, usually metallic device (such as a rod or wire) for radiating or receiving radio waves [1]. The antenna also can define a device designed for radiating (or receiving) electromagnetic energy [2]. To put it another way, the antenna serves as a bridge between free space and a guiding system. The guiding system, also known as a transmission line, is a hollow pipe (waveguide) that transports electromagnetic energy from the transmitting source to the antenna or from the antenna to the receiver.

An antenna is one of the most important elements in wireless communication systems. The antenna with a good design will reduce system requirements while still improving overall system efficiency. A good example is a television, which may benefit from the use of a high-performance antenna to increase overall broadcast reception. An antenna serves the same function for a communication device as eyes and eyeglasses do for a person. Most electronic equipment has undergone several changes in recent years. Not only has technology advanced, but the size of the equipment has shrunk too small. Since most electronic equipment today has antennas, these developments often impact the antennas. The textile antenna is one form of antenna that attracts a lot of attention from researchers.

1.2 Problem Statement

Antenna is a very important device in today's electronic equipment and is often the subject of research by researchers. There are various types of antennas, shapes, frequencies and applications that have been studied by researchers. However, each of the proposed antennas still has weaknesses or problems that can be improved or overcome according to the suitability of the application used. Base on my research, the problem of antenna are:

a) Antenna structure where most of the antennas offered are rigid structures, big in size and not light weight.

b) Material used in antenna design which is most of the antenna used costly materials such as Taconic fiberglass5, and Roger hydrocarbon ceramics while there are still have a cheaper material.

1.3 Objective

The main objectives of this research are:

a) To design a combination of ring patch wearable antenna for single band frequency range.

b) To analyze antenna parameter and radiation pattern which is applicable for wearable antenna design.

c) Develop a design for a wearable antenna that can be integrated into leather materials while maintaining flexibility and comfort.

1.4 Scope of Work

First scope is to develop the olympic ring antenna for wideband 2 Ghz to 3 GHz frequency range by using the graphene conductive ink patch and fabrics substrate. It is proposed to cover the large frequency ring shaped antenna band that will design the structure of the finite ground plane. CST Studio Software will be carrying out layout and substrate designs.

For the second scope is to fabricate a prototype of an olympic ring antenna for the frequency range of 2 Ghz to 3 GHz of bandwidth using Copper patch and fabrics substrate. It is proposed to cover a large frequency ring -shaped antenna strip that will design a finite ground plane structure. CST Studio software will perform the layout and substrate design. Then, the antenna is fabricated using etching method and tested with a vector network analyzer to measure S11 parameters, VSWR and gain.

1.5 Thesis Framework

This work is divided into numerous chapters and subtopics. The introduction has started as Chapter 1 and offers the context of the study, problem statement, the objectives, the scope of the thesis, as well as the structure of the thesis.

Chapter 2 briefly addressed the literature review of the work covering relevant hypotheses and studies like an antenna, wearable antenna, ring antenna, material used and many other previous researchers related to wearable antenna properties.

Chapter 3 describes the fundamental research approach implementing used for different essential stimulation. This chapter also contained the flowchart of total analysis methods from start to finish.

Finally, Chapter 4 will present the findings of this work and the discussion that proceed. Besides, most of the data and relevant figures of stimulation were put and addressed furtherin this portion.

CHAPTER 2

LITERATURE REVIEW

2.1 Why this design is so special compared to previous design?

There are several factors that make this proposed antenna so special when compared to other antennas:

a) The combination of leather and graphene is not much available in literature, this is a good opportunity to investigate the characteristic of leather antenna made from graphene conductive ink.

b) This proposed antenna has a small size where it is suitable for use on clothing or electronic equipment.

c) Based on research, the proposed antenna design is simple and unique because most of the antenna designs that have been introduced have a complex shape and no research is conducted as the proposed shape makes the design unique.

d) Based on research, ring antennas offer a large bandwidth when compared to circular and rectangular antennas. This proposed antenna has a small size where it is suitable to use on clothing or electronic equipment.

2.2 Global issues and sustainability

Global challenges like resource depletion and climate change are becoming more and more important in today's globe. The necessity for sustainable solutions that minimize environmental damage while serving multiple societal requirements is thus on the rise. In the area of communication technology, the idea of a leather antenna offers a chance to investigate sustainability. Given that it is a natural material, leather may offer an alternative to traditional antenna designs, which predominantly make use of metals and plastics. We may take advantage of sustainability in several ways by using leather as a major building block for antennas. We may concentrate on a few things, including resource conservation, trash reduction, carbon footprint reduction, and cultural and creative expression. Reducing the use of non-renewable materials, which include metals and plastics, is possible with the use of leather antennas. Utilizing a renewable and biodegradable material like leather allows us to contribute to the protection of valuable resources for generations to come.

The waste reductions of leather business produce a lot of trash and byproducts, which frequently adds to environmental problems. We can lessen the impact of leather manufacturing and disposal on the environment by turning leather scrap or waste products into antenna components. Carbon impact is when compared to traditional antenna designs, leather antennas may have a less carbon impact. In many areas, leather may be obtained locally, lowering transportation emissions. Additionally, when handled appropriately, leather manufacture can need less energy than other industrial processes used in the production of conventional antennas.

Leather antennas may also be a platform for showcasing conventional workmanship and cultural history, contributing to the preservation of culture and the arts. We may encourage cultural preservation and establish a link between technology and regional craftsmanship by using distinctive leatherwork methods or patterns from various areas.The idea of using a leather antenna could call for further study and development to assure usefulness and effectiveness, but it shows how important it is to think creatively about sustainability. We may work towards a more sustainable and ecologically conscious future in a variety of industries, including communication technology, by investigating alternative materials and production techniques.

2.3 Wearable Antenna

Wireless communication, especially body-centric wireless communication, has developed rapidly in recent years and is a significant pulse on the Fifth Generation (5G) mobile communication network. This is because this network is promising a technology that allows integration with a variety of devices. Therefore, the IEEE 802.15 standardization group has been created to support the increasing interest of researchers in antennas, especially for body communication systems. The group was founded with the aim of standardizing the application by splitting it into three categories. The first category is On the Body and Off the Body. In this function, communication takes place between the antenna located on the body with other devices located outside the body. This category is widely used including antennas for portable radio transmitters, such as mobile phones and military radios [3]. Another category is On the Body and On the Body. For this type, communication occurs between the antenna that is in the body with another antenna that is also in the body. This category can enable a wide range of applications, including ubiquitous (U-health) monitoring, sports, fitness, rescue, and critical operations [4]. And the last category is On the Body and In the Body. For this category, communication occurs between an antenna on the body and another one is an implant on the body. Usually, this category is used for medical purposes [5].

A topic that often gets attention among researchers in body-centric communication is wearable antennas. A flexible antenna is one that is intended to interact with the body's wearable fabric/cloth antenna. Wearable antennas are made of fabric or textile that are a part of the wearer's clothing. The important reason for constructing the wearable antenna due to its appealing features and potential for allowing lightweight, low-cost, versatile, and portable wireless communication [6].

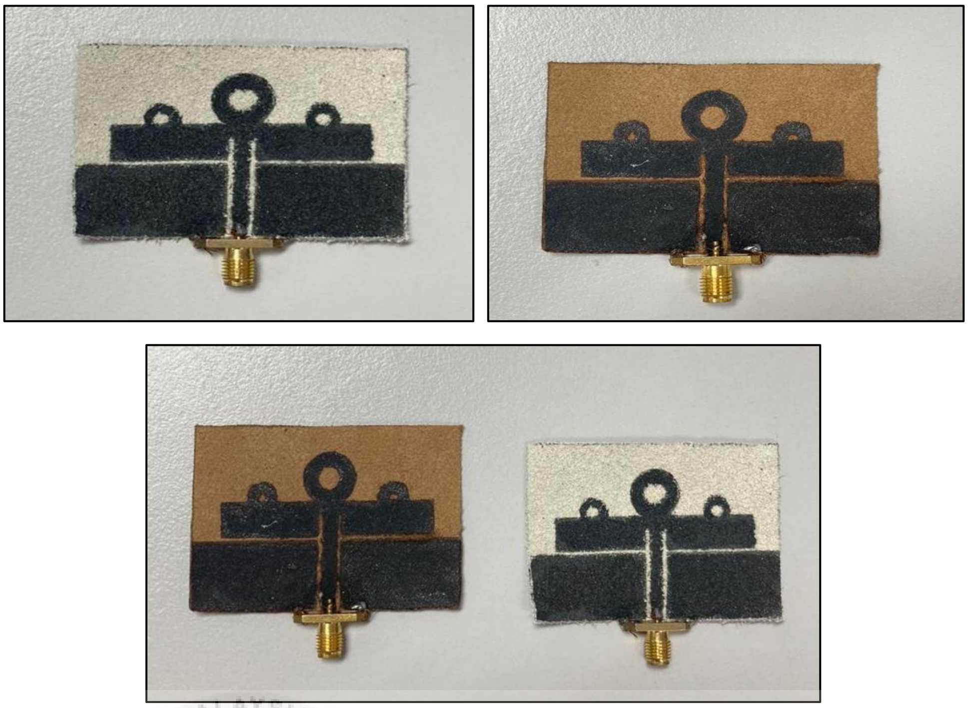


Figure 2.1: Example of design antenna on leather

Figure 2.1 shows an example of antenna that have been print on leather by using the graphene conductive ink. It shown that this antenna can be use a portable wireless antenna that got its own advantages which is small, flexible, and also lightweight.

2.3.1 Application of Wearable Antenna

Some specialist career segments, including paramedics [7], firefighters [8], and military personnel [9], use a wearable antenna. In addition, for tracking, wearable antennas may be used on children, the elderly, and athletes. In the military field, the wearable antenna can be worn in a military beret or uniform to track soldiers' exact positions. In the medical field, the wearable antenna is used to monitor the patients' health conditions like a thermometer to monitor the heartbeat, temperature, and blood pressure. Several aspects needto be considered before designing the wearable antenna which is the impact of the output antenna on the human body. The researcher must be unobtrusive, adaptable, and work with minimal deterioration near humans [10].

The shape of the antenna may be square, rectangular, circular, ring, or many other configurations. Ring antenna is one of the most common shapes that researchers are used because of ease of analysis and fabrication and its attractive radiation characteristics. Bergman and Schultz studied the annular-ring structure as a traveling wave antenna for the first time in 1955. It has also been used in the resonator and as a radiator in medical applications [11].

Table 2.1: The wearable devices and its Applications

Field	Applications
Health Care	Glucose Monitoring/ Endoscopy/ Oximetry/ GPS Tracker/ Breast Cancer Detection/ Wearable Doppler Unit/ Wearable Thermometer.
Entertainment	Smartwatches/ Music Jackets/ LED Dress/Intelligent Shoes.
Rescue and Security	Helmet/ Trackers/ Fitness Bands/ E-shoes/ Rain Coat/ Life Jackets.

2.3.2 Ring Antenna

In 2019, a researcher in [12] presented the ring-shaped defected ground structure microstrip antenna for wireless application with 2.15 GHz resonant frequency to achieve circular polarization with good bandwidth and minimum losses. The antenna output was measured in terms of reflection coefficient, an axial ratio plot, radiation pattern, the matching antenna, and voltage standing wave ratio. From the analysis, the radiation pattern achieved at the resonant frequency with maximum gain at 1.5963 dB while the 3D radiation pattern shows an eight shape. The antenna resonates at 2.1 GHz with a S11 of -29.5 dB while the bandwidth is 22.85%. The proposed antenna provides significant performance for applications such as Bluetooth, wireless networking, and so on.

In 2017, researchers at [13] have proposed a ring-shaped microstrip antenna for dual-polarized multiband with rectangular-shaped slots in the 1000 MHz frequency range. Such antenna applications are for short-range frequencies that involve the signal transmission and reception. Typically, ordinary microstrip antennas, such as Rectangular, Circular, etc., cannot show the response of more than one band. This is due to the different radiation pattern characteristics between them and the higher frequency ratio between the two consecutive modes. The proposed antenna excites a mode like a round microstrip antenna, but at a much lower frequency, making it a more portable option. By inserting a rectangular slot on the patch, it is also able to achieve multi-strip characteristics.

Further, in the same year, researchers in [14] in turn proposed a round-shaped ring patch antenna with a truncated patch. The proposed antenna is to determine the position of a person either outside or inside the building. The antenna was developed in a military beret using Felt material as a substrate, textile, and yarn from a conductive material. This antenna has two ports to operate in 2 modes. The first mode is a round-shaped ring Patch. This patch operates at a frequency of 915MHz and has a monopole-like radiation feature for RFID applications. While the second mode is a truncated patch operating at a frequency of 1.575 GHz for GPS applications. As a result, the proposed 10-dB antenna loss bandwidth on the antenna covers the entire 915 MHz ISM band and the L1 GPS band. These findings indicate the great potential that can be applied, especially in military applications.

Next, another researcher in [15] presented antennas for WBAN / WLAN and 5G applications. The proposed textile antenna has two modes of operation namely the first mode is ring-shaped with an operating frequency of 2.45 GHz and while the second mode is bar-shaped with an operating mode at 3.5 GHz. The antenna has an overall dimension of 70 x $70mm^2$ made of textile. ShieldIt Super material as conductive textile and Felt material as a substrate. As a result, when the antenna is in a flat bend configuration, the 10-dB impedance bandwidth obtained is 135 MHz which is 57 percent. The maximum gain for the 3.5 GHz frequency is 6 dBi. These findings indicate that the antennas proposed for use in WBAN / WLAN bands and 5G bands can be improved.

For air-borne radar applications, the researcher [16] designed a circular ring with a rectangle patch of 27.7 GHz. A small rectangular slot was loaded onto the ground plane of the substrate to increase the gain. A circular ring has been loaded with a rectangular patch to a wide band frequency range between 21 GHz to 31.8 GHz. With a return loss of -36.5dB, a gain of 7.40dB, and a bandwidth of 10.8 GHz, the results are given.

According to researcher [17], the proposed antenna is a three -strip textile antenna. The antenna is for WLAN and WiMAX applications in the form of a separate annular ring. This antenna uses Felt fabric material as a substrate that has an electrical constant of 1.90 to obtain a lightweight and stable structure. The proposed antenna is to increase the impedance characteristics of the antenna which is capable of operating at frequencies of 2.4 GHz, 3.5 GHz, and 5.2 GHz. This antenna can produce omnidirectional patterns at an operating frequency with gains of 2.52 dBi, 2.85 dBi, and 2.92 dBi, respectively.

Next, researchers [18] have proposed antennas that have a larger bandwidth and maintain a monopole-like radiation pattern. This antenna is a combination of 2 annular ring shapes and in the middle is a feed line. as a result, the antenna can produce a bandwidth of

27.1 percent by emitting a monopole-like radiation pattern with a gain of about 6 dBi. The proposed antenna bandwidth exceeds a single ring coupling antenna by more than 51 percent. According to [19] microstrip antennas have been proposed for wireless communication applications like WLAN, WIFI and others operating at frequencies between 2 to 5 GHz. The proposed antenna is a round shaped ring using a material of Fabrics as the dielectric and copper as the patch antenna. The substrate used is 1.6 mm thick and the dielectric constant is 4.4. By using ADS software, the return loss achieved in this simulation is 11.898 dB at a frequency of 3.24 GHz. The return loss produced should be lower than -10 dB to get a good result. Therefore, the authors suggest adding a slot on the antenna to increase the frequency range.

Square fractal antennas have been designed using defected ground structure technique on the ground plane of the antenna to increase the bandwidth for broadband applications has been introduced by [20]. The overall dimension of this antenna is 16 mm x 10 mm where the height of the substrate is 0.575 mm. This antenna uses Roger RT/Duroid 5880 as a substrate with a relative permittivity of 2.2 and a loss tangent of 0.0009 while the patch is from copper material. The antenna patch consists of several square-shaped slots that are separated from each other by a certain distance to form a fractal shape. The results of the ADS simulation found that the bandwidth generated by the proposed antenna is ranging from 5.4 GHz to 19.6 GHz which is 113.8%. While the minimum gain produced by the antenna is 1.5 dBi at 5.5 GHz and the maximum gain at 5.5 dBi at 19.5 GHz. Therefore, based on the results produced, it is found that the size of this antenna is small and provides a large bandwidth suitable for the manufacture of devices in wireless communication.

Next, two antenna designs have been proposed namely a single double-ring resonator (DRR) and double DRR by [21]. Antennas for both designs have been embroidered using metal thread on the ring and transmission line as a conductive material while the substrate is from felt material. The substrate used has a thickness of 1 mm, the dielectric constant is 1.2 while the loss tangent is 0.0013. The results of the simulation show that double DRR has a better return loss than single DRR which is at -19 dB with a frequency of 3.97 GHz. Similarly, the gain and efficiency double DRR which is 9.78 dB and 95% respectively. Both antennas also perform SAR analysis to measure the radiated force absorbed per unit mass in human tissue. The results from the analysis show that both antennas are safe from radiation and can be used on the human body. This proves that embroidered DRR antennas are a useful technique on wearable antenna applications to transmit/receive microwave signals.

In addition, coplanar waveguides fed (CPW-fed) ring wearable antennas have been introduced by [22] for body-area-network applications. This antenna uses a flexible textile material that is leather as the substrate material which has a dielectric constant equal to 1.79 and tangent loss is 0.042. The proposed antenna operates at a frequency of 1.5 GHz to 6.5 GHz. Copper foil cut to the correct size and then pasted on textile leather is the conductive material used on this antenna. This antenna also performs SAR analysis where the results show that there is little power absorbed by the human body. In addition, this antenna also operates at 1.5 GHz to 6.5 GHz and suitable for use in GPS, WIMAX and WIFI applications.

In [23] presents an e-textile in the form of a split ring resonator consisting of two rings separated from each other for RFID applications. The antenna uses EPDM as a substrate with a thickness of 2 mm. Several tests have been conducted on the antenna such as the Voyantic Tagformance measurement system. The results of the test found that the antenna has reduced its footprint size by up to 25% compared to the antenna that has been introduced previously and maintained the same performance with the tag reading at 2.8 meters for frequency 915 MHz.

Meanwhile [24] also presented a split-ring resonator (CSRR) with a design of metamaterials on the ground plane structure for C-Band frequencies to support 5G networks. The proposed antenna development use metamaterial techniques to increase antenna efficiency and reduce antenna dimensions. The antenna used Fabrics material with a thicknessof 1.6 mm for the substrate. In this study, the researcher has compared the proposed antennawith a conventional antenna. The simulation results of the study found that the overall size of the proposed antenna has decreased, return loss and bandwidth increased when comparedto conventional antennas but the gain of the antenna is reduced. This shows the CSSR method of metamaterial on the ground plane is effective in reducing the antenna size.

According to [25] annual ring slot antennas have been introduced for wideband and low cross-polarization using two different feeds. This technique was used to reduce the level of cross-polarization while ensuring a low antenna profile. This antenna uses a single-layer Rogers RT/Droid 5880 with an electric constant of 2.2 and a tangent loss of 0.0009. The results produced by this antenna show that the bandwidth is from 9 GHz to 15.17 GHz, the level of cross-polarization remains below -32 dB, the gain is 9dBi, and efficiency at 93% are obtained.

In [26] has introduced a compact dual band filtering antenna consisting of a rectangular patch engraved on it two rectangular slots and two ring slots. This antenna operates at a frequency of 5 GHz and 5.8 GHz for WIFI and ISM. each shape on the antenna has its own function. The proposed dimensions are 41.5 mm x 33.9 mm x 1.524 mm using a substrate from Rogers RO4232 having dielectric constant = 3.2 and loss tangent = 0.0018.

The results of simulations and tests carried out on the proposed antenna found that it is suitable to be placed on the body to communicate with other outdoor equipment.

According to [27] has introduced a rectangular microstrip antenna and placed a copper ring superstrate on top of the patch for X-Band applications. This antenna uses RT-Duroid as a substrate with dielectric constant = 2.2 and thickness = 1.6 mm. Simulation and experimental results show that the antenna operates in dual-band at 9 GHz and 11.35 GHz, gains at 8.2 dBi and 10.1 dBi have been achieved.

Antennas consisting of two annular ring slots to achieve two operating bands have been introduced by [28]. The annular ring slot is loaded with capacitors to achieve dual-sense circular polarization radiation and dual-band. The results show that the bandwidth generated at the lower frequency is 21.5% ranging from 1510 to 1874 MHz and 22.5% from 2431 to 3047 MHz for the upper frequency and the gain is from 2.2 to 2.8 dBic and from 1.9 to 3.1 dBic for the lower and upper frequencies, respectively. Good circular polarization performance and simple structure are suitable for wireless communication system applications.

Table 2.2: Comparison of the ring shaped used to design the antenna.

Ref	Shape	Frequency (GHz)	Application	Dielectric Material	Conductive Material
[12]	Circular Ring-Shaped Defected Ground Structure	2.15	Wireless	FR 4	Silver
[13]	Ring Shape with Rectangular Slot	1	-	Glass Epoxy	-
[14]	Circular Ring with truncated patch	0.915 / 1.575	GPS	Felt	Shieldex
[15]	Split Ring Shaped with bar slotted	2.45 / 3.5	WBAN/WLAN and 5G	Felt	ShieldIt Super
[16]	Circular Ring with rectangular patch	27.7G	Airborne Radar	Duroid	Silver
[17]	Split annular Ring	2.4 /3.5/ 5.2	WLAN/WiMAX	Felt	conductive fabric
[18]	Monopolar Patch with Dual-Ring Couplers	5.45 – 7.16	Wireless Communication	-	-
[19]	Ring Shaped	3.24	Wireless Communication	FR4	Copper
[20]	Square Fractal Ring	9.8 / 15.1	Broadband	Roger RT/Duroid 5880	Copper
[21]	Single Double Ring Resonator (DRR)	2.18	Microwave	Felt	Shieldex 117/17 dtex 2-ply
	Double (DRR)	3.97			
[22]	CPW-fed Ring	1.5 – 6.5	BAN	Leather	Copper
[23]	Split Ring Resonator	0.915	UHF RFID	EPDM	ShieldIt Super

[24]	Split Ring Resonator	3.5	5G Network	FR4	Silver
[25]	Planar Annual Ring Slot	9 – 15.17	5G Network	Rogers RT/duroid 5880	Copper
[26]	Dual-band Filtering Antenna with Ring Slot	5 /5.8	Wearable Applications	Rogers RO4232	Copper
[27]	Microstrip Patch Antenna with Copper Ring Superstrate	9 / 11.35	X-Band Applications	RT-Duriod	Copper
[28]	Annular Ring Slot	1.51 – 1.874/ 2.431-3.047	Wireless Communication	FR4	Silver
[29]	Rectangular Split Ring Resonator	3.5 /5.8	Wimax/WBAN/WLAN	-	-
[30]	L-Shaped Slot Antenna with Split Ring Resonator	2.34/3.47	WiFi/Wimax	FR4	Silver
[31]	Ring Monopole Antenna with Stripline and Ring Resonator	1.8/2.45/3.5	LTE/WLAN/WiMAX	FR4	-

2.4 Antenna Material

A wearable antenna consists of two types of material which are conductive, and substrate as shown in Figure 1. There is a various type of conductive and dielectric materials are used to build wearable antennas. These materials were chosen with care to allow for a fair number of mechanical deformations (bending, twisting, and wrapping) with minimal impact based on various weather conditions and proper EM radiation safety. Other fabrics/nonfabric materials have recently been used for wearable antennas.

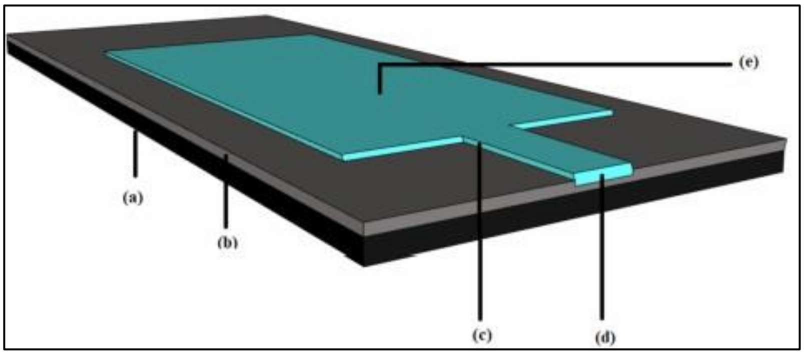


Figure 2.2: Basic structure of microstrip antenna (a) Ground plane (b) Substrate (c) Transmission line (d) Feed (e) Conductive patch

2.4.1 Conductive Materials

Electromagnetic waves (EM) can transmit electricity effectively or transmit energy through conductive materials. When this material is used on a flexible antenna, the selected conductive material should have squeezing, stretching, and flexible properties without reducing the performance of the antenna. Such materials must also have resistance to material degradation. The conductive material selected must also have low durability / high conductivity, stability, weatherproof, tensile strength, and textile integration.

There are three types of conductive materials available in the market, namely pure or intrinsic metal, a mixture of ink and metal, and a mixture of fabric and metal. Typically, among the pure metal materials often used by researchers in the development of textile antennas are such as copper foil, silver paste, and copper gauze. This is due to the high conductivity found in the material apart from the more cost-effective and ease of manufacture. Instead of stitching and embroidery, adhesive lamination or backing foam is commonly used when the material is mixed with garment textiles [32].

Metal mixed fabric, or electro-textile, on the other hand, is a conductive fabric made by interpolating conductive metal/polymer threads with regular fabrics. The Wearable, robust, and versatile characteristics of these fabrics made them ideal for incorporation into clothing [33]. While conductive inks that contain a mixture of metals such as silver and carbon nanoparticles are very conductive and easy to produce. This is because this ink can be used on standard printers in developing flexible antennas. The only drawback of conductive ink is the high manufacturing cost [34].

Silver (Ag) is a transitional metal with a soft, white lustre that has the highest electrical conductivity, thermal conductivity, and reflectivity of any metal. Ag is a malleable, brittle, and precious metal that has been known since ancient times and is included in the periodic table's group 11 and 5 with copper (Cu) and gold (Au) [35]. Silver is plentiful in nature. However, in comparison to other metals, the concentration on the earth's surface is very low (0.05 ppm). Most of the silver is produced as a by-product of copper, gold, lead, and zinc mining. Gold, copper, iron, mercury, tin, and lead are among the seven ancient minerals discovered [36].

Electrical conductors, electrical contacts, catalysis, sensors, lenses, the construction of chemical devices and brazing alloys, drinking filtration systems, bathtub filtration systems, medical care products, and pharmaceuticals are only a few of the applications for silver and its compositions [37]. Silver can also bind easily to human body proteins and participate in metabolic processes with visible metals. Silver has the lowest resistance to being touched of all the metals [38].

Table 2.3: Summary of Silver as a Conductive Material

Ref	Application	Dielectric Constant				Freq.	S11	Others
		Material	t (mm)	ε_r	tan δ	(GHz)	(dB)	
[39]	5G Application	PDMS	2	2.85	0.02	6	-25	4.98dB (Gain)
[40]	Wearable Antenna Applications	Mitsubishi Photo paper	0.14	3.6	0.14	2.4/ 5.58	-32/ -22	-
[41]	5G Application	Polylactic acid (PLA)	1	2.4	-	28	-15	4.3% (BW)
[42]	Body-Centric Communication	PDMS	3	2.8	0.02	2.45 /5.8	-29/ -17	81MHz/ 242 MHz (BW)
[43]	Wearable Microwave Stroke Imaging	Polyester	0.5	2.2	-	2.5	-20	3.75 GHz (BW)
[44]	5G Application	PET	0.135	3.2	0.002	28	-45	2.62dBi (Gain)
[45]	Medical band, Industrial	PDMS	0.1	2.8	0.02	2.4	-15	5.2 dBi (Gain)
[46]	ISM/UWB	Jeans	3.2	1.7	0.025	5.8/ 10.48	-22.6 /-33	160 MHz/ 1.18GHz (BW)
[47]	Smart Clothing	Felt	-	1.38	0.02	2.84	-11.5	100MHz (BW)
[48]	WLAN	PDMS	0.8	2.8	0.03	5	-18	160 MHz (BW)

2.4.2 Substrate

The substrate material is also an important material in antenna design, which serves to support the conductive element of the antenna. There are various types of substrates used in antenna design, depending on the nature of the conductive material used in the design. In recent decades, researchers have studied more flexible materials to be used as substrates for antennas such as polymers, textiles, or fabrics as well as paper to give antennas more flexibility [49]. Each of these substrates has different characteristics from each other.

2.4.2.1 Polymer as Substrate

Recently, many researchers have suggested polymer-based substrates as a new material in the development of flexible antennas such as polyimide. This material is widely used because of its properties that are able to maintain chemical stability and increase conductivity. In addition, the cost of this conductive polymer material is cheap and able to reduce the cost of an antenna [50].

Polymer nanocomposites are one type of nanocomposites in which polymer serves as the matrix and other nanoscale components serve as the nanofiller [51]. Due to the synergistic effects induced by the polymer matrix and nanofiller, conductive polymer nanocomposites, a special category of polymer nanocomposites that are made conductive by combining polymer matrix (either conducting or insulating) with nanofillers (either conducting or insulating), have a lot of potential in a lot of different areas [51]. Polyaniline (PANI), polypyrrole (PPy), polyacetylene (PAc), polythiophene (PTh), and their derivatives are the most widely studied conducting polymers, while conducting nanostructures such as carbon nanotubes, Graphene, metals, and ceramic insulating nanostructures are the most widely incorporated nanofillers [51].

When compared to typical polymer composites, polymer nanocomposites have increased mechanical and tensile strength, [52] lower scratch and abrasion resistance, higher thermal distortion temperature, and noise dampening. Problems associated with high composite reinforcement content, such as decreased strength, low optical clarity, and higher melt viscosity, are less of an issue in nanocomposites manufacturing because less than 10%

nano-reinforcement load is sufficient to manufacture high-performance polymer nanocomposites [52].

One of the polymer materials is polyimide. This material has a thin, versatile, and lightweight shape. It is often used in the manufacture of PCBs such as PI films to support coating because of the flexible core material. It is also widely used to make antenna substrates, chip packaging, mobile phones, and so on. In the IEEE 802.11 standard, polyimide is the most prescriptive material due to its high compatibility with signal processing circuits [53].

Table 2.4: Summary of Polyimide as a Substrate

Ref	**Patch Material**	**Frequency (GHz)**	**S11 (dB)**	**Others**
[54]	Copper	2.45	-25	350 MHz (BW)
[55]	Copper	2.4	-12.51	600 MHz (BW)/ 1.9 dB (Gain)
[56]	Copper	2.45/5.8	-32 dB/-40 dB	140 MHz/260 MHz
[57]	Copper	38	-61	1.394 GHz
[58]	Graphite	63.42	-36.87	9.30 dB (Gain)
	Copper	55.16	-9.74	8.83 dB (Gain)
[59]	Metallic	59	-21.8	1.1 GHz (BW)
[60]	Silver	2.4	-24.56	2.43 dB (Gain)
[61]	Polymer Silver	2.5	-19.5	-5.49 dB (Gain)
[62]	Silver	2.5	22.8	662 MHz (BW)
[63]	Carbon Coated Cobalt	2.45/5.4	-14.4	1.05 dB (Gain)

2.4.3 Important Features in Substrate Material

2.4.3.1 Dielectric Constant

In general, dielectric properties are highly dependent on surface roughness, temperature, and frequency apart from material uniformity, moisture content and purity [64]. The real part of the relative permeability, ε, is called the dielectric constant, but it is not fixed in frequency. The constitutive parameter of a dielectric is permittivity, ε, which is a complex value parameter. It is usually expressed as the relative value of:

$$\varepsilon_r: \varepsilon = \varepsilon_0\varepsilon_r = \varepsilon_0 (\varepsilon'_r - j\varepsilon'_r) \tag{2.1}$$

where ε_0 is the vacuum permittivity, i.e. 8.854 × 10–12 F / m [65]. The ratio of the imaginary part to the real part is called the tangent loss. In general, textiles have a very low dielectric constant since they are porous, and the presence of air exceeds the relative permittivity to one. The lower dielectric constant reduces surface wave losses caused by directed wave propagation inside the substrate [65]. Therefore, a low dielectric constant will increase the spatial wave and in turn increase the bandwidth of the antenna impedance, this will lead to antenna expansion with acceptable efficiency and high gain.

2.4.3.2 Loss Tangent

A setback dissipation factor is another name for tangent (tan δ). It explains how much of the substrate's power is converted to heat. As a result, the tangent loss is defined as the ratio of the imaginary part to the relative part permeability in the following relationship. The loss tangent's value is increasing, resulting in more losses on the dielectric substrate and lower radiation efficiency [66]. The loss tangent equation as follow:

$$\tan \delta = \varepsilon''r / \varepsilon'r \tag{2.2}$$

2.4.3.3 Dielectric Thickness

The substrate dielectric constant and thickness are the primary determinants of a wearable antenna's bandwidth and efficiency. As previously stated, increases in permittivity can alter the antenna bandwidth, but decreasing the substrate permittivity can also boost the antenna's resonance frequency [64]. The following equation shows the relationship between the influence of thickness on bandwidth (BW) antenna quality (Q):

$$BW \sim 1/Q \tag{2.3}$$

As seen in the following equation, the Q component is affected by space wave (Qrad) losses, conduction ohmic (Qc) losses, surface waves (Qsw), and dielectric (Qd) losses.

$$1/Qt = 1/Qrad + 1/Qc + 1/Qd + 1/Qsw \tag{2.4}$$

2.5 General Design Requirements for Wearable Antenna Properties

2.5.1 Radiation Patterns

The concept of radiation trend in the sector of antenna architecture corresponds to the directional (angular) dependency of radio wave intensity from an antenna or some other source [67]. The radiation pattern is the conceptual model of an antenna's distant-field radiation property. The field magnitude versus angle θ, φ plots offer the radiation pattern three-dimensional figures. The design taken in the planes identical to the portion of the E-field is named an E-plane pattern while those obtained in planes perpendicular to such an E-plane are known the pattern of the H-plane pattern. In the subsequent three scales [68], levels of radiation are usually plotted.

a) Field pattern (in linear scale).
b) Power pattern (in linear scale).
c) Power pattern (in dB).

The field or even power pattern is standardized with respect towards their maximal value in most situations, resulting in the uniform field and power patterns shown on a logarithmic (dB) scale much like in Figure 2.9. A practical antenna is built to model directed radiation. As an example, emit or absorb radiation more efficiently in one path than for others. An isotropic radiator is sometimes used as a tool to describe the spatial properties of an antenna. This implies it's a hypothetical lossless antenna which radiates in all regions uniformly. The omnidirectional design is a unique case of a directional pattern where all the rays in the azimuthal plane are non-directional, however in the elevation plane is directional [69].

2.5.2 Antenna Gain

An antenna gain (in a given direction) is defined as the ratio of intensity to the radiation intensity in a given direction that would be achieved if radiated by the power agreed by the isotropic ally of the antenna. Throughout many wireless applications, gain can be expressed in dBd units. Gain in dBd is equal to gain at dB is reduced by gain of 2.15 dB semi-wave dipole reference antenna. The strength of radiation corresponding to the radiated power of the isotropic ally is equal to the power acknowledged (input) by the antenna separated by "4π." This can be expressed as in equation form.

$$\text{Gain} = 4\pi \frac{radiation\ intensity}{total\ input\ (accepted)\ power} = 44\pi \frac{U\ (\theta\theta,\Phi)}{P_{in}} \tag{2.5}$$

2.5.3 Return Loss

Return Loss describes characteristics that fit the antenna. This shows the effectiveness of the antenna in absorbing and propagating electromagnetic waves at a certain frequency. In addition, radiation patterns also play an important role in determining the efficiency of an antenna specific to a private wireless body network area.

Table 2.5: Summary of Ring Shape Antennas

Ref	**Antenna Shape**	**Frequency (GHz)**	**S11 (dB)**	**Gain**	**BW**
[70]	Circular Patch Ring	5.8	-34	5.7 dBi	12.8%
[71]	Split-Ring Resonators	1.895	-26	1.85 dBi	60.31%
[72]	Annular Ring	1.605	-23	-	2.5%

[73]	Dual-Ring	39	-30	4.5 dBi	33.2%
[74]	Triangular Split Ring	2.6 / 3.7	-20 / -19	1 dBi/ 0.5 dBi	400 MHz/ 850 MHz
[75]	Annular Ring	1.224 /1.48	-26 /-15	1.35 dBi/ 3.5 dBi	72 MHz/ 90 MHz
[76]	Gauging Trowel shaped with Circular Rings	60	-50.2	4.57 dBi	-
[77]	Rectangular Microstrip Patch Array using Split Ring Resonator	5.24	-38.65	4.39 dBi	192 MHz
[78]	Annular Ring	5.25	-27.26	7.23 dBi	3.85%
[79]	Loaded with Split Ring Resonators	8.2 / 9.21	-20/-17	-	0.36 GHz/ 0.57 GHz

2.6 Conclusion

This chapter delves into the many types of antennas in depth. Silver has a high aspect ratio, mechanical strength, brightness, thermal and electrical conductivity, low cost, and a planar structure, all of which are desirable properties. The return loss, antennas' gain, and wearable antenna features all have an impact on performance, according to the study. Wearable textile antennas are evolving and posing new challenges, and they have a bright future in the development of advance communication that extend and simplify communication systems.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Several phases based on the flow chart in Figure 3.1 must be completed in order to meet the project's goals.

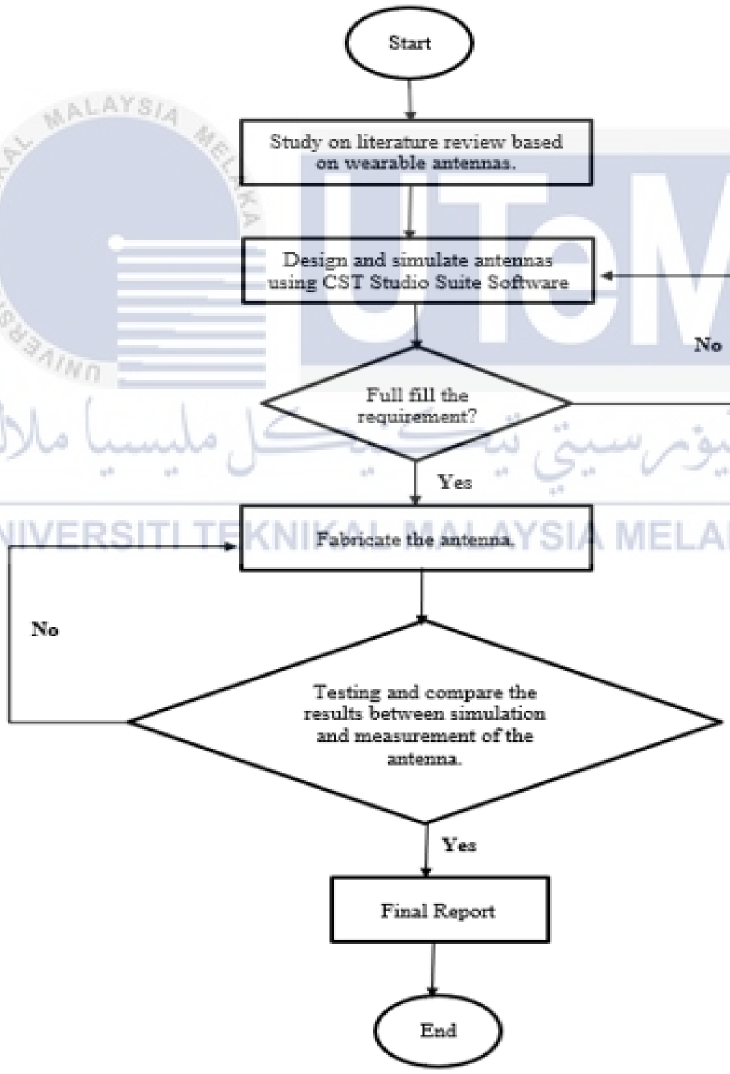


Figure 3.1: Project flow chart

3.2 Literature Review

The purpose of literature study and research is to get a better understanding and knowledge of the project, as well as to establish its feasibility. During this step, all papers, books, and websites pertaining to design an antenna and modelling were thoroughly examined.

3.3 Design and Simulation

3.3.1 Type of Antenna

As discussed earlier, there are many types of antennas used by researchers for antenna development including microstrip patch antennas due to the advantages of such antennas such as light weight, low development cost and low profile plan configuration. microstrip. The antenna has a basic structure consisting of three layers which are the ground field at the bottom of the antenna, the substrate layer, and the conductor patch at the top of the antenna.

In antenna development, various materials are used to form a substrate or dielectric such as electrical, thermal, and mechanical that will affect the antenna itself. Several substrates with dielectric constants between 1.17 to around 25 are now available in this industry. In this study, Polyimide was used as the substrate material as mentioned earlier.

While the conductive patch is a conductive layer of flat metal with various shapes such as rectangle, round, triangle, ring, or other shapes. The project proposes a combination of ring-shaped patches with a silver material as a conductive layer. For the antenna design, two types of design experiments were carried out. All the design used a frequency range between 1 GHz to 8 GHz with dual-band frequencies.

3.3.2 Antenna Parameters

A Polyimide substrate is employed in a suggested antenna designs, and its dimensions and electrical attributes are listed in Table 3.1. A circular ring patch of a specific radius is employed to obtain the appropriate resonance frequency, as shown in equations (1) and (2). A 50 microstrip line is used to feed the antenna's circular ring patch. The proposed antenna designed in CST software in Figure 3.2. The formula presented is used to compute the actual radius of the circular ring patch.

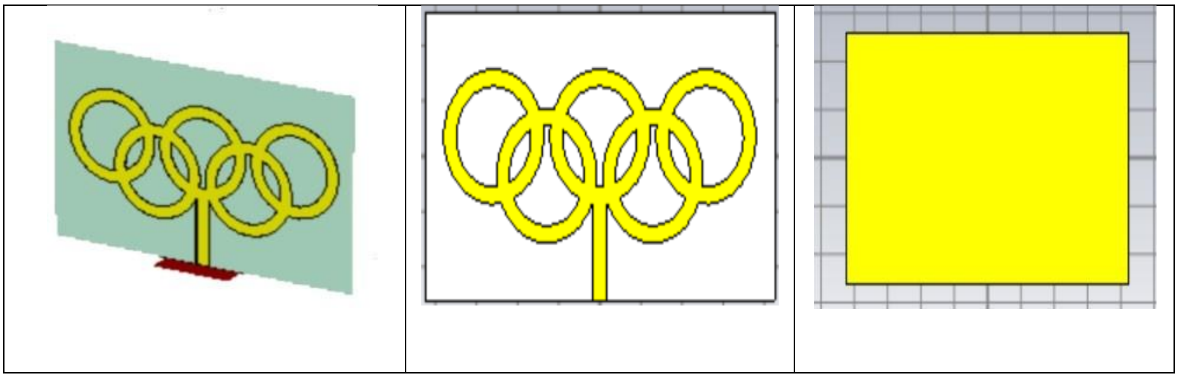
$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \epsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \qquad (1)$$

Where

$$F = \frac{8.791 \times 10^9}{f_r\sqrt{\epsilon_r}} \qquad (2)$$

Table 3.1: FR4 electrical properties

Parameters	Values
Dielectric Constant	4.7
Loss Tangent	0.03
Height of Substrate	1.6 mm



(a) (b) (c)

Figure 3.2: Antenna design (a) Perspective view (b) Front view (c) Back view

3.3.3 Design and Simulation in CST Studio

In the process to design the antenna, there is much software used in analyzing the output of the antenna that has been developed among them is CST Microwave Studio (CST). This software is often used in the development of known and reliable antennas in Research & Development (R&D). The program is capable of simulating high-frequency components in 3D EM. It is also capable of analyzing the structure of high-frequency devices such as filters and couplers, antennas, planes, and various layers easily and accurately. The software also provides a guide for new users and is very user-friendly.

3.3.3.1 Creating Project Template

After selecting the new template in the software, there are 5 options of applications area and workflows that needs to be selected depending on the type of antenna to be designed. In this study, MW & RF/Optical for application area and antennas for the workflows are selected as presented in Figure 3.3.

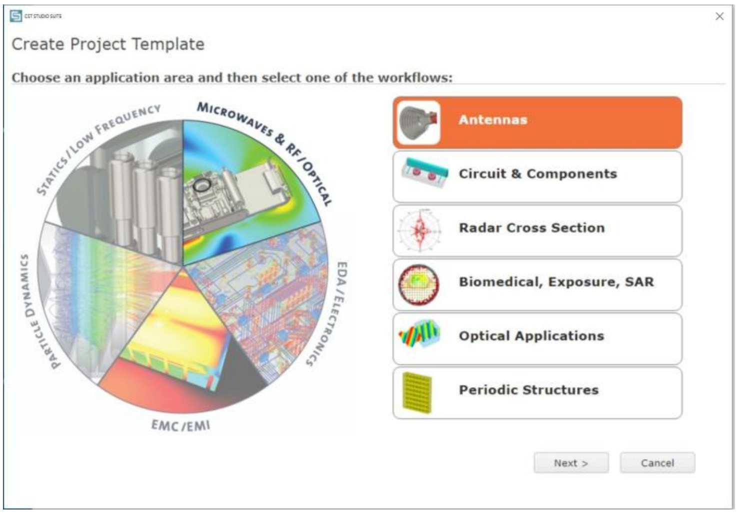


Figure 3.3: Applications areas and workflows

Then, planar is selected to design the microstrip patch antenna for this project as depicted in following Figure 3.4. By using this software also, there are various type of antenna can be design like wire antenna, RFID antenna and etc.

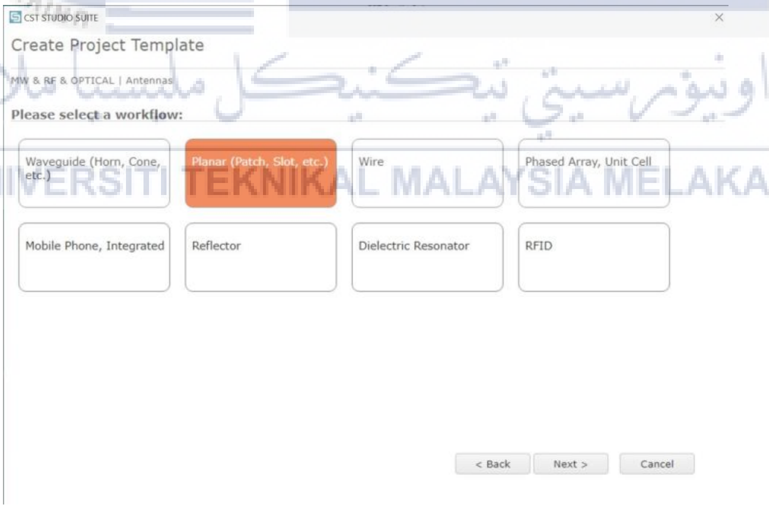


Figure 3.4: A workflows on antenna simulation

The next step in the microstrip patch antenna project is to select a solver. Silver will be checked as a patch for our antenna in this analysis. Since a broad frequency range is needed, we choose time domain for wideband and multiband antennas. Figure 3.5 shows that the option of solver are provided by the software.

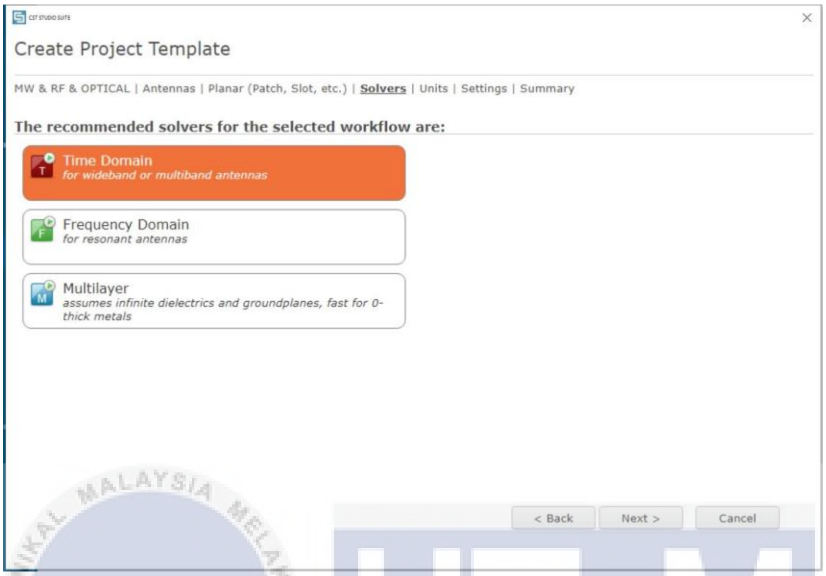


Figure 3.5: The option of solver

Then, we need to select the unit that will be used in the antenna design where the unit has been identified during the calculating process as Figure 3.6.

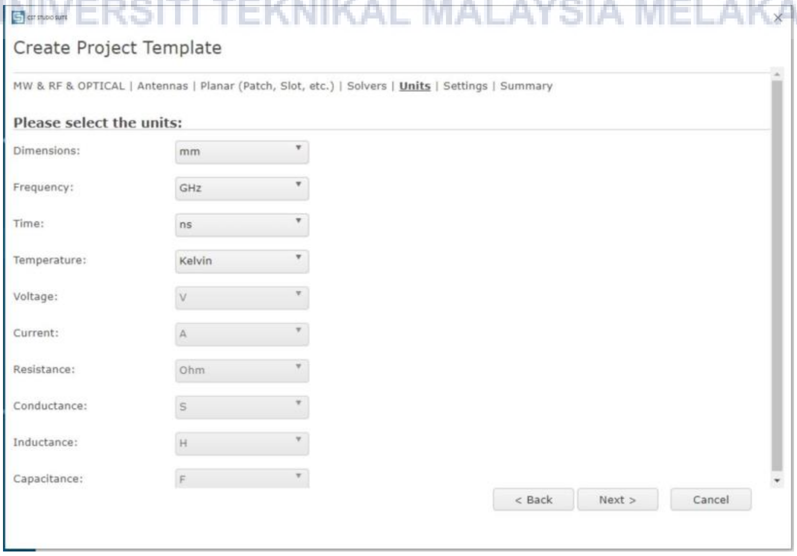


Figure 3.6: Selection units for antenna simulation

Another step in using these simulation methods is to choose the appropriate antenna frequency, as shown in Figure 3.7. The frequency range was set to 1 GHz for the minimum and 8 GHz for the maximum frequency while for the second design are from 2 GHz to 3 GHz to measure the parameters of the Silver patch antenna. All the parameters are needed to be monitored during the antenna simulation.

Figure 3.7: Frequency Selection

The last step before starting to design the antenna, the software will show a summarize of the choices has been made before as presented in Figure 3.8.

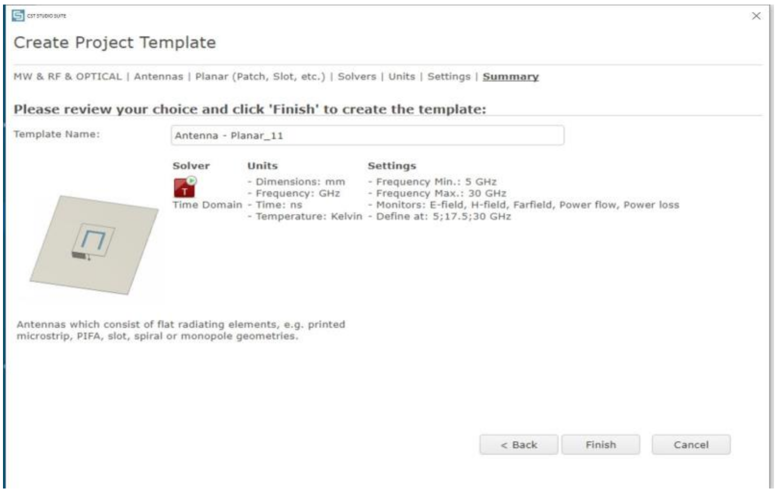


Figure 3.8: Review of the setting for simulation of antenna

3.3.3.2 Forming a Ground Plane

A brick is chosen to build a ground plane, and the related information is filled to it. The values filled are according to previous subtopic. A ground plane used copper content in this project like those seen in following Figure 3.9.

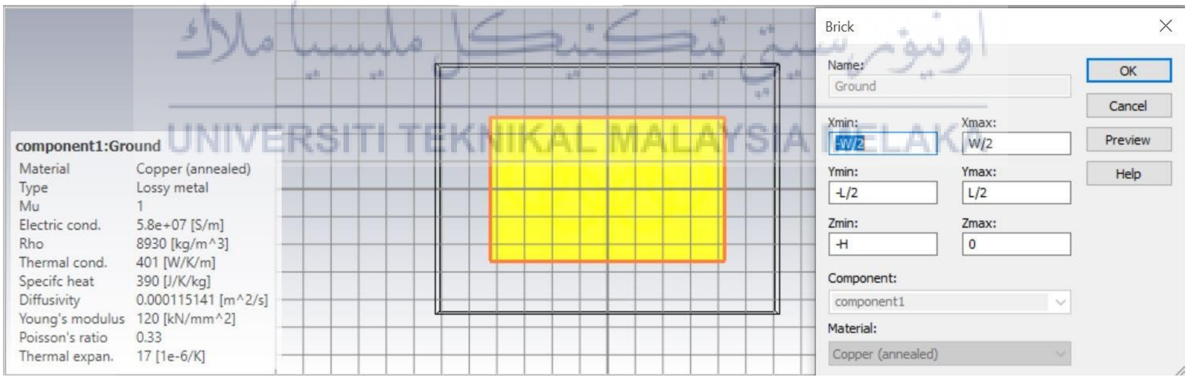


Figure 3.9: Forming a ground plane

3.3.3.3 Forming a Substrate

A brick is again chosen to build a substrate base, and the related specifics were necessary in that. The substrate plane employed polyimide content in this project such as in Figure 3.10 below:

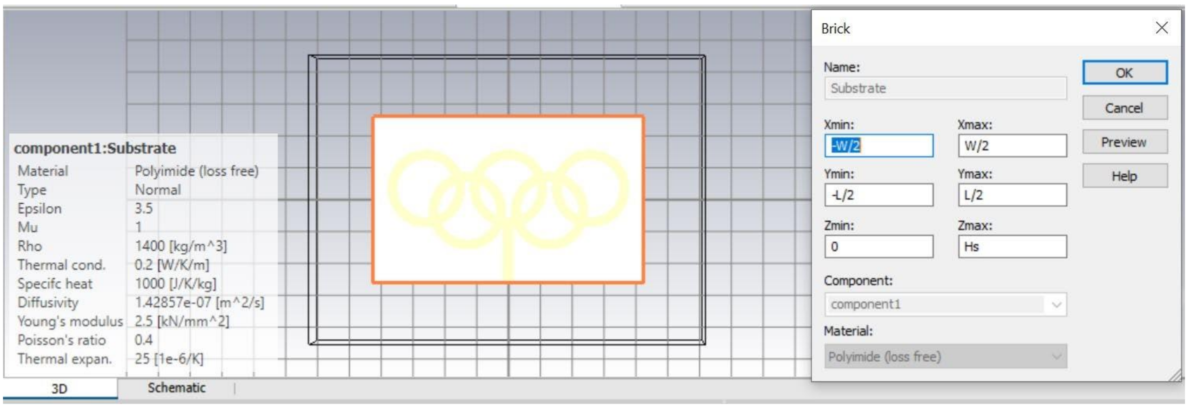


Figure 3.10: Forming a substrate plane

3.3.3.4 Forming Patch Plane

A cylinder is chosen to build Olympic Ring and the related specifics were necessary in that. The substrate plane employed polyimide content in this project such as in Figure 3.11 below:

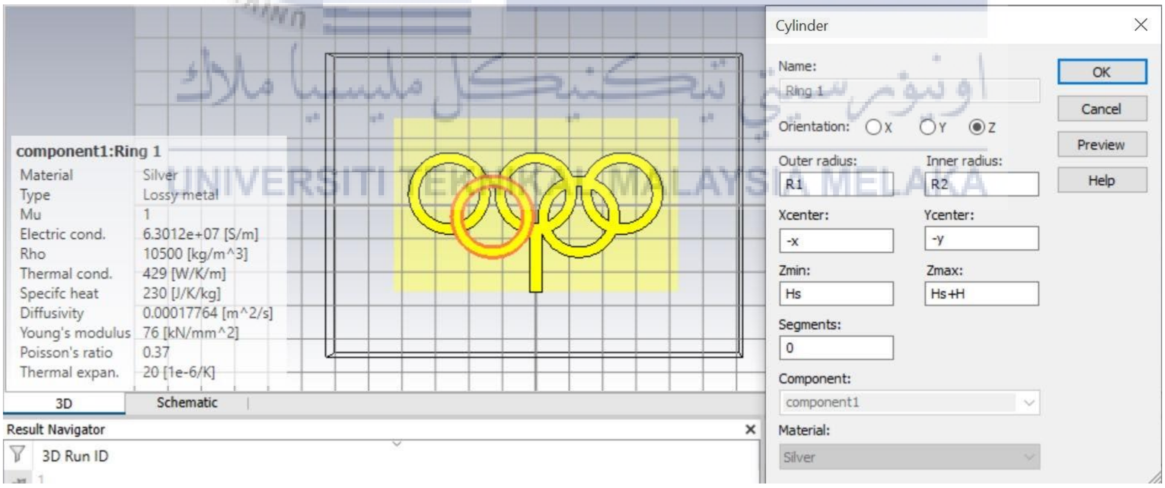


Figure 3.11: Forming a patch plane

3.3.3.5 Forming a Feed Line

A brick is chosen to build a feed line, and the related specifics were necessary in that. The substrate plane employed polyimide content in this project such as in Figure 3.12 below:

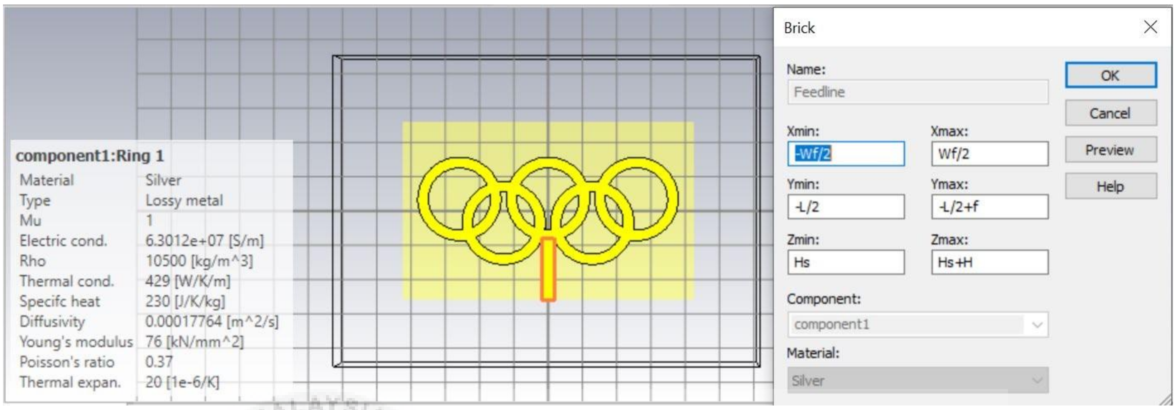


Figure 3.12: Forming a feed line

3.3.3.6 Optimization Parameter

After completing the design of the antenna using the parameters based on Table 3.2 and Table 3.3, the antenna must be simulated to obtain output such as return loss, gain, radiation pattern. If the output produced does not meet the requirements as described in chapter 2, parameters such as length, width, radius, thickness of substrate need to be varied by using sweep parameters on the CST software to obtain an appropriate output. Figure 3.13 shows the sweep parameter method carried out on the proposed antenna.

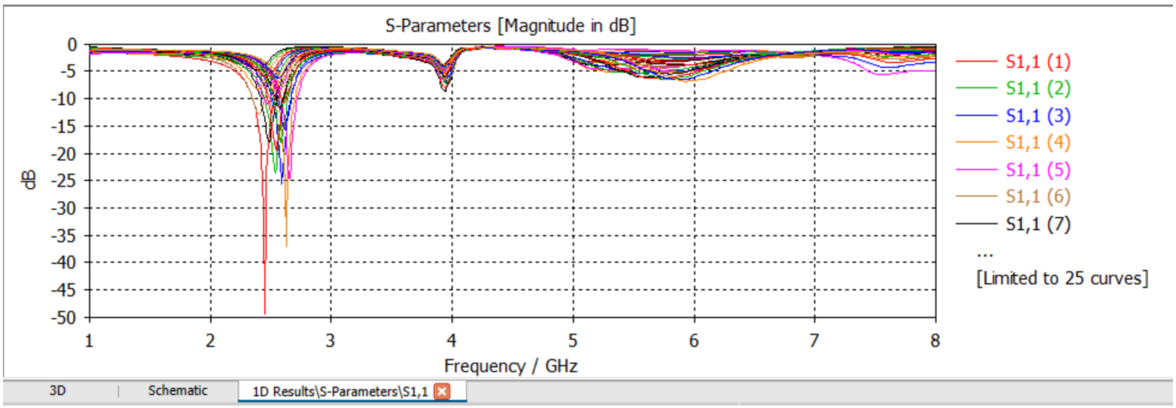
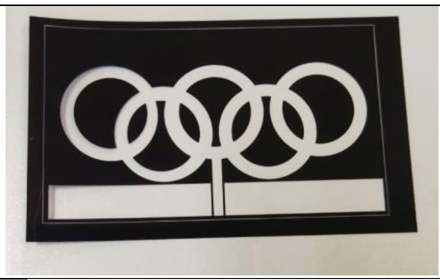


Figure 3.13: Parameter Sweep

3.4 Fabricate

After completing the simulation by obtaining the appropriate dimensions, the next step is to fabricate the proposed antenna. The proposed antenna will go through a fabrication process and several tests will be performed on the antenna to ensure that the antenna produced can work properly. Then, the data will be recorded and compared with the data from the simulation and analyzed. Table 3.2 show the antenna fabrication process

Table 3.2: Antenna fabrication process

No	Action	Description
1.		**Printing.** The proposed antenna design is printed on the transparent sheet by using the CorelDraw software. The top layer of the antenna which is the patch layer only will be printout.
2.		**Material Selection**. The selected material should be cut to the specified size and cleaned of debris, wax, oil as well as dust before the material is laminated.

3.		**Lamination**. A light-sensitive photoresist is applied to the board by using the lamination machine.
4.		**Printing.** Place the printout design on the photo resist layer and put it on the glass in the ultraviolet exposure machine. Ultraviolet light passes through a photo tool mask of the component design, transferring it to a photoresist.
5.		**Developing**. The process of removing the photoresist from the board to expose the copper. The board is placed in developing tank board holder and immerse in the developing tank. The board should be fully developed in 120 seconds. It is important to ensure the board is not over-developed. The developed image can look good, but over-developing can cause a reduction in the thickness of the resist, which could then break down at the etching stage. The photoresist is selectively removed to expose the copper.
6.		**Spray washing.** Use the spray wash tank immediately after the board is removed from the developer.
7.		**Etching.** The board is placed into the etching machine. The etching solution is sprayed onto the board to remove the exposed copper.

8.		**Stripping**. The remaining photoresist is removed to reveal the final etched component.
9.		**Drying**. Antenna that is ready to be dried using the drying oven.
10.		**Cutting**. Cut the board according to the selected size
11.		**Soldering**. The final process is soldering the port to the antenna feedline.

3.5 Graphene Conductive Ink Leather Antenna

After completing the fabrication on FR-4, the nextstep is to fabricate that leather antenna using graphene conductive ink on top of a leather. As for creating a graphene-based antenna on a leather involves several step that need to be done. Then, the data will be recorded and compared with the data from the simulation and analyzed. Table 3.3 show the graphene-based antenna on leather fabrication process.

Table 3.3: Leather antenna fabrication process

NO.	ACTION	DESCRIPTION
1.		**Prepare the Leather**. Clean the surface of the leather to ensure, it is free from dust and unwanted material.
2.		**Prepare the Graphene Ink**. Shake the ink well to ensure uniform consistency.
3.		**Screen Printing Machine**. The printing technique that uses a mesh screen with a light-sensitive emulsion, and a design is burned onto the emulsion.

4.		**Apply the graphene conductive ink**. The ink will go through the machine during the printing, and between below the machine got the leather.
5.		**Drying and repat coating**. Allow the ink to completely dry. Once its dry multiple the layers of ink to enhance the conductivity.
6.		**Attach Cooper Wire**. Securely attach the cooper wire to graphene coated area and add the ink to ensure a good electrical connection

7.		**Trim Excess Leather and Copper Wire.** To refine the antenna shape.

3.6 Antenna Measurements

3.6.1 S11 Parameter and VSWR Measurement

Experimental setup is shown in Figure 3.14 for the determination of the return loss and VSWR of the proposed antenna. The designed antenna is connected to the SWR Bridge and the network analyzer. This is attached to the available network analyzer of range 0-3 GHz. This analyzer determines the return loss of the designed microstrip antenna and demonstrate the return loss versus frequency.

Figure 3.14: Process to measure S11 Parameter using VNA Equipment

3.6.2 Radiation Pattern Measurement

Anechoic chambers are rooms designed to absorb the reflections of electromagnetic radiation and to minimize interfering energy disturbances from external spurious sources. Such chambers are used to measure the performance of the Antenna Under Test (AUT), in particular gain and pattern characteristics. Figure 3.15 show the radiation pattern measurement in anechoic chamber.

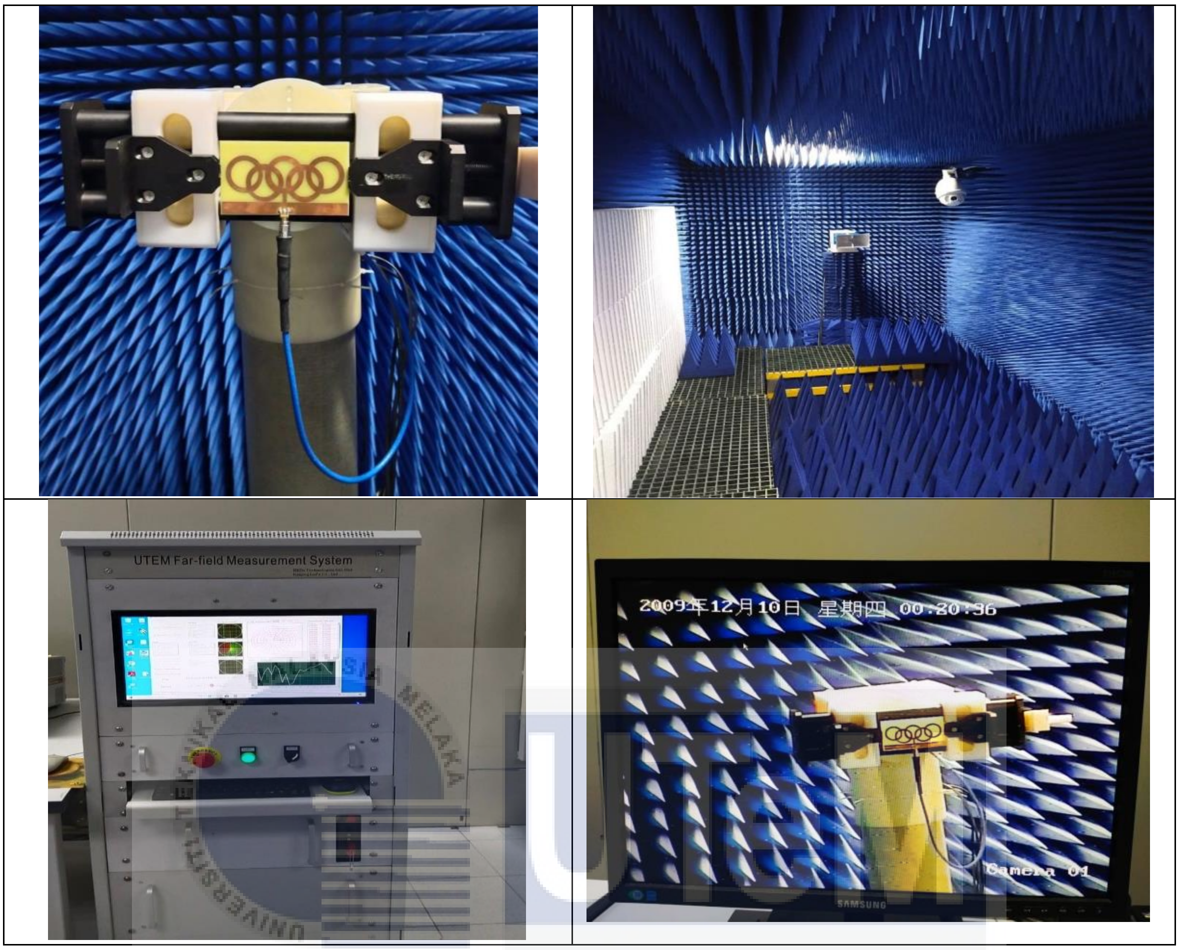


Figure 3.15: Radiation Pattern Measurement In Anechoic Chamber

3.6.3 Gain Measurement

The two-antenna method is a measurement technique that employs the Friis transmission equation to determine the far-field gain of an antenna. This method requires two sample of antennas namely horn antenna and antenna under test which is the proposed antennas. The two antennas are separated by a distance at 1 meter and are at the same height from the ground, facing each other. The radiating antenna will be horn antenna, while the receiving antenna will be the antenna under test. The antennas should be properly matched in terms of impedance and polarization. The power delivered from transmit antenna to receiver antenna was measured using a Rohde & Schwarz HF906 portable spectrum analyzer. Figure 3.16 show the setup of the two-antennas method.

Figure 3.16: Gain Measurement Setup

3.7 Material

3.7.1 Leather

The tanning, or chemical treatment, of animal skins and hides to stop them from decomposing results in leather, a robust, pliable, and long-lasting material. Cattle, sheep, goats, horses, buffalo, pigs, hogs, and aquatic creatures like alligators and seals are the most prevalent sources of leather.

Leather lasts for decades and is used to produce a wide range of products, such as apparel, shoes, purses, furniture, tools, and sporting goods. The production of leather dates back over 7,000 years, and China and India are currently the world's two biggest producers. Substrate materials is one of factors that affect the performance of the antenna. The parameters that need to be considered are its thickness, dielectric constant permittivity (εr) and loss tangent ($tan\ \delta$). It plays a significant role in determining the size and the resonant frequency as well as the bandwidth of an antenna. Textile, in general, have a very low relative permittivity (in comparison to conventional rigid substrate materials for electronic applications such as FR-4) as they are very porous fabrics. By increasing the dielectric constant, it will be decreasing the size of an antenna but lowers the bandwidth and its efficiency of the antenna. While, by decreasing the dielectric constant it will increasing the bandwidth but with an increase in size. As the performance comparison of the proposed antenna, the dimension of the antenna is obtained from the optimized process by taking the sequences of values using the FR-4 material as initial dimension. The values will be simulated by feature of parameter sweep in computer simulation technology (CST) software. The parameters such as feed width, patch length, and radius of slotted antenna dimensions are set as to execute the series of simulations in order to improve the performance of the proposed antenna.

Figure 3.17: Leather used in this project

3.7.2 Graphene Conductive Ink

Graphene Conductive Ink is a kind of ink that has a single layer of carbon atoms organized in a hexagonal lattice, known as graphene. Graphene has remarkable mechanical strength, electrical conductivity, and flexibility, rendering it a very promising material for a range of uses, such as conductive coatings, sensors, and electronic devices. It is also an extraordinary high electrical and thermal conductivity that have been used in this project. The barrier layer of performance can also prevent the permeation of water and oxygen which can be lead to corrosion and oxidation.

Graphene Conductive Ink high stability due to its inert behaviors to chemical attack. The process involves dispersing graphene in a liquid carrier, which can be either water or an organic solvent, to create a printable ink. The composition of graphene conductive ink can vary based on the specific application and the desired properties of the final printed material. The primary conductive element of the ink is graphene, which is a single sheet of carbon atoms organized in a hexagonal lattice. Several techniques may be used to create graphene, including as reduction of graphene oxide, liquid-phase exfoliation, and chemical vapors deposition (CVD). To enhance the qualities of the ink, such stability, adhesion, and printability, additives can be added to the formulation. Binders, stabilizers, and surfactants are a few types of additives. It is true that graphene has exceptional electrical conductivity, and when applied as an ink, it may serve as a conductor in a variety of applications. For applications such as smart clothing or health-monitoring devices, graphene conductive ink can be utilized to print circuits on textiles or flexible materials.

The inherent electrical conductivity of graphene guarantees minimal resistance in printed circuits. Electronic components that are elastic and bendable can be made possible by the ink's ability to take on the shape of flexible substrates. In conclusion, graphene conductive ink takes advantage of graphene's special electrical qualities to act as a conductor in the creation of electronic parts, sensors, and flexible circuits. The spectrum of applications for graphene-based conductive inks is expected to increase with further developments in material science and production processes.

Figure 3.18: Graphene Conductive Ink

Figure 3.19: Graphene Conductive Ink on top of leather

CHAPTER 4

RESULTS AND DISCUSSION

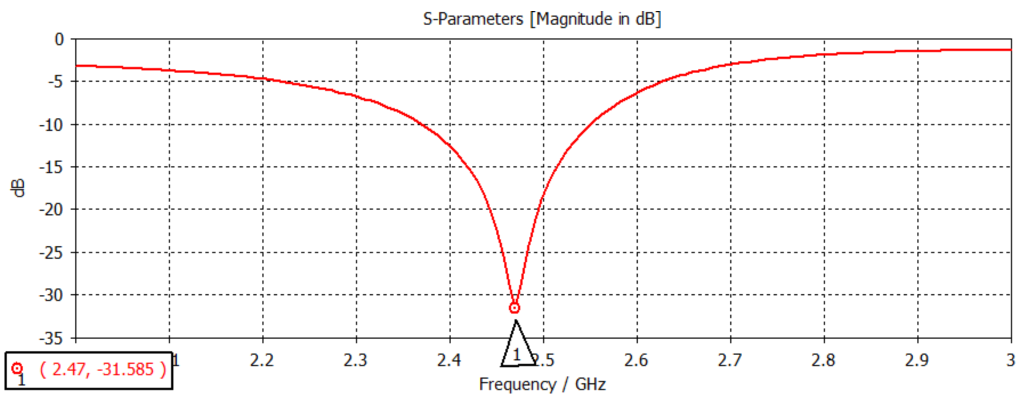
4.1 Result and Analysis

The proposed wearable antenna attributes in terms of resonant frequency (GHz), return loss (dB), impedance bandwidth (GHz), Voltage Standing Wave Ratio (VSWR), total efficiency (dB), directivity (dBi) and gain (dBi), and are being described in this portion.

4.1.1 Return Loss and Bandwidth

Based on the result for one of the parameters that were observed is return loss and also known as S11. The value of return loss for copper in Figure 4.1 (a) is -31.585 dB achieved at 2.47 GHz. This design is having a bandwidth of 182.04 MHz for S11 $\leq$ -10dB ranging from 2.3687 to 2.5507 GHz. For the graphene return loss is -21.4 dB at 2.42 GHz and its bandwidth is 170 MHz ranging from 2.33 to 2.4 GHz as Figure 4.1 (b).

(a)



(b)

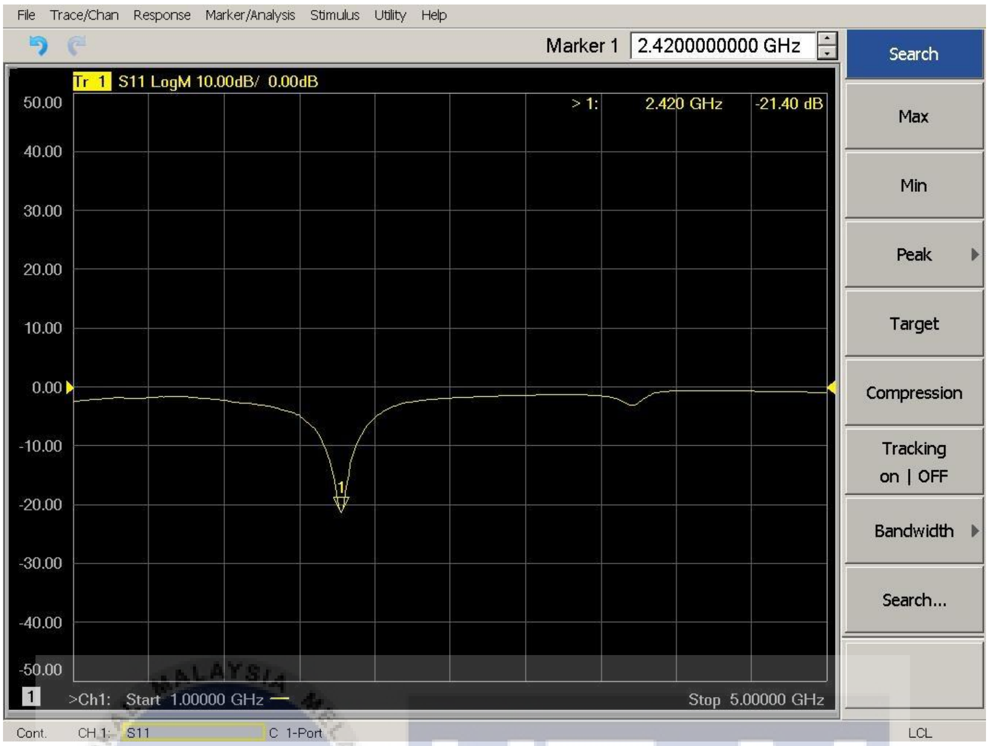


Figure 4.1: Return Loss Ouput (a) Copper (b) Graphene

From the result, show that copper and graphene obtain a reasonable valuefor the return loss which is it should be at least -10 dB in order to execute effectively. This means that incident power is transmitted to the source by 10%. If the rate higher than -10 dBwhich is between 0 dB to -10 dB, this implies that the antenna operates with less return lossor has strong RF efficiency. The bandwidth increases as the substrate thickness increases, but the antenna size decreases and the centre operating frequency drifts away from the ideal resonance frequency. Furthermore, when the patch size increases, the wearable design's resonance frequency changes rapidly. Figure 4.2 show the comparison between copper and graphene antenna. The difference of shift between copper and graphene antenna results is due to the sensitivity of microstrip and the factors that effect on the microstrip suchas temperature and fabrication process.

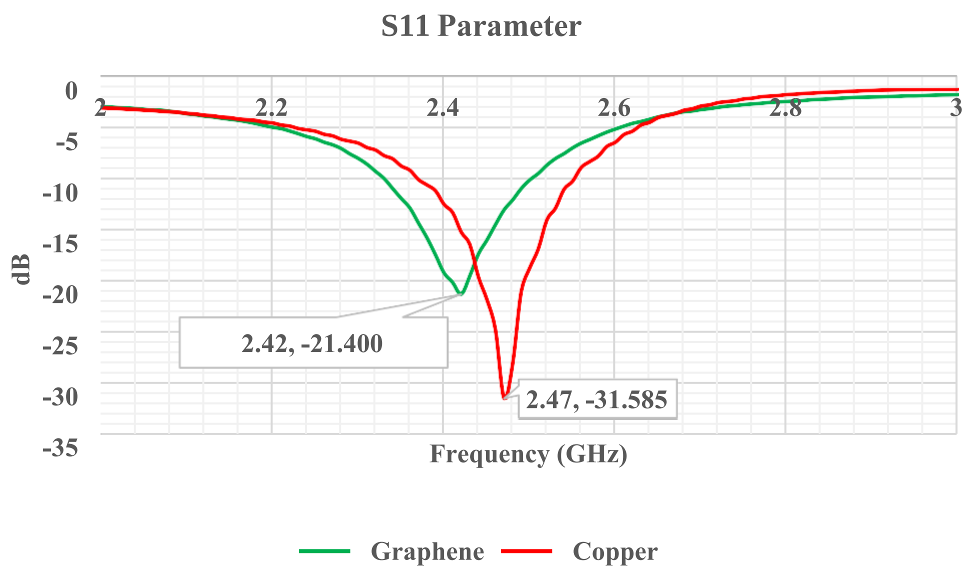


Figure 4.2: Return Loss Comparison

4.1.2 Voltage Standing Wave Ratio (VSWR)

The figure 4.2 shows the results of VSWR for simulated for the proposed antenna. It is found that the copper antenna meet the requirementfor the VSWR which is below than 2. Figure 4.2 (a) show the VSWR output for the copper which achieved value is 1.0541 at 2.47 GHz.

(a)

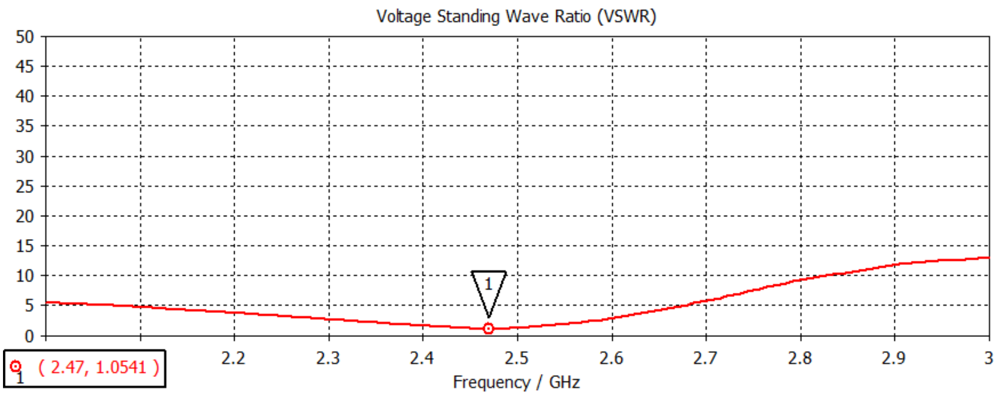


Figure 4.3: VSWR output (a) Copper

(b)

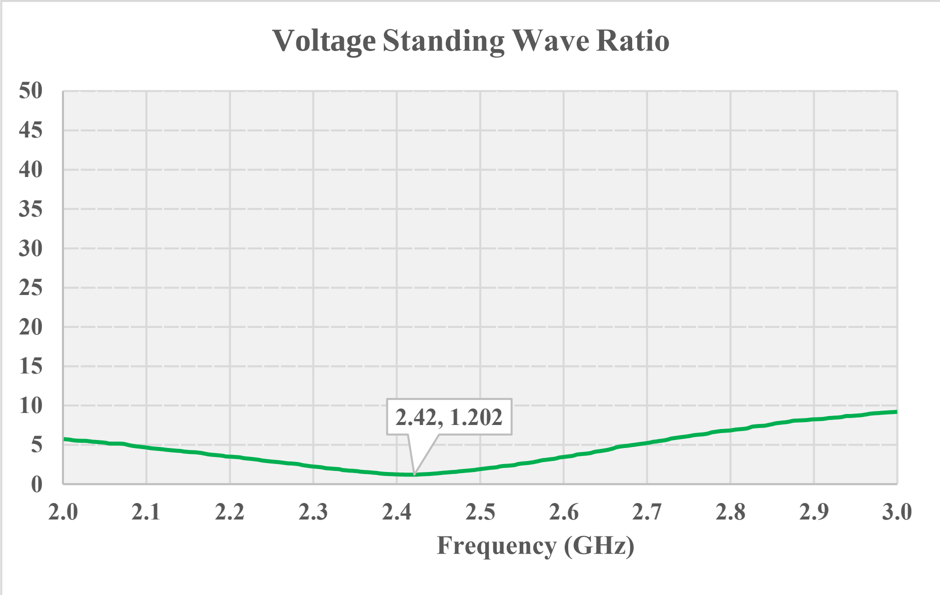


Figure 4.3: VSWR output (a) Copper (b) Graphene

The VSWR is a reflection coefficient function that shows the power reflected from the antenna. The VSWR values are slightly more than 1, suggesting that a small power is reflected from the antenna in each of these designs. The smaller the VSWR, the better the transmission line suits the antenna and the more power is transmitted to the antenna. It also will have less loss and transmitting signal to the antenna. Figure 4.4 show the comparison between copper and graphene antenna.

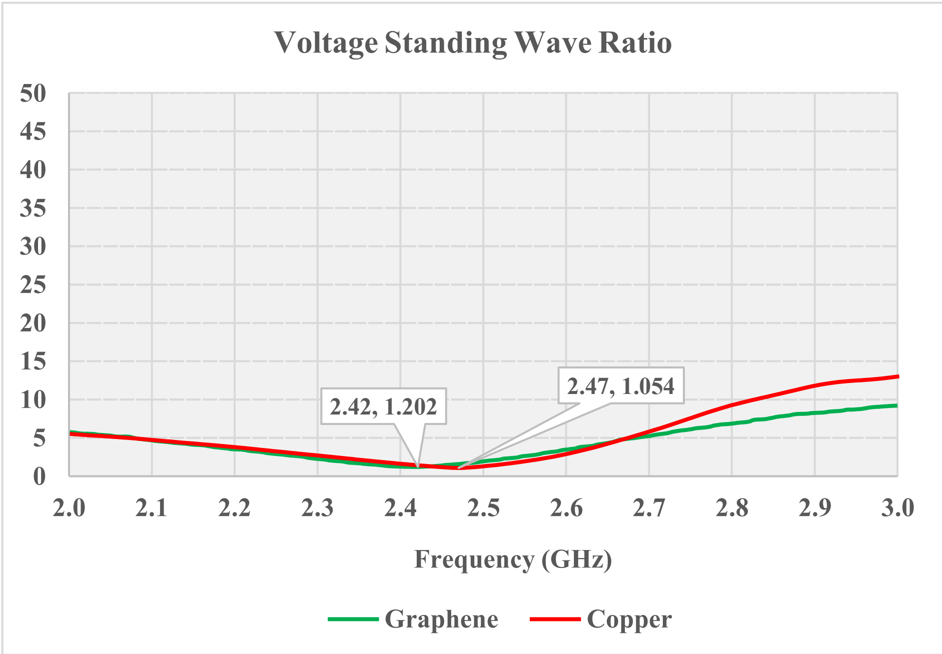


Figure 4.4: VSWR Comparison

4.1.3 Efficiency

The simulation value of a total efficiency produced for simulated antenna is -0.032 dB at 2.47 GHz as seen in Figure 4.3. According to the study, the main reasons influencing the overall performance of the microstrip patch antenna that makes it positive or negative, relies on the permittivity and thickness of the dielectric substrate and even the conductivity of the ground plane. As in this analysis, Fabrics substrate was employed with a dielectric constant of 4.4 with such a thickness of 1.6 (Hs). Fabrics substrate is used for these designs rather than other substrate since it can be used as a lightweight substrate for microstrip antennas construction owing to its consistent dielectric substrate. In addition, it can be found that the simulated overall performance of both antennas is very constant in the desired frequency range.

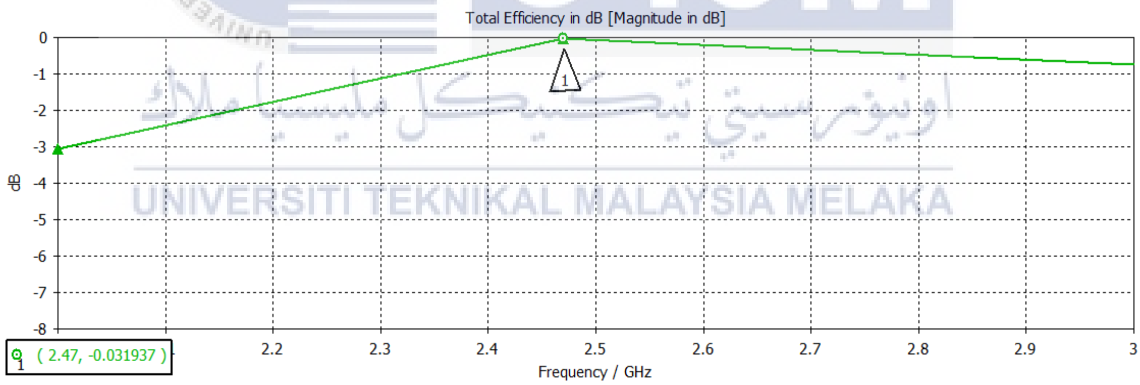
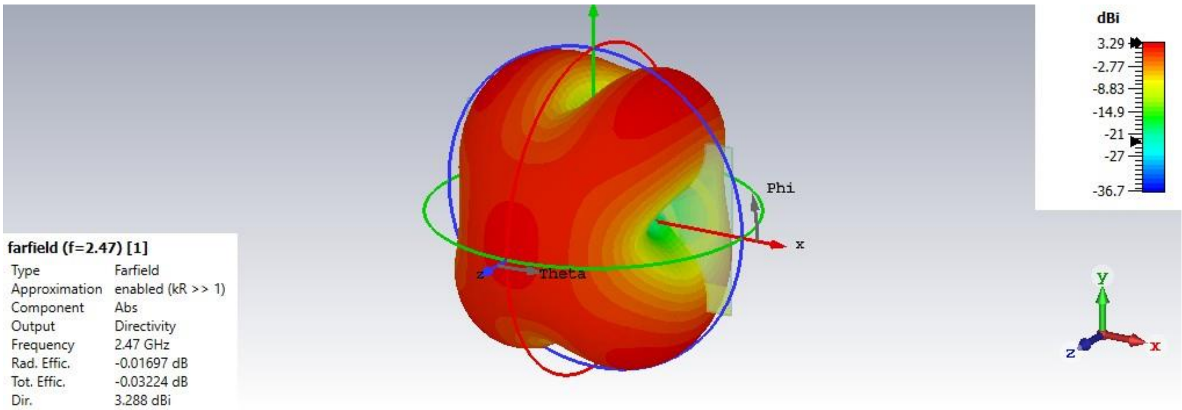


Figure 4.5: Total efficiency output for copper antenna

4.14 Radiation Pattern of Directivity

The directivity for antenna provides 3.29 dBi at 2.47 GHz as seen at Figure 4.4 (a). From the shape of the radiation pattern, it is clearly can be seen the designed antennas are omnidirectional antennas. As in the shape of radiation pattern we can conclude these antennas have one main lobe and multiple minor lobes. The antenna's 3-dB beam width or half-power beam width is usually specified for each of the main planes. The 3-dB beamwidth in the figure is shown as the angle in the 2D polar plot between the two blue lines. In Figure 4.4 (b), the 3-dB beamwidth in this plane about 80 degrees. Wide beam width antennas usually have low gain and narrow beam width antennas appear to have higher gain. The greater the directivity, the more the beam radiated by an antenna is concentrated or centered. A greater directivity also indicates that the beam can pass faster.

(a)



(b)

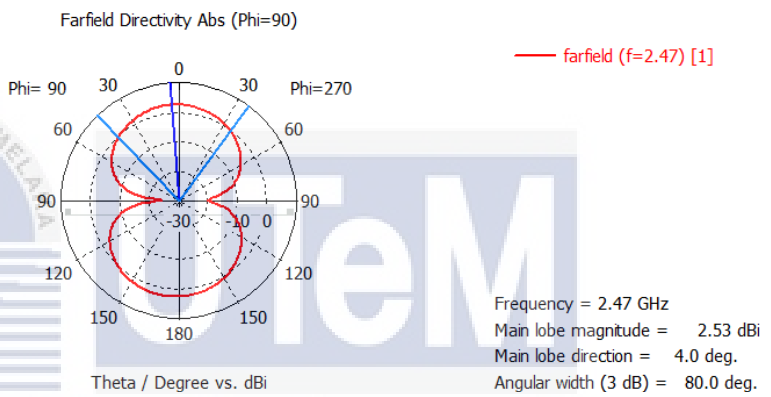


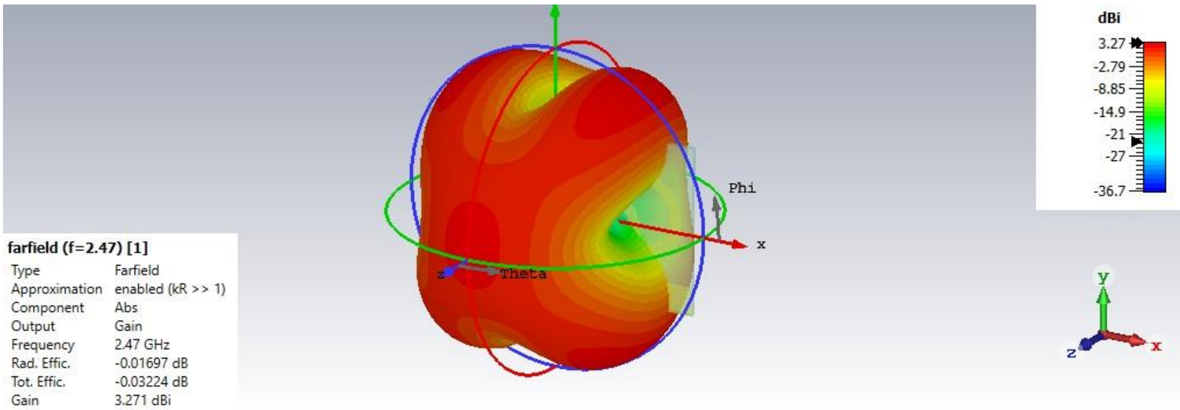
Figure 4.6: Radiation pattern of directivity for copper antenna (a) 3 D view (b) 2D view

4.1.5 Radiation Pattern of Gain

The term Antenna Gain describes how much power in the direction of peak radiation is transformed to that of an isotropic source. Antenna gain is closely related to directivity, but it is also a measure that takes into account the antenna's efficiency. In order to obtain other desirable features, such as a low side-lobe level or broad bandwidth output, antenna efficiency is often sacrificed.

Figure 4.5 demonstrate the gain of antenna in 3D and 2D for the proposed antenna. From the figure shows that the copper antenna yielded 3.27 dBi at 2.47 GHz while the beamwidth of the antenna 80 degree with the main lobe directed at angle of 4 degree.

(a)



(b)

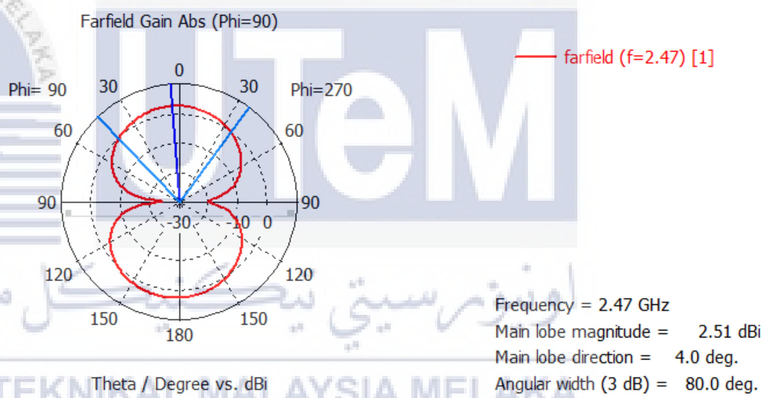


Figure 4.7: Radiation Pattern Of Gain For Copper Antenna (a) 3D View (b) 2D View Figure

4.6 show the radiation pattern for the graphene antenna which is the data from the measurement were imported to the excel to generate the graph. The radiation pattern of the graphene antenna is a omnidirectional which is good agreement with the copper antenna. Figure 4.7 show the graph gain versus frequency. The graphene antenna achieved the gain value at 1.014 dB at resonance frequency 2.42 GHz. It is show the gain value of the graphene antenna decreased to the 67% compare to the copper antenna.

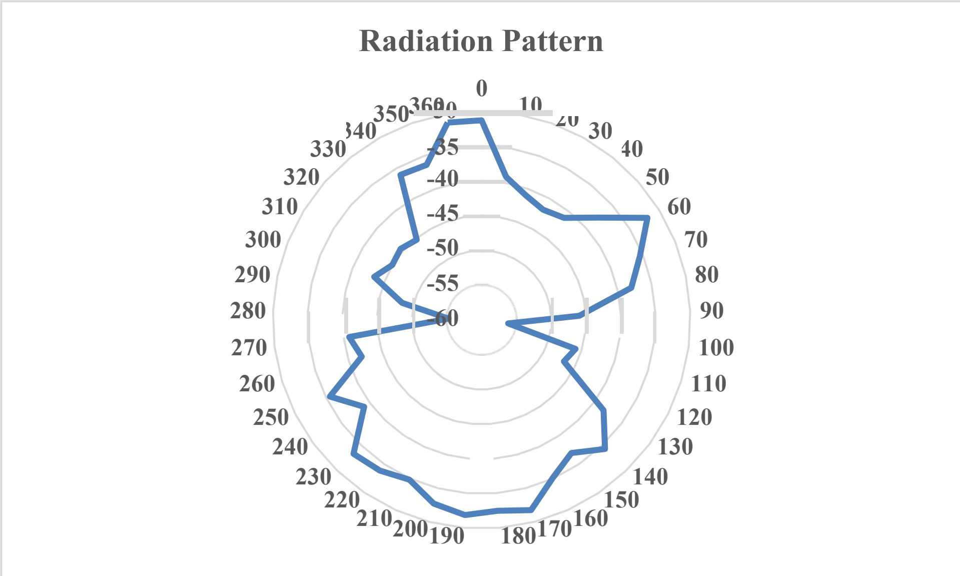


Figure 4.8: Radiation pattern for graphene antenna

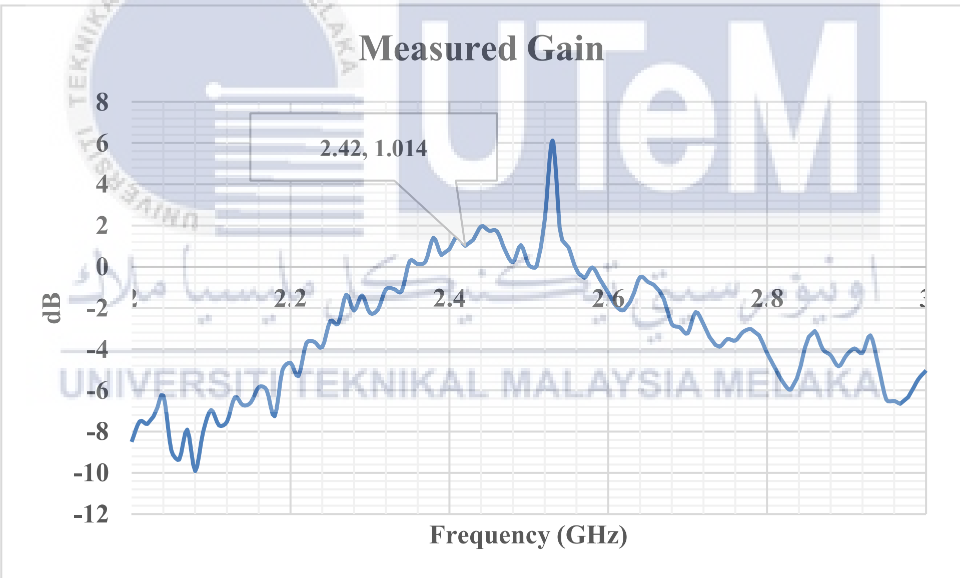


Figure 4.9: Gain graph for graphene antenna

4.2 Summary

Overall, the simulated and the measured result of the proposed antenna has a better performance in term of the return loss, bandwidth and VSWR. Table 4.1 shows a comparison between copper and the graphene antenna. Based on the table, the antennas that have been measured show a decrease in terms of frequency, bandwidth, return loss, VSWR and gain. However, the proposed antenna can still operate well as discussed earlier but the antenna gain needs to be further improved so that the antenna can operate more better. Among the factors that cause this situation is the cutting of the antenna board is not accordingto the size as in the simulation. After the board cutting process, the antenna board needs to be sanded using sandpaper and remeasured until it gets the size like the simulation. From this situation, the proposed antenna size is larger than the simulated antenna size. In addition,environmental factors also affect the result produced by the antenna because the microstrip antenna is a sensitive antenna.

Table 4.1 Comparison between simulated and measured antenna

Parameter Analysis	Copper	Graphene	Difference Percentage (%)
Resonant Frequency (GHz)	2.47	2.42	2.02
Bandwidth (MHz)	182.64	170	7.44
Return Loss (S11) (dB)	-31.585	-21.40	32.25
VSWR	1.054	1.202	12.31
Total Efficiency (dB)	-0.032	-	-
Directivity (dBi)	3.070	-	-
Gain (dBi)	3.045	4.059	24.98

4.2 Summary

At the end of this Chapter 4 of the project research paper is all about the study analysis and finding. As for this Olympic ring antenna need a lot more improvement by getting and accurate result or suitable result. This also proof how the study can be used in the real world and by providing in detail on how the project can be done properly and precisely.

CHAPTER 5

CONCLUSION

5.1 Conclusion

As for the conclusion, the project on the development of a wearable leather antenna made from graphene conductive ink for advanced communication applications represents a significant advancement in the field of wearable technology. This project successfully combines the unique properties of graphene with the comfort and versatility of leather, resulting in a wearable antenna with numerous benefits and potential applications.

The project's key achievement lies in the successful integration of graphene conductive ink into a leather material, creating an antenna that offers excellent conductivity, flexibility, and durability. Graphene's exceptional electrical properties, such as high conductivity and low resistance, make it an ideal material for antenna applications. The use of conductive ink enables precise and efficient antenna design, ensuring optimal signal transmission and reception.

The incorporation of the antenna into a wearable leather material further enhances its usability and acceptance. Leather is widely recognized for its comfort, durability, and aesthetic appeal. By integrating the antenna technology into leather, the wearable device becomes both functional and fashionable, making it suitable for a variety of advanced communication applications.

The project's implications for advanced communication applications are significant. The wearable leather antenna can be seamlessly integrated into various items, such as clothing, accessories, or standalone devices, enabling continuous and unobtrusive communication in diverse contexts. This technology holds tremendous potential for industries such as healthcare, sports, security, and more, where reliable and discreet communication is crucial.

Lastly, this project on the development of a wearable leather antenna made from graphene conductive ink for advanced communication applications showcases the successful integration of cutting-edge materials and fabrication techniques. The resulting wearable antenna offers exceptional conductivity, flexibility, and comfort, making it a promising solution for various industries. Further research and development in this field can lead to advancements in wearable technology, transforming the way we communicate and interact with our environment.

5.2 Recommendation

In many industries, such as the military, medical applications and more, these wearable textile antennas are widely used. Therefore, research on microstrip antennas needs to be continued to support the industry. Therefore, the same study can be conducted using different techniques likely to produce more efficient antenna performance. This is because there are still various techniques that can be used to produce microstrip antennas according to the desired specifications. In addition, we can also use some other designs such as different shapes or different configurations to improve the performance of the antenna.

Although the proposed antenna is physically ready and has undergone tests on the VNA for measurement of S11 parameters, VSWR and gain, some measurements need to be carried out to ensure that the proposed antenna can operate properly. One of the measurements that needs to be carried out is that the Specific Absorption Rate (SAR) needs to be calculated for each model and its specifications need to comply with the specifications set by either IEEE which is 1.6 W/kg for 1g of tissue or International Commission on Non-Ionizing Radiation Protection (ICNIRP) which is 2 W/kg for 10g of tissue. SAR evaluation involves several stages, first the antenna must be simulated at a voxel platform in CST Microwave Studio to provide an initial understanding.

In addition, measurements for flexible wearable antennas need to be done with different bending positions. This is to ensure the performance of the antenna in real life applications reaches set standards, especially when the antenna is used on a foldable body part such as an arm.

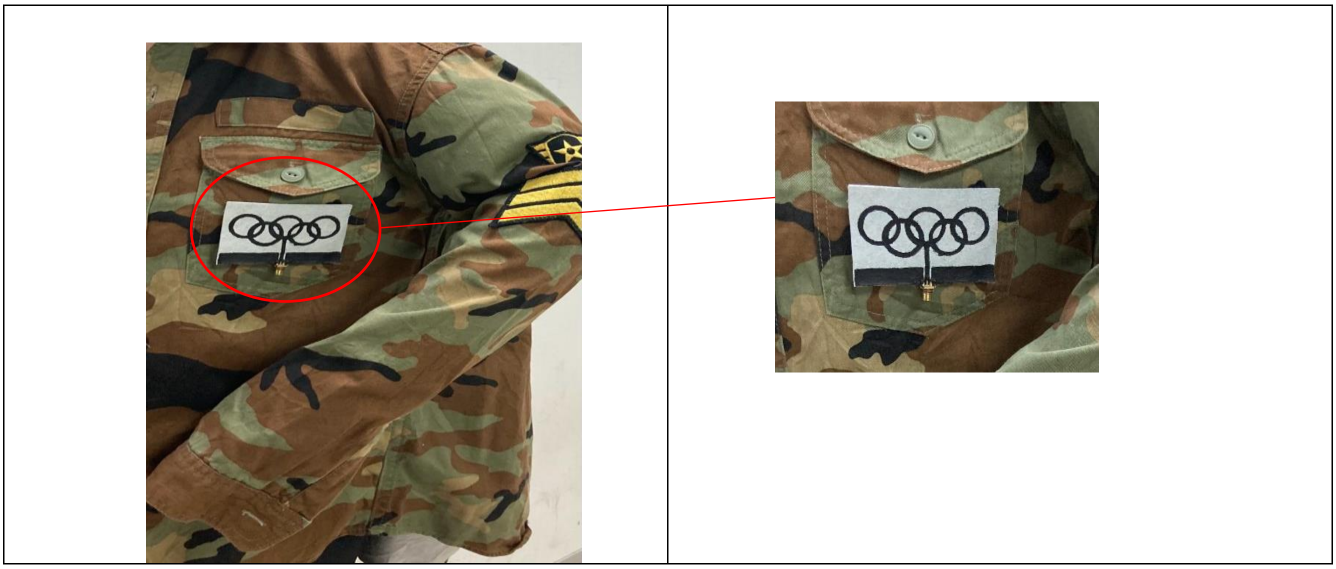
5.3 Project Potential

In the future, the potential for the development of this project is as follows:

a. This project has good potential to be commercialized as we are heading towards IR 4.0 where a lot of wireless equipment will be used and created on.

b. This project also suitable use in various sectors such as health care application for glucose monitoring, wearable thermometer; entertainment application for smartwatches, LED dress; rescue and security application for trackers, helmet and many more.

c. In military, military personnel in the battlefield need a lot of individual equipment such as weapons, communication equipment, bags containing clothes, food, ammunition and so on, as well as other equipment. This will burden the military personnel as well as interfere their performance in carrying out the mission that has been set. This project will reduce the burden of military personnel where it is light and small in size attached on military uniforms and can use as tracking device or communication between units.



REFERENCES

[1] "Antenna." *Merriam-Webster.com Dictionary*, Merriam - Webster, https://www.merriam-webster.com/dictionary/antenna. Accessed 13 Apr. 2021.

[2] "IEEE Recommended Practice for Measurements and Computations of Radio Frequency Electromagnetic Fields With Respect to Human Exposure to Such Fields,100 kHz-300 GHz," in IEEE Std C95.3-2002 (Revision of IEEE Std C95.3-1991) , vol., no., pp.i-126, 2002, doi: 10.1109/IEEESTD.2002.94226.

[3] Dhupkariya, Seema & Singh, V. (2015). Textile Antenna for C-Band Satellite Communication Application. Textile Antenna for C-Band Satellite Communication Application.

[4] R. Khan and M. Mahtab Alam, "Body-to-Body Communication: Applications, System Design Aspects and Performance Evaluation," 2018 12th International Symposium on Medical Information and Communication Technology (ISMICT), Sydney, NSW, Australia, 2018, pp. 1-2, doi: 10.1109/ISMICT.2018.8573721.

[5] F. Di Franco et al., "The effect of body shape and gender on wireless Body Area Network on-body channels," IEEE Middle East Conference on Antennas and Propagation (MECAP 2010), Cairo, Egypt, 2010, pp. 1-3, doi: 10.1109/MECAP.2010.5724195.

[6] P. Singh, D. C. Dhubkarya, and A. Aggrawal, "Design and Analysis of Annular Ring Slot MSA for wireless and UHF Applications," vol. 2013, no. Cac2s, pp. 541–544, 2013.

[7] A. Sabban, "Small New Wearable Antennas for IOT, Medical and Sport Applications," 2019 13th European Conference on Antennas and Propagation (EuCAP), Krakow, Poland, 2019, pp. 1-5.

[8] G. Monti et al., "Textile Wearable Antenna for Firefighters Positioning," 2019 URSI Asia-Pacific Radio Science Conference (AP-RASC), New Delhi, India, 2019, pp. 1-4, doi: 10.23919/URSIAP-RASC.2019.8738181.

[9] B. Rama Sanjeeva Reddy and A. Amulya Kumar, "Dual Band Circular Polarized Wearable Antenna for Military Applications," 2018 International CET Conference on Control, Communication, and Computing (IC4), Thiruvananthapuram, India, 2018, pp. 220-223, doi: 10.1109/CETIC4.2018.8530936.

[10] Y. Hao, "Antennas and propagation for body centric wireless communications," 2011 IEEE International Conference on Microwave Technology & Computational Electromagnetics, Beijing, China, 2011, pp. 3-3, doi: 10.1109/ICMTCE.2011.5915576.

[11] B. R. Kumar, “Design and Analysis of Circular Ring Microstrip Antenna,” *Glob. J. Res. Eng.*, vol. 11, no. 1, 2011.

[12] U. Kumari, T. V Nahar, A. Mewara, L. Narayan Balai, and A. Professor, “Circularly Polarized Ultra Wide Band Ring Shaped DGS Microstrip Antenna for Wireless Applications,” *Int. Res. J. Eng. Technol.*, vol. 9001, no. July, p. 861, 2008, [Online]. Available: www.irjet.net.

[13] P. Verma, “Ring Shape Microstrip Antenna for Multi-band Response,” vol. 5, no. 01, pp. 5–8, 2017.

[14] H. Lee, J. Tak and J. Choi, "Wearable Antenna Integrated into Military Berets for Indoor/Outdoor Positioning System," in IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 1919-1922, 2017, doi: 10.1109/LAWP.2017.2688400.

[15] H. A. Mashaghba et al., "Bending Assessment of Dual-band Split Ring-shaped and Bar Slotted All-Textile Antenna for Off-body WBAN/WLAN and 5G Applications," 2020 2nd International Conference on Broadband Communications, Wireless Sensors and Powering (BCWSP), 2020, pp. 1-5, doi: 10.1109/BCWSP50066.2020.9249403.

[16] P. A. V. Sri et al., "Analysis of wideband circular ring with rectangular patch antenna for airborne radar application," 2017 International conference of Electronics, Communication and Aerospace Technology (ICECA), 2017, pp. 459-461, doi: 10.1109/ICECA.2017.8203726.

[17] W. Chaihongsa and C. Phongcharoenpanich, "Triple band textile antenna using split annular ring," 2017 International Symposium on Antennas and Propagation (ISAP), 2017, pp. 1-2, doi: 10.1109/ISANP.2017.8228770.

[18] Y. Zhang, J. Liu, Z. Liang, and Y. Long, “A wide-bandwidth monopolar patch antenna with dual-ring couplers,” *Int. J. Antennas Propag.*, vol. 2014, pp. 1–7, 2014, doi: 10.1155/2014/980120.

[19] P. Divyabharathi, M. Abirami, S. Puvaneshwari, and N. Vikram, “Ring structured patch antenna for wideband applications,” *Int. J. Innov. Technol. Explor. Eng.*, vol. 8, no. 5s, pp. 358–360, 2019.

[20] K. Nadeem, I. Nadeem and Z. Ahmed, "Performance Analysis of a Square Fractal ring Antenna for Broadband Application," 2019 International Conference on Communication Technologies (ComTech), 2019, pp. 36-40, doi: 10.1109/COMTECH.2019.8737796.

[21] B. Moradi, M. Martínez, R. Fernández-García and I. Gil, "Study of Double Ring Resonator Embroidered Wearable Antennas for Microwave Applications," 2019 13th European Conference on Antennas and Propagation (EuCAP), 2019, pp. 1-5.

[22] M. I. Ahmed, M. F. Ahmed and A. A. Shaalan, "CPW ring wearable antenna on leather material for BAN applications," 2017 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, 2017, pp. 589-590, doi: 10.1109/APUSNCURSINRSM.2017.8072337.

[23] S. Ma, L. Ukkonen, L. Sydänheimo and T. Björninen, "Wearable E-textile split ring passive UHF RFID tag: Body-worn performance evaluation," 2017 IEEE Asia Pacific Microwave Conference (APMC), 2017, pp. 166-168, doi: 10.1109/APMC.2017.8251404.

[24] E. Sandi, B. Maruddani and N. Khairunisa, "Complementary Split Ring Resonator on the Ground Plane for Wearable Antenna," 2020 International Conference on Radar, Antenna, Microwave, Electronics, and Telecommunications (ICRAMET), 2020, pp. 66-69, doi: 10.1109/ICRAMET51080.2020.9298691.

[25] C. Chen, C. Li, Z. Zhu and W. Wu, "Wideband and Low-Cross-Polarization Planar Annual Ring Slot Antenna," in IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 3009-3013, 2017, doi: 10.1109/LAWP.2017.2757963.

[26] H. Zhu, Y. Fan, X. Liu and M. M. Tentzeris, "A Compact, Low-Profile Dual-Band Patch Filtering Antenna for Off-Body Communications," 2018 International Applied Computational Electromagnetics Society Symposium - China (ACES), 2018, pp. 1-2, doi: 10.23919/ACESS.2018.8669222.

[27] H. R. Gajera, K. Dutta, C. K. S, P. S and C. S, "Dual-Band Design of Microstrip Patch Antenna with Copper Ring Superstrate for X-Band Applications," 2020 IEEE 1st International Conference for Convergence in Engineering (ICCE), 2020, pp. 371-373, doi: 10.1109/ICCE50343.2020.9290729.

[28] J. Li, H. Shi, J. Chen and A. Zhang, "Dual-band dual-sense circularly polarized annular ring slot antenna," 2017 International Applied Computational Electromagnetics Society Symposium (ACES), 2017, pp. 1-2.

[29] S. Chakraborty, M. Chakraborty and N. N. Pathak, "Transition of Wide Band to Dual Band CPW fed Rectangular Wearable Microstrip Antenna for Implementation in WBAN," 2019 3rd International Conference on Electronics, Materials Engineering & Nano-Technology (IEMENTech), 2019, pp. 1-3, doi: 10.1109/IEMENTech48150.2019.8981070.

[30] N. Dakhli and F. Choubani, "Multiband L-Shaped Slot Antenna Loaded with Split Ring Resonator," 2020 International Wireless Communications and Mobile Computing (IWCMC), 2020, pp. 1087-1090, doi: 10.1109/IWCMC48107.2020.9148052.

[31] N. Wongsin, T. Suangun, C. Mahatthanajatuphat and P. Akkaraekthalin, "A rhombic ring monopole antenna with stripline and ring resonator for multiband operation," 2017 14th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2017, pp. 706-709, doi: 10.1109/ECTICon.2017.8096336.

[32] M. Usman *et al.*, "Bending Analysis of Polymer-Based Flexible Antennas for Wearable , General IoT Applications : A Review," *Polymers (Basel).*, vol. 13, p. 357, 2021.

[33] N. H. M. Rais, P. J. Soh, F. Malek, S. Ahmad, N. B. M. Hashim, and P. S. Hall, "A review of wearable antenna," *Loughbrgh. Antennas Propag. Conf. LAPC 2009 - Conf. Proc.*, no. May 2014, pp. 225–228, 2009, doi: 10.1109/LAPC.2009.5352373.

[34] K. N. Paracha, S. K. Abdul Rahim, P. J. Soh, and M. Khalily, "Wearable Antennas: A Review of Materials, Structures, and Innovative Features for Autonomous Communication and Sensing," *IEEE Access*, vol. 7, pp. 56694–56712, 2019, doi: 10.1109/ACCESS.2019.2909146.

[35] X. B. Chao-Jun Li, Silver Catalysis in Organic Synthesis, 2nd ed. John Wiley & Sons, 2018.

[36] J. E. MacIntyre and J. E. MacIntyre, "Ag Silver," Dict. Organomet. Compd., pp. 1–1, 1996.

[37] I et al., "We are IntechOpen , the world ' s leading publisher of Open Access books Built by scientists , for scientists TOP 1 %," Intech, vol. i, no. tourism, p. 13, 2012.

[38] K. K. Sadasivuni et al., Silver Nanoparticles and Its Polymer Nanocomposites—Synthesis, Optimization, Biomedical Usage, and Its Various Applications, no. January. 201

[39] H. A. Rahman, S. K. A. Rahim, M. Abedian and N. Najib, "Design of a flexible antenna using printed silver loaded epoxy on PDMS/plastic substrate for wearable applications," 2016 10th European Conference on Antennas and Propagation (EuCAP), 2016, pp. 1-4, doi: 10.1109/EuCAP.2016.7481327.

[40] C. Baytöre, E. Y. Zoral, C. Göçen, M. Palandöken and A. Kaya, "Coplanar flexible antenna design using conductive silver nano ink on paper substrate for wearable antenna applications," 2018 28th International Conference Radioelektronika (RADIOELEKTRONIKA), 2018, pp. 1-6, doi: 10.1109/RADIOELEK.2018.8376382.

[41] M. Fawaz et al., "3D printed patch Antenna for millimeter wave 5G wearable applications," 12th European Conference on Antennas and Propagation (EuCAP 2018), 2018, pp. 1-5, doi: 10.1049/cp.2018.0851

[42] R. B. V. B. Simorangkir, Y. Yang, L. Matekovits and K. P. Esselle, "Dual-Band Dual-Mode Textile Antenna on PDMS Substrate for Body-Centric Communications," in IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 677-680, 2017, doi: 10.1109/LAWP.2016.2598729.

[43] X. Lin, Y. Chen, B. Seet, F. Xia, Q. Zhang and J. Hu, "Compact Textile Wideband Antenna for Wearable Microwave Stroke Imaging," 2019 13th European Conference on Antennas and Propagation (EuCAP), 2019, pp. 1-5.

[44] S. F. Jilani and A. Alomainy, "An inkjet-printed MMW frequency-reconfigurable antenna on a flexible PET substrate for 5G wireless systems," Loughborough Antennas & Propagation Conference (LAPC 2017), 2017, pp. 1-3, doi: 10.1049/cp.2017.0237.

[45] Z. H. Jiang, Z. Cui, T. Yue, Y. Zhu and D. H. Werner, "Compact, Highly Efficient, and Fully Flexible Circularly Polarized Antenna Enabled by Silver Nanowires for Wireless Body-Area Networks," in IEEE Transactions on Biomedical Circuits and Systems, vol. 11, no. 4, pp. 920-932, Aug. 2017, doi: 10.1109/TBCAS.2017.2671841.

[46] Prahlad, R. A. Kandakatla and M. Riyaz Ahmed, "Design and Performance Analysis of Dual-band Microstrip patch antennas for Smart Apparels," 2018 Second International Conference on Green Computing and Internet of Things (ICGCIoT), 2018, pp. 573-576, doi: 10.1109/ICGCIoT.2018.8752967.

[47] H. Liu and H. Ma, "Design of Diamond Textile Antenna based on Flexible Material," 2020 IEEE 4th Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), 2020, pp. 1672-1675, doi: 10.1109/ITNEC48623.2020.9084914.

[48] T. T. Estu, V. Fauzia and Y. Wahyu, "Design 4-Element Flexible Microstrip Patch Array Antenna Using Silver Nanowires and Polydimethylsiloxane for WLAN Application," 2018 International Conference on Radar, Antenna, Microwave, Electronics, and Telecommunications (ICRAMET), 2018, pp. 94-98, doi: 10.1109/ICRAMET.2018.8683923.

[49] C. Lin, C. Chang, Y. T. Cheng and C. F. Jou, "Development of a Flexible SU-8/PDMS-Based Antenna," in IEEE Antennas and Wireless Propagation Letters, vol. 10, pp. 1108-1111, 2011, doi: 10.1109/LAWP.2011.2170398.

[50] Z. Hamouda, J. Wojkiewicz, A. A. Pud, L. Koné, S. Bergheul and T. Lasri, "Magnetodielectric Nanocomposite Polymer-Based Dual-Band Flexible Antenna for Wearable Applications," in IEEE Transactions on Antennas and Propagation, vol. 66, no. 7, pp. 3271-3277, July 2018, doi: 10.1109/TAP.2018.2826573.

[51] C. Zhan, G. Yu, Y. Lu, L. Wang, E. Wujcik, and S. Wei, “Conductive polymer nanocomposites: a critical review of modern advanced devices,” J. Mater. Chem. C, vol. 5, no. 7, pp. 1569–1585, 2017.

[52] G. Armstrong, “An introduction to polymer nanocomposites,” Eur. J. Phys., vol. 36, no. 6, p. 63001, 2015.

[53] A. Timoshenko, K. Lomovskaya, A. Levanov, E. Borodulin and E. Belousov, "Analysis and design of planar flexible antenna prototype," 2016 IEEE East-West Design & Test Symposium (EWDTS), 2016, pp. 1-5, doi: 10.1109/EWDTS.2016.7807741.

[54] S. Morris, A. R. Chandran, N. Timmons and J. Morrison, "The fabrication and analysis of a polyimide based loop antenna for 2.45GHz WBAN applications," 2016 Loughborough Antennas & Propagation Conference (LAPC), 2016, pp. 1-4, doi: 10.1109/LAPC.2016.7807510.

[55] M. Wagih, "Direct-Write Dispenser Printing for Rapid Antenna Prototyping on Thin Flexible Substrates," 2020 14th European Conference on Antennas and Propagation (EuCAP), 2020, pp. 1-4, doi: 10.23919/EuCAP48036.2020.9135625.

[56] J. M. Mesquita, N. Pires and A. A. Moreira, "Influence of deformations on the matching of a flexible dual-band antenna," 2013 7th European Conference on Antennas and Propagation (EuCAP), 2013, pp. 3283-3285.

[57] M. M. Rahman, M. A. Nayeem, S. Nahid, S. R. Bin Alvee, R. Rashidul Hasan and M. A. Rahman, "On-Body Humidity Sensing Antenna with Polyimide for BAN Applications over 5G Networks," 2020 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), 2020, pp. 1-7, doi: 10.1109/IEMTRONICS51293.2020.9216331.

[58] V. Kumar, "Patch antenna for wearable electronics," 2017 2nd International Conference for Convergence in Technology (I2CT), 2017, pp. 636-640, doi: 10.1109/I2CT.2017.8226207.

[59] G. S. Karthikeya, K. K. Devaiah, R. S. G. Sharma, M. H. B. Patel, N. R. Mandi and T. Thyagaraj, "Wearable button antenna array for V band application," 2016 IEEE 5th Asia-Pacific Conference on Antennas and Propagation (APCAP), 2016, pp. 283-284, doi: 10.1109/APCAP.2016.7843206.

[60] S. Mokha, S. Jangir, S. Pimple, and S. Bandhaokar, “Design Of Flexible Micrstrip Patch Antenna Of 2.4 Ghz Operation Frequency Using HFSS,” *Int. Res. J. Eng. Technol.*, p. 7, 2016, [Online]. Available: www.irjet.net.

[61] M. Haerinia and S. Noghanian, “A printed wearable dual-band antenna for wireless power transfer,” *Sensors (Switzerland)*, vol. 19, no. 7, 2019, doi: 10.3390/s19071732.

[62] H. K. Raad, H. M. Al-Rizzo, A. Isaac, and A. I. Hammoodi, “A compact dual band polyimide based antenna for wearable and flexible telemedicine devices,” *Prog. Electromagn. Res. C*, vol. 63, no. April, pp. 153–161, 2016, doi: 10.2528/PIERC16010707.

[63] Z. Hamouda, J. Wojkiewicz, A. A. Pud, L. Koné, S. Bergheul and T. Lasri, "Magnetodielectric Nanocomposite Polymer-Based Dual-Band Flexible Antenna for Wearable Applications," in IEEE Transactions on Antennas and Propagation, vol. 66, no. 7, pp. 3271-3277, July 2018, doi: 10.1109/TAP.2018.2826573.

[64] S. Hanif, J. Ahmed, and M. Raees, "Characterizations of Flexible Wearable Antenna based on Rubber Substrate," *Int. J. Adv. Comput. Sci. Appl.*, vol. 7, no. 11, pp. 190–195, 2016, doi: 10.14569/ijacsa.2016.071124.

[65] R. Salvado, C. Loss, Gon, and P. Pinho, "Textile materials for the design of wearable antennas: A survey," *Sensors (Switzerland)*, vol. 12, no. 11. pp. 15841–15857, Nov. 2012, doi: 10.3390/s121115841.

[66] N. T. Dishovsky and P. A. Malinova, "Comparison of properties of natural rubber composites with hybrid fillers containing different modifying phase and their applicability in flexible antennas," vol. 50, no. 3, pp. 484–493, 2018.

[67] G. A. T. Warren L. Stutzman, Antenna Theory and Design, 3rd ed. John Wiley & Sons, 2012.

[68] Sisir K. Das and A. Das, Antenna and Wave Propagation, 1st ed. Tata McGrawHill Education, 20

[69] P. F. W. Christos G. Christodoulou, Fundamentals of Antennas: Concepts and Applications, Vol 50. SPIE Press, 2001.

[70] A. Al-Zoubi, F. Yang and A. Kishk, "A Broadband Center-Fed Circular Patch-Ring Antenna With a Monopole Like Radiation Pattern," in IEEE Transactions on Antennas and Propagation, vol. 57, no. 3, pp. 789-792, March 2009, doi: 10.1109/TAP.2008.2011406.

[71] K. E. Kedze, H. Wang and I. Park, "Compact Broadband Omnidirectional Radiation Pattern Printed Dipole Antenna Incorporated With Split-Ring Resonators," in IEEE Access, vol. 6, pp. 49537-49545, 2018, doi: 10.1109/ACCESS.2018.2868989.

[72] X. Chen, X. Li, G. Fu and Y. Yan, "CP higher-order mode annular-ring microstrip antenna for mobile satellite communication," 2012 International Conference on Microwave and Millimeter Wave Technology (ICMMT), 2012, pp. 1-4, doi: 10.1109/ICMMT.2012.6230168.

[73] Y. Ren and K. Chang, "An Ultrawideband Microstrip Dual-Ring Antenna for Millimeter-Wave Applications," in IEEE Antennas and Wireless Propagation Letters, vol. 6, pp. 457-459, 2007, doi: 10.1109/LAWP.2007.905012.

[74] S. N. Islam, A. Ghosh, M. Kumar, G. Sen and S. Das, "A Compact Dual-band Antenna Using Triangular Split Ring Resonator for Bluetooth/WiMax/LTE Applications," 2018 IEEE Indian Conference on Antennas and Propogation (InCAP), 2018, pp. 1-3, doi: 10.1109/INCAP.2018.8770768.

[75] X. L. Bao and M. J. Ammann, "Dual-Frequency Circularly-Polarized Patch Antenna With Compact Size and Small Frequency Ratio," in IEEE Transactions on Antennas and Propagation, vol. 55, no. 7, pp. 2104-2107, July 2007, doi: 10.1109/TAP.2007.900271.

[76] R. A. Panda, D. Mishra, P. Kumari, B. Hansdah and R. K. Singh, "Gauging trowel shaped patch with circular rings for 60 GHz WLAN," 2020 7th International Conference on Signal Processing and Integrated Networks (SPIN), 2020, pp. 113-116, doi: 10.1109/SPIN48934.2020.9070868.

[77] S. B. Sarkar, "Design and analysis of 5.2 GHz rectangular microstrip patch array antenna using split ring resonator," 2017 Fourth International Conference on Signal Processing, Communication and Networking (ICSCN), 2017, pp. 1-5, doi: 10.1109/ICSCN.2017.8085654.

[78] P. K. Sarkar, I. Rahaman, M. N. Rahman and M. F. Hasan, "Investigation of Reduced Size Annular Ring Patch Antenna with EBG Structure for Wireless Applications," 2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT), 2020, pp. 1-4, doi: 10.1109/ICCCNT49239.2020.9225531.

[79] B. Tao, M. Jiang, L. Zhang and S. Hu, "Dual-Band and Dual-polarization Microstrip Antennas Loaded with Split Ring Resonators," 2020 9th Asia-Pacific Conference on Antennas and Propagation (APCAP), 2020, pp. 1-2, doi: 10.1109/APCAP50217.2020

APPENDIX

APPENDIX A

Gantt Chart for Final Year Project

This project is divided into two phases, namely phase one which is implemented this semester and phase two will be implemented next semester. Phase one includes a literature review as well as an understanding of the project being implemented. Research need to be carried out to identify problems, project objectives as well as the methods or techniques used to develop this project. In addition, this phase also requires a prototype of the proposed antenna using CST Microwave Studio software. A Gantt Chart for the Phase 1 project is shown as Table 1:

Table 1: Project Schedule Phase 1 (FYP 1)

Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Research														
Antenna Design by CST														
Chapter 1: Introduction														
Chapter 2: Literature Review														
Chapter 3: Methodology														
Submit First Draft														
Submit Report														
Presentation														

Meanwhile, for the second phase includes the proposed antenna fabrication process and some tests that will be conducted as well as analyze each data obtained such as radiation patterns, return loss and so on. Each data obtained will be compared with the simulation results and will be discussed in the project report. A Gantt Chart for the Phase 2 project is shown as Table 2:

Table 2: Project Schedule Phase 2 (FYP 2)

Activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
CST Simulation														
Fabricate														
Chapter 4: Results and Discussion														
Chapter 5: Conclusion														
Submit First Draft														
Submit Report														
Presentation														