COMPARATIVE RESEARCH OF MICROSTRIP ANTENNA FOR DIFFERENT SUBSTRATE MATERIAL AT 5.8 GHZ IN MEDICAL APPLICATIONS

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

Signature : ……………………………………..

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Date : 12 June 2017

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LIST OF ABBREVIATION

ISM	Industrial,Scientific and Medical Radio Band
CST	Computer Simulation Technology
ECG	Electrocardiogram
PCB	Printed Circuit Board
EBG	Electromagnetic band gap
BAN	Body Area Network
PAN	Personal Area Network
WBAN	Wireless Body Area Network
CPW	Coplanar width feed
LCP	liquid Crystal Polymer
PDMS	Polydimethylsiloxane

LIST OF SYMBOLS

GHz	Gigahertz
MHz	Megahertz
ε_r	Relative permittivity
ζ	Conductivity
Tanϑ	lost tangent
$\lvert S_{11} \rvert$	S parameter
RL	Return Loss
Θ	tangent
dBi	decibel
Γ	Gamma
D	Directivity
G	power gain
Ω	Omega
Fi	Inset feed
π	Pi
Δ	Delta

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ABSTRACT

Wireless communication is used as the medium communication in the wearable application and an antenna is used as the transceiver to transmit and receive a signal between devices. Currently, the largest category of wearable application is the healthcare wearable application. Therefore, the selection of antenna is important because the body will directly degrade the performance of the antenna. The Body area network (BAN) technology, is a wireless network technology of wearable computing devices targeted at monitoring physiological conditions surrounding patient that has a capability to process and communicate data of heart beat, body temperature and blood pressure. This Body Area Network devices along with the help of wearable antennas are embedded inside the human body in a fixed position Due to that, a study will be conducted in order to identify the most suitable antenna to be used for on body wearable application. The study is aim to improve on body wearable application design in term of antenna selection. The method used in the study is by comparing the antenna types that have been used in on body wearable application. The study will be done using other related works that had been done by other researchers. The textile patch antenna is found to be the suitable antenna that can be implemented into the on body wearable application. The main challenge is using denim and felt textile as the substrate. The performance such as return loss, radiation pattern, gain and efficiency of the antenna are extensively investigated and carried out. The simulated result from the Computer simulation Technology (CST) software is being compared on the two different type of the textile materials. All results have been demonstrated using simulation and experimental. The design that being choose is rectangular patch microstrip antenna. 1st modification antenna suffers frequency at 5.8 GHz. Its return loss at -18.30 dB and 8.82 gain. On the 2nd modification antenna, it also suffers frequency ranges at 5.8 GHz and has return loss of the antenna at -13.89db and have a gain at 6.57db

Abstrak

Komunikasi tanpa wayar digunakan sebagai komunikasi sederhana dalam aplikasi yang boleh pakai dan antena digunakan sebagai transceiver untuk menghantar dan menerima isyarat antara peranti. Pada masa ini, kategori terbesar aplikasi yang boleh pakai adalah aplikasi yang boleh diguna pakai oleh kesihatan. Oleh itu, pemilihan antena adalah penting kerana badan akan secara langsung menurunkan prestasi antena. Teknologi rangkaian Kawasan Badan (BAN), adalah teknologi rangkaian tanpa wayar peranti pengkomputeran yang boleh dipakai yang disasarkan untuk memantau keadaan fisiologi di sekeliling pesakit yang mempunyai keupayaan untuk memproses dan menyampaikan data denyutan jantung, suhu badan dan tekanan darah. Peranti Rangkaian Kawasan Badan ini bersama-sama dengan bantuan antena yang dapat dipakai tertanam di dalam tubuh manusia dalam kedudukan tetap Oleh itu, kajian akan dilakukan untuk mengenalpasti antena yang paling sesuai untuk digunakan pada aplikasi dpt dipakai. Kajian ini bertujuan untuk meningkatkan reka bentuk aplikasi yang boleh pakai badan dari segi pemilihan antena. Kaedah yang digunakan dalam kajian ini adalah dengan membandingkan jenis antena yang telah digunakan pada aplikasi dpt dipakai badan. Kajian ini akan dilakukan dengan menggunakan kerja-kerja berkaitan lain yang telah dilakukan oleh penyelidik lain. Antena patch tekstil didapati sebagai antena yang sesuai yang boleh dilaksanakan ke dalam aplikasi dpt dipakai badan. Cabaran utama menggunakan denim dan tekstil yang dirasakan sebagai substrat. Prestasi seperti kehilangan pulangan, corak radiasi, keuntungan dan kecekapan antena disiasat secara meluas dan dijalankan. Hasil simulasi dari perisian Teknologi Simulasi Komputer (CST) sedang dibandingkan pada dua jenis bahan tekstil yang berbeza. Semua keputusan telah ditunjukkan menggunakan simulasi dan eksperimen. Reka bentuk yang sedang dipilih ialah antena microstrip patch segi empat tepat. Antena pengubahsuaian pertama mengalami kekerapan pada 5.8 GHz. Kerugian pulangannya pada -18.30 dB dan keuntungan 8.82. Pada antena pengubahsuaian ke-2, ia juga menghadapi rentang kekerapan pada 5.8 GHz dan kehilangan kembali antena pada -13.89db dan mempunyai keuntungan pada 6.57db

CHAPTER 1

INTRODUCTION

1.1 Background

Telemedicine is becoming more used in health care providers due to the growing demand for remote monitoring of human vital signs. Telemedicine applications include but not limited to monitoring of seniors, recovery tracking of patients, monitoring the health parameters of astronauts and athletes, and E-psychiatry. The health parameters that may be forwarded to remote stations via wireless transmission (off body mode) range from basal body temperature, heart rate, respiratory rate, blood pressure, to glucose levels and Electrocardiogram (ECG) waveforms . In addition to off- body means, on-body mode is also essential for communication between sensor devices worn or implanted within the patient's body. For optimum. So, from this research, a micro strip patch antenna is used in this research. This is because it's lighter in weight, low volume, low cost, low profile, smaller dimension and ease of fabrication and conformity .The frequency bands and power are regulated by the Industrial,Scientific and Medical Radio Band (ISM) band . For medical use, 5.8Ghz resonating frequency is proposed for micro strip antenna. When the antenna designed on the body surface is placed inside of the body, its resonating at 5.8GHz.This micro strip is used for the Electrocardiogram (ECG) applications. This antenna will help the doctor to record and get the data on the cardiac patients form a far place. For this antennas, a textile materials form interesting substrates, because fabric antennas can be easily integrated into clothes.

1.2 Problem statements

Antenna plays an important role in the wearable system which functions to transmit and receive radio signal in the wireless communication process. However, most conventional antennas are not suitable for the wearable system because the antennas have rigid structure, big size and high cost manufacturing. Therefore, textile antenna is introduced into the wearable system due to its flexibility, robustness and light weight material. The textile antenna based on the fabric material also could be integrated into the garment without disrupting the user's comfort. A reliable low profile antenna which is micro patch antenna is required for the best performance and used fabric as the substrate, every person who is using wireless technology device easily to move around while doing their job. The person can wear the smaller device onto their cloth. The problems of limited movements are considered solved.

1.3 Objective

1. To design textile antenna using 2 different materials operating at 2.45 GHz.
2. Compare the performances of antenna in term of gain, return loss, bandwidth and resonant frequency.
3. To evaluate the placement antenna on the body by using two different fabric material as the substrate by maintain the antenna performance.

1.4 Scope of the project

To design and create the micro strip antenna by using CST Studio Suite software that can be used on the medical devices machine. This antenna maybe forwarded to remove stations via wireless transmission (off body mode) but the project will be focused on designing the antenna only. The characterization of different fabric properties including permittivity and loss. The characterization of fabric properties including permittivity and loss tangent has been determined using microstrip line feed technique. The software called Computer Simulation Technology (CST) an electromagnetic software has been used to simulate the antenna design and analyse the antenna result performance in terms of return loss, radiation patterns, efficiency, current distribution, and other

1.5 Significance of the project

The importance of this research are for make the micro strip antenna that can be used for telemedicine application especially on the human vital signs. From this research, this antenna can be lightweight, compact and almost free maintenance. This antenna also make the user record the cardiac activity without attach the probe on the human skins.

1.6 Outline of the thesis

This thesis is divided into 5 chapters. Each chapter discuss ion the different issues which related to this project. The outline of each chapter is stated in the paragraphs below. Chapter one covered the introduction and overview of the project background, problem statement, objective, and scope of work of this project. All of the data should be stated clearly before design the antenna. Chapter two gives the general description and the overview of the wearable antenna. The previous studies that are related to this project are studied to get clear view of the title project. This chapter also discusses about the various feeding techniques that can be applied towards the design. Chapter three explained the flowchart ant the methodology that will be done to finish the project successfully. The design specification which includes the denim and felt fabric as a substrate are presented in this chapter. In addition, the procedures to fabricate and measure are explained briefly. Chapter four is the result and discussion of the project. Simulated and measured results for return loss, radiation patterns and current distribution are analysed for all antennas designed. Lastly, in chapter five gives the summarized works and conclusion for the overall of the project. Besides, future works and recommendations to improve the performance of the designed antenna are also stated.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

2.1 Micro strip patch antenna [1]

Micro strip is a type of electrical transmission line which can be fabricated using printed circuit board (PCB) technology, and is used to convey microwave frequency signals. It consists of a conducting strip separated from a ground plane by a dielectric layer known as the substrate. Microwave components such as antennas, couplers, filters, power dividers can be formed from micro strip, the entire device existing as the pattern of metallization on the substrate. Micro strip is much less expensive than traditional waveguide technology, as well as being far lighter and more compact. A micro strip antennas became very popular primarily for space borne applications. Today they are used for government and commercial applications. These antennas comprise a plurality of generally planar layers including a radiating element, an intermediate dielectric layer, and a ground plane layer. The radiating element is an electrically conductive material imbedded or photo etched on the intermediate layer and is generally exposed to free space. Depending on the characteristics of the transmitted electromagnetic energy desired, the radiating element may be square, rectangular, triangular, or circular and is separated from the ground plane layer as shown in Figure 2.1. Micro strip patch antennas have numerous advantages compared to conventional microwave antennas, and for that many applications cover the broad frequency range from 100 MHz to 100 GHz [3]. A microstrip patch antenna is a type of antenna that offers a low profile, thin and easy manufacturability, which provides a great advantage over traditional antennas. Patch antennas are planar antennas used in wireless links and others. It's also Light weight, low volume, and thin profile configurations, which can be conform.

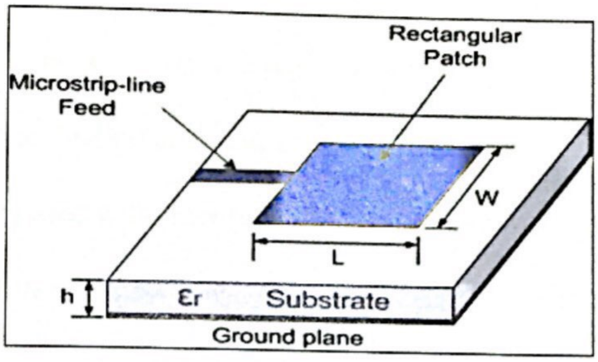


Figure 2.1 micro strip patch antenna (MPA) Balanis (1997)

A micro strip patch antenna is an apparatus that offers a position of low profile, i.e. thin and simple manufacturability, which gives an awesome preferred standpoint over conventional antennas. The patch antennas are planar receiving wires utilized as a part of remote connections and other microwave applications.

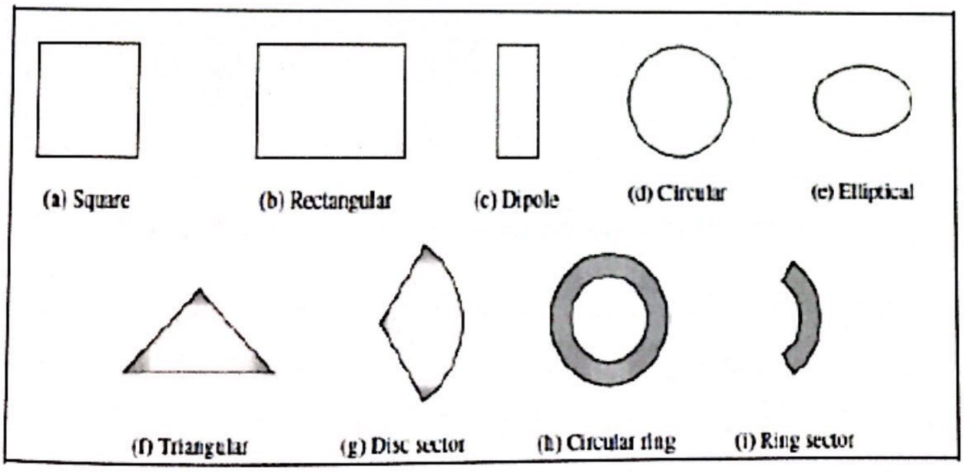


Figure 2.2 Different types of patch antenna according to Balanis(1997)

2.1.1 Micro strip antenna and limitations [1]

Microstrip patch antennas have various points of interest contrasted with conventional microwave antennas and for that numerous applications cover the expansive frequency range from 100 MHz to 100 GHz. Some of principle advantage of microstrip antenna is presented by [2].

i. Light weight, low volume, and thin profile configurations,

ii. Low fabrication cost, its agreeable to large scale manufacturing

iii. Linear and circular polarizations are possible with simple feed.

iv. Dual frequency and dual polarization antennas can be easily made.

v. Can be easily integrated with microwave integrated circuit.

vi. Feed lines and matching networks can be fabricated concurrently with the antenna structure.

And the limitation of microstrip antenna compared with conventional microwave antennas:

i. Narrow Bandwidth (BW) and associated tolerance problems.

ii. Complex feed structure required for high performance arrays.

iii. Unrelated radiation from feeds and junction.

iv. Excitation of surface waves.

v. Lower power handling capability (100 Watt).

2.2 Dual-band Wearable Textile Antenna on an EBG Substrate [7]

There are two types of body-worn communication which is on- body communication and off-body communication. This body applied antennas might be produced using materials and connected on body or into attire, or might be worn as a patch button antenna. This paper can be considered as updated antenna which is from single frequency band wearable antennas and dual frequency band design. This paper displayed on further results from an investigation of dual-band textile antenna incorporating an EBG surface. This antenna worked at 2.45GHz and 5GHz, ISM band.

The antenna was composed using coplanar patch antenna with coplanar strip line feeding and integrated with a dual-band EBG material and these adaptable materials are promptly covered up and sewn into the attire.

The most critical part for this paper extremely accommodating for this venture is textile characterization. The operating frequency is vital aspect in order to design wearable antenna. This paper demonstrated the imperative properties for common textile and leather materials that were measured through transmission waveguide 12 method. . The creators utilized six textures tests and two reference strong examples (Perspex and PTFE) [7] and the waveguide framework work in 2.6 to 3.95GHz recurrence ranges. Table 2.1 below explained the properties of dielectric constant for each fabric material.

Material	Silk	Felt	Fleece	PTFE	Perspex	Tween
Single layer thickness(mm)	0.58	1.1	2.55	11.66	11.67	0.685
Permittivity	1.75	1.38	1.17	2.05	2.57	1.69
Loss Tangent	0.012	0.023	0.0035	0.0017	0.038	0.0084

Table 2.1: Properties of Dielectric Constant for Each Fabric Material [5]

The references showed the result of permittivity and loss tangent values of the other fabric materials in expected ranges. Leather materials were also characterized and the relative dielectric constant varied from 2.5 to 2.8 with loss tangents between 0.035 and 0.073.

2.3 Design and Equivalent circuit analysis of Textile antenna for WLAN and WBAN application

. There are two types of body-worn communication which is on- body communication and off-body communication. This body applied antennas might be produced using materials and connected on body or into attire, or might be worn as a patch button antenna. This paper tells about systems can be integrated into daily wearable and accessories which will be integrated by the so called body area network (BAN). BAN which is an extension of Personal Area Networks (PANs) that enables various devices to communicate with each other by placing them on or in the vicinity of the human body[5]. The applications of BAN include tracking, mobile computing, and assessing physiological changes during testing an measurement and navigation One can also continuously monitor the changes in human body so that it is possible to maintain the data base of the health condition of the patient. The frequency bands used for such purposes are Wireless Body Area Network application band and Industrial, Scientific and Medical (ISM) band (2.40 GHz to 2.50 GHz)[3][4]. WBAN systems are mainly used to send and receive the data or information pertaining to patient's health. The design of this antenna is circular patch with diameter of 26.44mm with 90mmx50mm of substrate and thickness at 35mm.

This antenna air gap between the centres of the circular patch antenna. The figure below shows the dimension of this antenna.

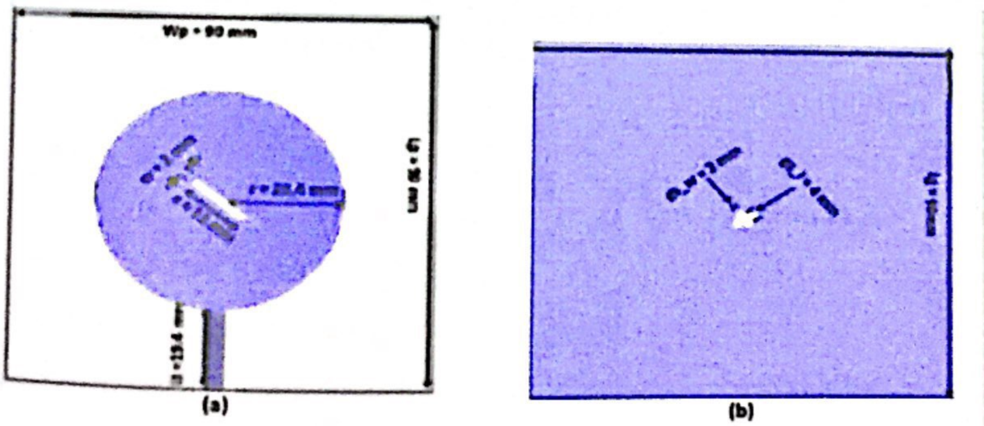


Figure 2.3a): Antenna (a) Front view **2.3(b) Back view of Patch Antenna**

The crucial parts is the substrate which is denim textile which is used in this antenna. The antenna is being fed with microstrip line with 50Ω with impedance operating at

2.45 GHz. In order to account for the above, the designed antenna is also analysed with human body model in the simulation with layers of skin, fat, muscle and bone. Antenna is separated from skin by a gap of 2 mm.

Phantom layers	Relative permittivity(ε_r)	Conductivity (ζ in S/m)	Loss tangent (tanϑ
Skin	35.114	3.717	0.328
Fat	4.955	0.293	0.183
Muscle	48.485	4.962	0.317
Bone	20.76	1.07	0.241

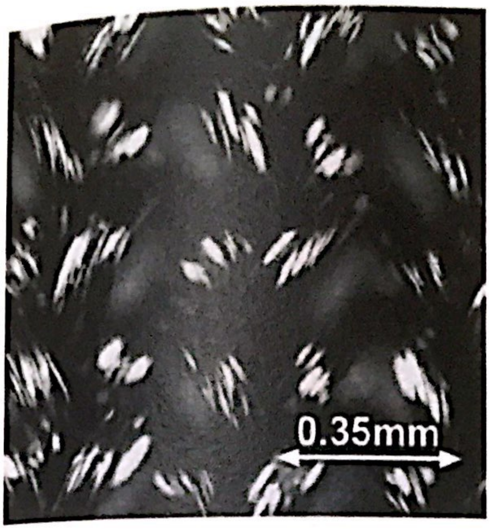
Table 2.2: Human Body model at 2.45Ghz

2.4 Materials used for rectangular patch antennas

Flexible antennas are developed making use of substrates that can be easily integrated in irregular surfaces without losing its functional features. The emerging of new materials, with very specifics chemical properties, and new manufacturing processes has led to the development of dielectric substrates that promise good results regarding flexibility, efficiency, weight, and reproducibility of the antennas. The choice of the dielectric on which the conductor is built influences the antenna's behaviour regarding impedance bandwidth, radiation efficiency and gain. Thickness, dielectric permittivity, loss tangent of antenna materials must be measured and controlled so as to reach the specifications of the different applications. The electromagnetic properties of the dielectric substrates can be characterized using several experimental techniques such as coplanar waveguide approach [9], differential open resonator method [10] and microstrip linear method [11]. The manufacturers of these antennas are also aware of environmental issues, and so they are using environmental friendly and low-cost materials (and even renewable), and easy production processes. In this section are presented three important groups of flexible antennas regarding the material used: Textile antennas, polymer based antennas, and paper based antennas. For each type is presented an example of an antenna design and its simulation/measurement results under certain conditions. Thus, this section presents the state of the art on flexible antennas made by different materials and for different applications.

2.4.1 Textile Antennas

For flexible and wearable applications, textile materials are interesting, due to their suitability to be easily integrated into clothes and other wearable devices. Textile antennas can be classified according to their structure. In the first category, the antenna substrate is made by a non-conductive fabric whereas the conductive layers and ground planes are copper foils. In the second group, the antennas are fully textile-composed, since the substrate and the conductive layer are made by textiles. Textile substrates provide the dielectric between the antenna patch and the ground plane. These textile materials can be divided into two categories which are natural and synthetic fibers. Unlike natural fibers like cotton and wool, which are obtained from the nature, synthetic fibers are polymers obtained from their molecular structures. These textile substrates generally have a very low permittivity, which reduces the surface wave losses and improves the impedance bandwidth of the antenna. The variation of the dimensions due to stretching and compression are typical for fabrics, and this has a strong influence on the electromagnetic characteristics of the antenna. The substrate thickness changes the resonant frequency, as well as the input impedance bandwidth [12]. Non-conductive textiles can also be integrated with other metallic pieces such as zipper and metallic buttons as the radiating patterns. In the second type of antennas, both substrate and conducting layers are based in fabrics. These metal-plated textiles (e-Textiles) are widely used as conductive materials and consist of polymer or metal conductors, which are embedded in normal textile materials, through the processes of weaving (the wires are arranged in two orthogonal directions) or knitting (the conductive material is incorporated into the normal fabric through a woven mesh), Figure 2.1. Thus, the amount of conductors that are added to the pure textile determines the reliability of the fiber in terms of the conductive structure, durability and mechanical properties [13]. Flectron, Nora, and Zelt are the most used Electro-Textiles in flexible antennas production.



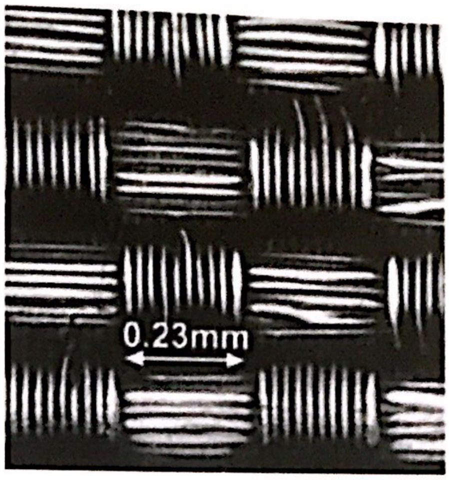


Figure 2.4(a)Silver Plated Knitted Fabric

Figure 2.4b) Silver copper Nickel plated woven fabric

Figure 2.5: Metal-plated textiles (e-Textiles).

The antenna presented in [14] is a compact and flexible CPW-fed UWB antenna, which consists of an elliptical patch and a modified ground plane to achieve an impedance bandwidth between 2.52 GHz and 13.35 GHz. The radiating element is made of a copper tape which has 0.035 mm of thickness. The substrate is composed of 0.78 mm of thickness denim textile which has a permittivity of 1.8 and tangent loss of 0.07 at 2.4 GHz. Figure 2.2 shows the dimensions of the designed antenna and the fabricated prototype.

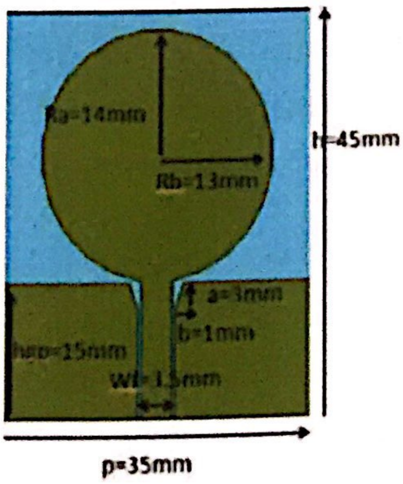


Figure 2.5(a)Antenna prototype dimension

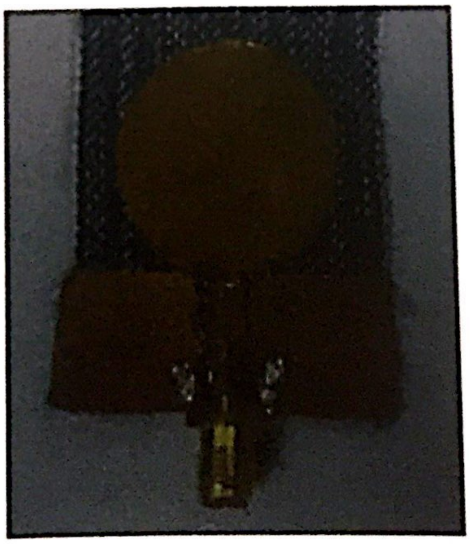


Figure 2.5(b)Fabricated antenna using denim textile as substrate

The return loss was simulated and measured for this CPW-fed antenna. The graph presented in Figure 2.3 shows a good agreement between the measured and simulated results. However, the simulated return loss is slightly higher than measured result. For simulated results, an operational -10 dB bandwidth between 2.4 GHz - 12.8 GHz is observed. For the measurements, the $|S_{11}|$ is below -10 dB within 2.52 GHz -13.35 GHz.

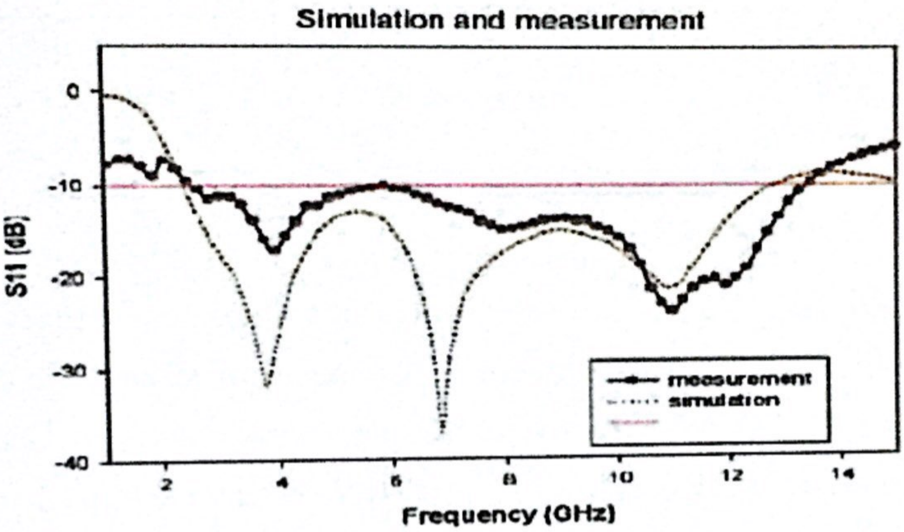
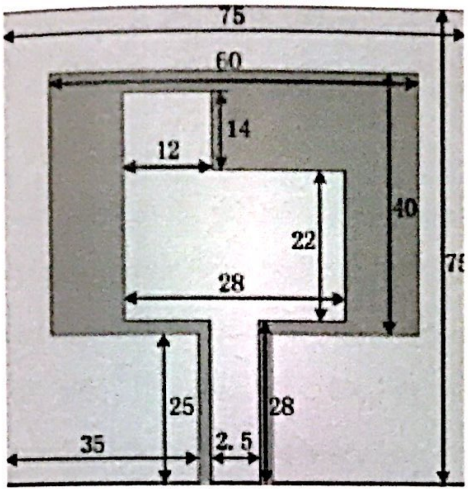


Figure 2.6: Simulated and measured return loss

In [15] a fully textile antenna for 2.4 GHz ISM bands is presented. This design is an L-shape patch antenna with CPW feeding structure. The proposed wearable antenna has two main layers: the top layer is the conductive fabric and the bottom layer is the denim substrate with thickness of 1mm, permittivity of 1.6, and a loss tangent of 0.02. The materials chosen are flexible, lightweight, and easy to integrate into ordinary clothes. The geometry and the fabricated antenna can be observed in Figure 2.4.



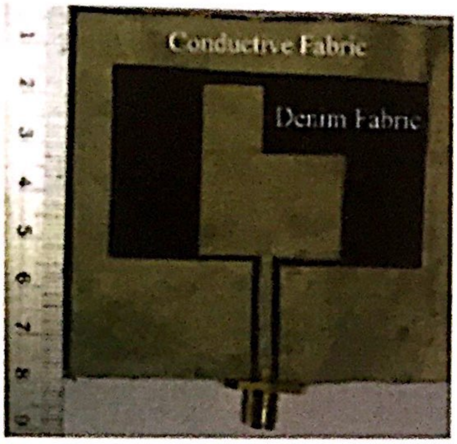


Figure 2.7 a) Dimension of the fully textile antenna in mm **Figure 2.7 b) fabricated antenna**

Once the antenna is projected to be used for wearable applications, it is important to observe its performance when attached on everyday clothing. The textile antenna is placed on right upper arm, which is one of the most common wearable positions. The return loss of the textile antenna on clothes are measured and then compared with free-space results. The simulated results for the return loss are also shown in Figure 2.5. The difference between on clothes measurements and in free-space measurements is probably due to the fact that the body tissues influence the substrate permittivity and change the surface current pattern of the antenna

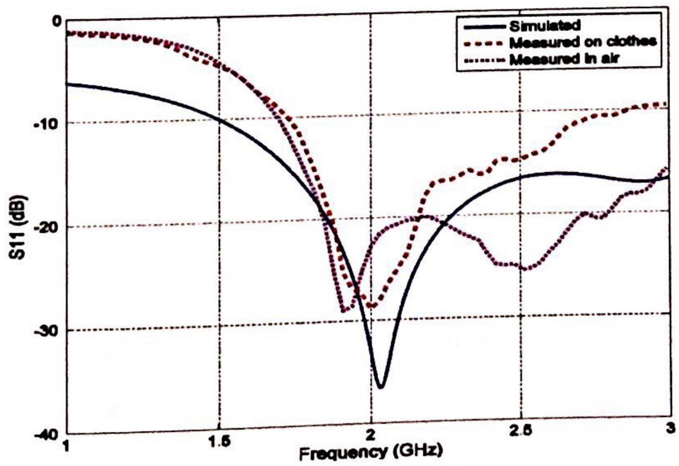
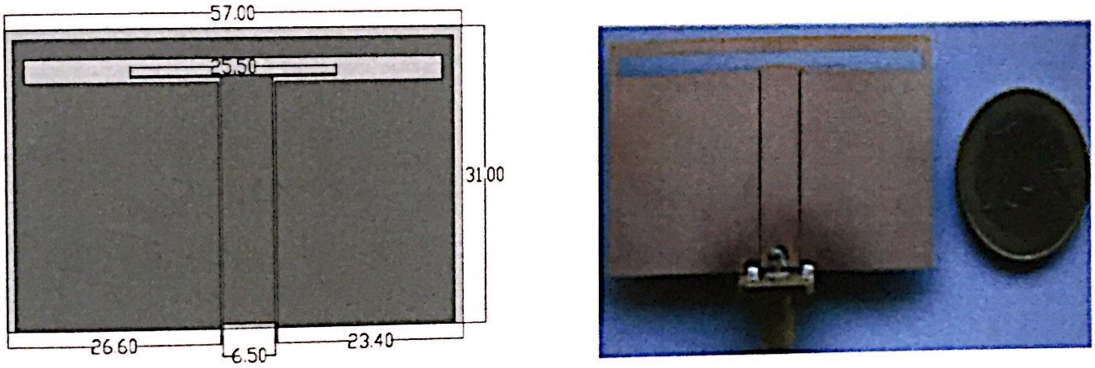


Figure 2.7: simulated and measured $|S_{11}|$ of the proposed textile antenna

2.4.2 Polymer Based Antennas

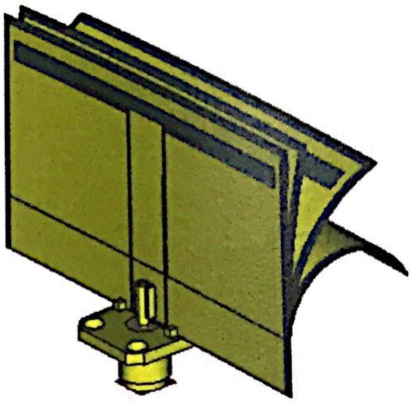
Polymers and their derivatives allow the fabrication of antennas with flexible substrates. These are the most often used materials in the production of flexible electronic devices. Among the variety of polymers available for this propose, liquid Crystal Polymer (LCP), Kapton polyimide, and Polydimethylsiloxane (PDMS) are the most frequently used [16]. They can be used in the form of silicone elastomers or mixed with ceramic composites. They can also be added to other composites like silver, carbon, and other polymers with different properties. The referred polymers have favourable mechanical properties, which give them the capacity of elastic deforming. These polymer-based substrates also have good electrical features (low dielectric permittivity and low loss tangent values up to mm-wave frequencies), and so they can be used in conformal antennas, and consequently having application in wearable and wireless devices [17]. In a flexible coplanar-fed dual-band antenna was built on Kapton polyimide substrate, tuned to cover the 2.45 GHz and 5.8 GHz ISM bands (Figure 2.6).



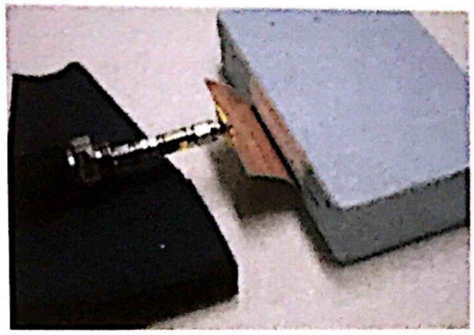
a) **Antenna geometry and dimensions(mm)** **b) Prototype antenna**

Figure 2.8: Flexible dual band antenna

As the antenna is developed to be integrated into a flexible and wearable device, its capability to flex and function properly under bending and crumpling conditions was evaluated. In this article the simulations and measurements of the $|S_{11}|$ parameter show that these deformations have a very low susceptibility to performance degradation in terms of impedance matching of the antenna. Figure 2.7 shows the simulation model, and the measurement setup for the bending deformation



(a) Bending in simulation environment.



(b) Measurement bending setup.

Figure 2.9: Antenna bending

The $|S_{11}|$ simulations for two different bending radius and the measurement for R = 17 mm are shown in Figure 2.8. Resonance shift and bandwidth changes are not significant, which indicates that the proposed structure is very robust under these bending scenarios.

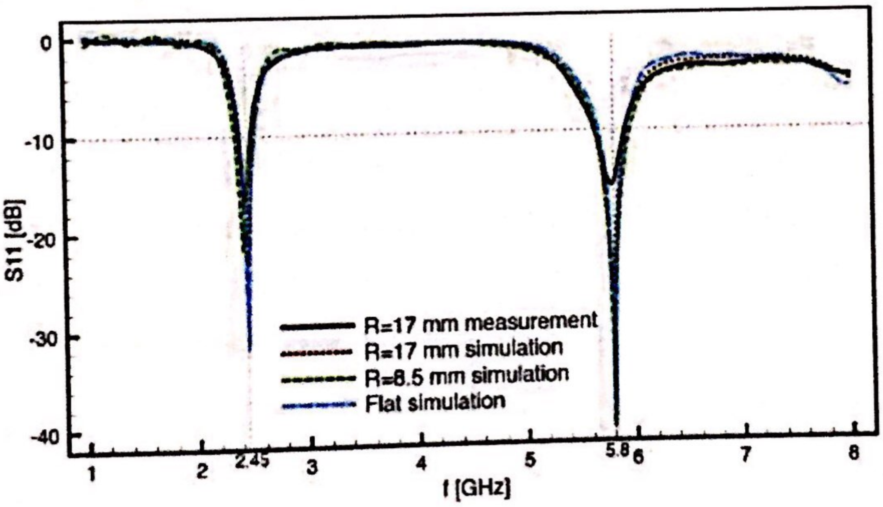


Figure 2.10: $|S_{11}|$ results for bent antenna: measurement for R = 17 mm and simulations for R= 17; 8;5 mm and at scenarios.

2.5 Fundamental Parameters of Antenna [12]

2.5.1 Return loss

The return loss is a logarithmic proportion measured in dB that differentiate between the powers reflected by the antenna to the input power form the transmission line. The return loss of antenna is computed by

$$RL = -10\log_{10}|s|\,|11|^2 = -10\log_{10}|r|^2$$

2.5.2 Radiation Pattern

The radiation pattern can be clear as a graphical representation of the radiation properties of the antenna as an element of space coordinates. Generally, The radiation pattern is resolved in the far field area There are a couple of radiation properties, for example, power flux density, radiation density, and directivity stage. The radiation patterns can be represented in 2-D and 3-D version.

Three dimensional radiation patterns are dignified on a spherical coordinate system indicating relative strength of radiation power in the far field sphere neighbouring the antenna. On the spherical coordinate system, the x-z plane (θ measurement where $\varphi = 0°$) usually indicates the elevation plane, while the x-y plane (φ measurement where θ = 0°) indicates the azimuth plane. Typically, the elevation plane will consist the electric-field vector (E plane) and the direction of maximum radiation, and the azimuth plane contain the magnetic-field vector (H plane) and the route of maximum radiation.

A two-dimensional radiation pattern is scheming on a polar plot with variable φ and θ respectively. Figure 2.6 illustrates a half-wave dipole and its three dimensional radiation pattern. The gain is expressed in dBi, which means that the gain is referred to an isotropic radiator. Figure 2.7 illustrates the 2 dimensional radiation patterns for varying θ at $\varphi = 0^0$ and changing. φ at $\theta = 90^0$, respectively.

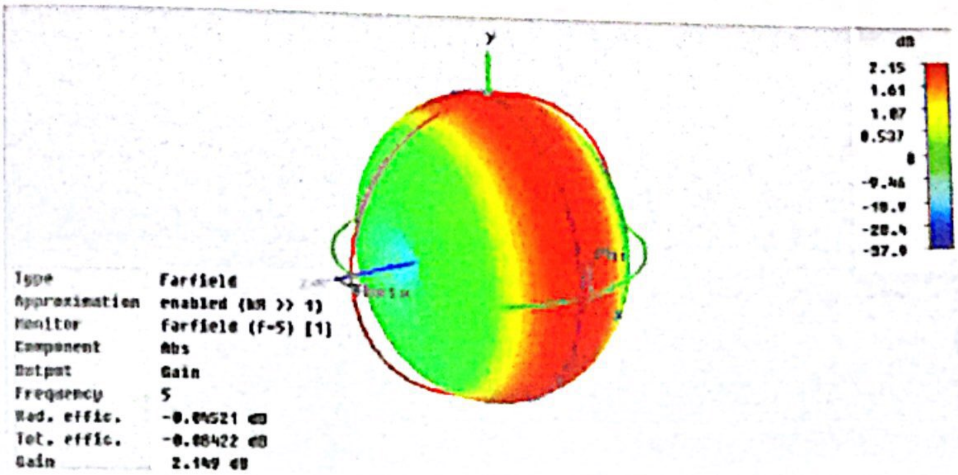


Figure 2.11 dipole model for simulation and simulated 3D radiation patterns Modelled in CST Microwave Studio [14]

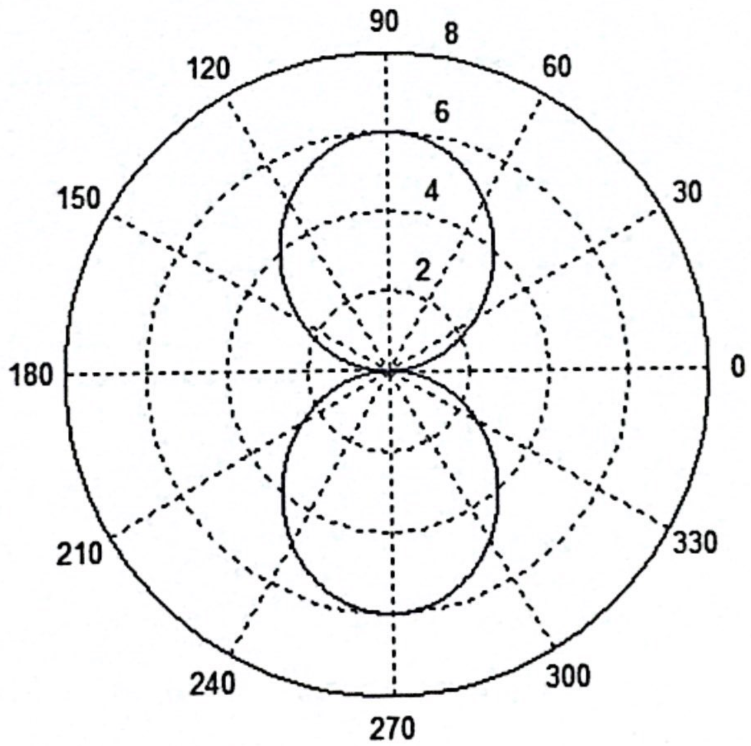


Figure 2.12 Two Dimensional radiation patterns are compulsory for half wave dipole. [15]

Both figures 2.6 and 2.7 is considered an omnidirectional radiator. The IEEE Standard Definition of Terms for Antennas describes an isotropic radiator as a lossless antenna having equal radiation in entirely way. Then, it has no nulls in the radiation pattern, and have 0 dBi directivity measurement.

2.5.3 Gain and Directivity

Directivity, D is the ratio of radiation intensity in a provided direction from the antenna to the radiation intensity averaged above all directions. Be that as it may,the directivity of no isotropic source is equal to the ratio of its radiation intensity in a provide direction over that of an isotropic source. In numerically form, it can be composed as

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}} \qquad (2.3)$$

If direction is not determined, maximum directivity is communicated as,D_{max}

$$Dmax = D_0 = \frac{Umax}{U_0} = \frac{4\pi Umax}{P_{rad}} \qquad (2.4)$$

Power Gain, G, is usually composed in the direction of the maximum radiation per unit area

$$G = \frac{\text{power radiated by an antenna}}{\text{Power radiated by a reference antenna}} \qquad (2.5)$$

2.5.4 Efficiency

The antenna efficiency mulls over the ohmic losses of the antenna over the dielectric material and the reflective losses at the input terminals. Reflection efficiency and radiation efficiency are mutually taken into interpretation to describe the total antenna efficiency. Reflection efficiency, or impedance mismatch efficiency, is straight connected to the S_{11} parameter (Γ). Reflection efficiency is specified by e_r and is distinct numerically as follows,

$$e_r = (1 - |\Gamma|^2) = \text{refelection efficiency} \qquad (2.6)$$

The radiation efficiency considers the conduction efficiency and dielectric efficiency, and is usually resolute experimentally with several measurements in an anechoic chamber. Radiation efficiency is resolute by the ratio of the emitted power,P_{rad} to the input power at the terminals of the antenna

$$,P_{in}\ e_{rad} = {}^{P_{out}}/_{P_{in}} = \text{radian efficiency} \qquad (2.7)$$

Total efficiency is basically the total of the radiation efficiency and the reflection efficiency. Rational values for total efficiency are between range of 60% - 90, while several commercial antenna reach only about 50-60% due to inexpensive, loss dielectric materials such as FR4.

2.5.5 Feeding Mechanism

Power can be united in or out of an antenna by a variety of methods that can be confidential to communicating and non-communicating [14]. Communicating feeds defined as a straight connection of a transmission lines, can be coax or microstrip lines to the patch antenna. The input impedance depends on the location of the connection within the patch boundaries [14].The electromagnetic field coupling is utilized to exchange the power between feed lines and the radiating patch. This sort is difficult to configuration yet give more level of freedom than contacting feed. Utmost general methods are microstrip lines, coaxial probe, aperture coupling and proximity coupling

2.5.5.1 Microstrip Line Feed

Microstrip line feed is a technique of a conducting strip is linked directly towards the edge of the microstrip patch as shown in figure 2.8. The conducting strip stands lesser in width compared to the patch. This kind of feeding has an advantage that the feed can be etched on the same substrate to provide a planar structure.

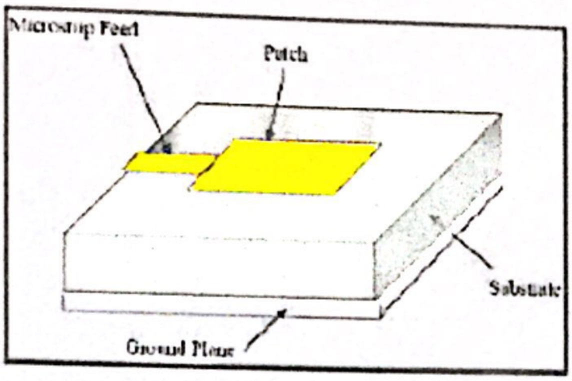


Figure 2.13 microstrip line feed

The purpose of inclusion cut of the patch is to coordinate the impedance between the feed line and the patch. Subsequently, it is easy to fabricate and simple to coordinate by controlling the inset position. One method of microstrip line feeding is Inset-fed, which is used for matching impedance of the feed line. This method can be done by an inset cut in the patch and that also controls the inset position, as shown in Figure 2.6.

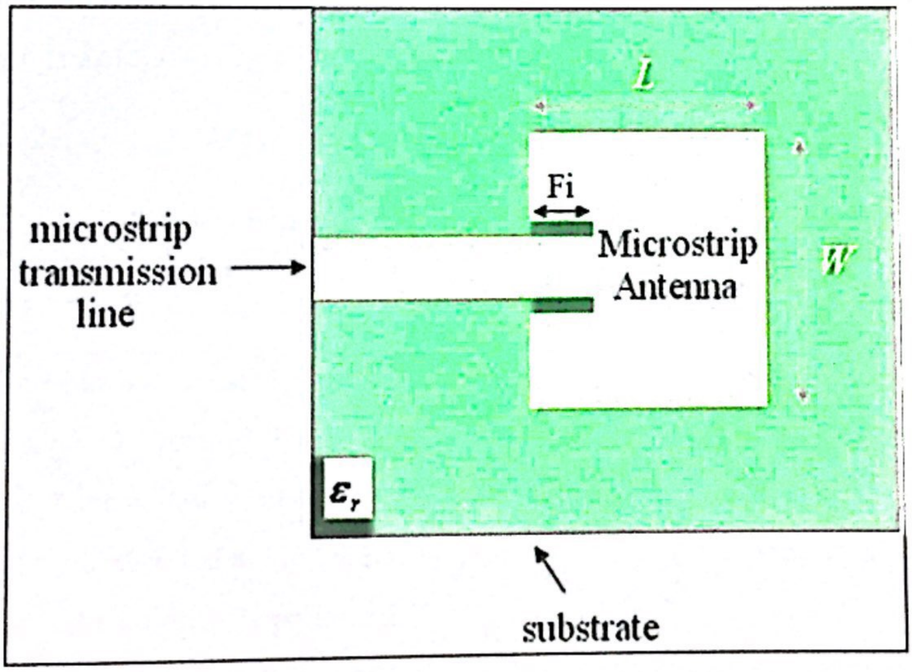


Figure 2.14 microstrip patch antenna with inset fed

By moving in a distance (Fi) from the edge of the patch, the current will increase by cos(π ×Fi/L). Meanwhile, the voltage will show as decrease in magnitude; however, the drop in magnitude is of the same amount as the increase in the current. Hence, the input impedance can be expressed in the analytical formula obtained from [14] and [15].

The formula is as follows:

$$R_{in}(y = Fi) = R_{in}(y = o)cos^2\left(\frac{\pi Fi}{L}\right) \qquad (2.8)$$

Where Z_{in} (0) is the input impedance if the patch was fed at the edge

Also the inset-feed length can be expressed in numerical formula obtained from [16].

The numerical formula is as follows:

$$Fi = \begin{pmatrix} 0.001699\times\varepsilon_r^7 + 0.13761\times\varepsilon_r^6 - 6.1783\times\varepsilon_r^5 + 93.187\times\varepsilon_r^4 \\ -682.69\times\varepsilon_r^3 + 2561.9\times\varepsilon_r^2 - 4043\times\varepsilon_r + 6697)\times\frac{L}{2} \end{pmatrix} \qquad (2.9)$$

Where ε_r dielectric constant and L is length of the patch

The microstrip patch antenna can also be matched to a microstrip line (characteristics impedance Z_o)by using a quarter-wavelength microstrip line (characteristics impedance Z1) as shown in Figure (2.7. The calculation for matching impedance for quarter wavelength is as follows:

$$Z_{in} = Z_o = (Z_1^2/Z_A) \qquad (3.0)$$

where ZA: is the impedance of the antenna

2.5.6 Polarization

The polarization of wave is defined as a wave transmitted or received by an antenna in a given direction. There are 3 types of polarization, which are linear, circular and elliptic. Linear polarized occurs when the electric field at a point in space as a function of time, directed along the line. When the electric field traces is an ellipse, the field is said to be elliptically polarized

2.5.7 S11 parameter

The S parameter are commonly used to show the results on the microstrip antenna or other design that used in the CST software. .It describes the input-output relationship between ports (or terminals) in an electrical system. For instance, if we have 2 ports (intelligently called Port 1 and Port 2), then S12 represents the power transferred from Port 2 to Port 1. S21 represents the power transferred from Port 1 to Port 2. In general, SNM represents the power transferred from Port M to Port N in a multi-port network. A port can be loosely defined as any place where we can deliver voltage and current. So, if we have a communication system with two radios (radio 1 and radio 2), then the radio terminals (which deliver power to the two antennas) would be the two ports. S11 then would be the reflected power radio 1 is trying to deliver to antenna 1. S22 would be the reflected power radio 2 is attempting to deliver to antenna 2. And S12 is the power from radio 2 that is delivered through antenna 1 to radio 1. Note that in general S-parameters are a function of frequency As an example, consider the following two-port network:

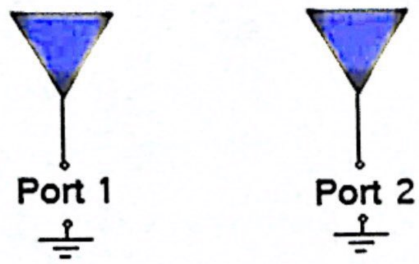


Figure 2.15 two port networks in S11 bands

In the above Figure, S21 represents the power received at antenna 2 relative to the power input to antenna 1. For instance, S21=0 dB implies that all the power delivered to antenna 1 ends up at the terminals of antenna 2. If S21=-10 dB, then if 1 Watt (or 0 dB) is delivered to antenna 1, then -10 dB (0.1 Watts) of power is received at antenna .If an amplifier exists in the circuitry, then S21 can show gain (i.e. S21 > 0 dB). This means that for 1 W of power delivered to Port 1, more than 1 W of power is received at Port 2.In practice, the most commonly quoted parameter in regards to antennas is S11. S11 represents how much power is reflected from the antenna, and hence is known as the reflection coefficient (sometimes written as gamma: Γ or return loss. If S11=0 dB, then all the power is reflected from the antenna and nothing is radiated. If S11=-10 dB, this implies that if 3 dB of power is delivered to the antenna, -7 dB is the reflected power. The remainder of the power was "accepted by" or deliver to the reflected power. The remainder of the power was "accepted by" or deliver to the antenna. This accepted power is either radiated or absorbed as losses within the antenna. Since antennas are typically designed to be low loss, ideally the majority of the power delivered to the antenna is radiated.

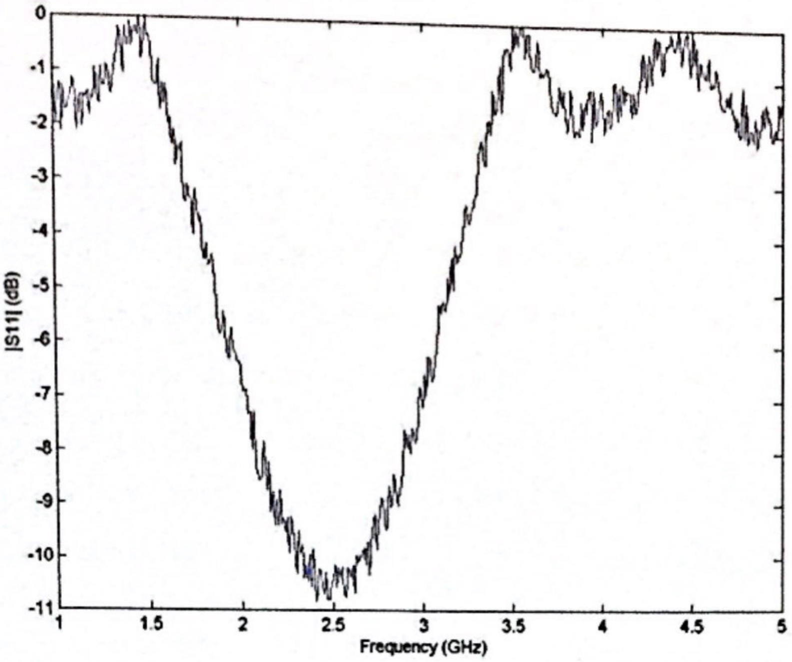


Figure 2.16 the S11 parameter at 2.5Ghz

The above would typically be measured using a Vector Network Analyser (VNA), which can plot S11. The above figure implies that the antenna radiates best at 2.5 GHz, where S11=-10 dB. Further, at 1.5 GHz the antenna will radiate virtually nothing, as S11 is close to 0 dB (so all the power is reflected). The antenna bandwidth can also be determined from the above figure. If the bandwidth is defined as the frequency range where S11 is to be less than -6 dB, then the bandwidth would be roughly 1 GHz, with 3 GHz the high end and 2 GHz the low end of the frequency band.

2.5.8 Substrate Material

The relative permittivity, $\varepsilon_r$of dielectric substrate is in range 1 to 10. Each material has its own value of dielectric permittivity. There are some important parameters of dielectric substrate in order to design the micro strip transmission line, which are

- Dielectric constant
- Dielectric loss tangent

In this project, two different fabric are used which is denim and Felt fabric as a substrate. The advantages of denim are long wearing, easy-care clothing, and cheap. It was made from a 100 percent of cotton. However, there are denim textiles that are composed of cotton blends. The base cotton fibres are woven with spandex, silk, and metallic threads. Denim clothing never goes out of style. It is perfect for most casual occasions denim most common as the fabric in many clothes such as for shirts, jackets, skirts, dresses, handbags and more .Then, another type of fabric used is Felt. The conducting material "Felt"' has a high-quality nylon based substrate and is plated with copper and tin with a conductivity of 1 + 006 S/m. Its thickness is 0.06 mm with a manufacturer's surface resistivity specification lower than 0.01 ohm/square, which is excellent for creating efficient antennas and RF circuits at wireless communication frequencies. Also Felt fabric is durable, tear resistant, and is easy to form and handle. From a manufacturing point of view, it can be cut using laser ablation into a precise shape, also it can conform to any shape and be sewn like ordinary fabric to make highly effective clothing structures. Therefore, for all the antennas and structures used in this project, the woven conductive fabric, felt, was used. In this project most of the structures were hand cut and either sewn together or tacked to each other using a very thin spray adhesive. No losses were detected due to the adhesive layer. However, denim and Felt fabric are chosen become the substrate

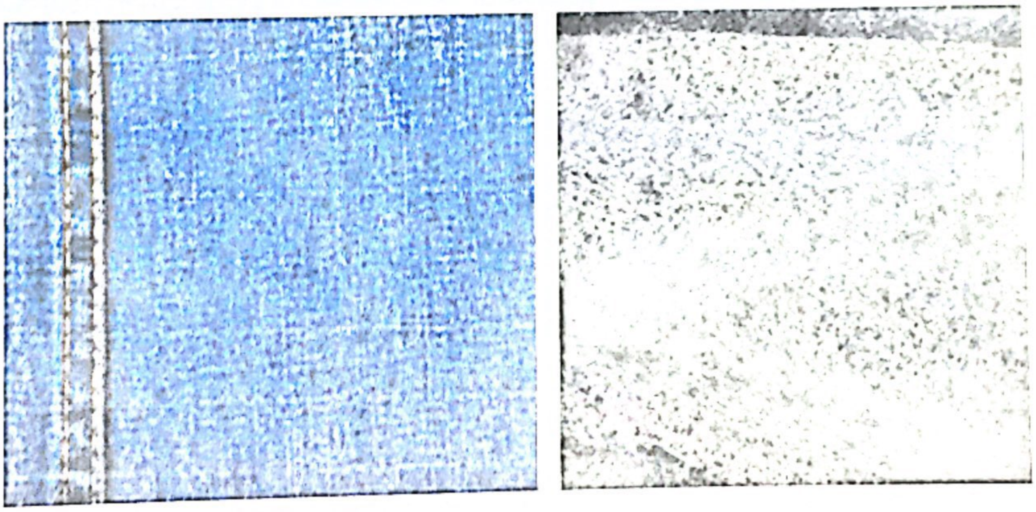


Figure 2.17 denim and felt textile fabric

2.5.9Microstrip Transmission Line design Equation

In order to design the microstrip transmission line, some of the parameters need to be considered first such as effective dielectric constant and characteristic impedance.

2.5.9.1 Effective Dielectric Constant

In homogeneous structure, effective dielectric constant is the same as the dielectric constant. However, this is not applicable to the inhomogeneous structure. There are ways to calculate the effective dielectric constant. The figure 2.10 shows the wide and narrow width microstrip line. Shows the different cases mentioned. The first case is when the width of the microstrip line, W is greater than the thickness of the substrate, h which is illustrated in upper figure. The figure at the bottom shows when the condition where the width of the microstrip line, W is lower than the thickness of the substrate, h.

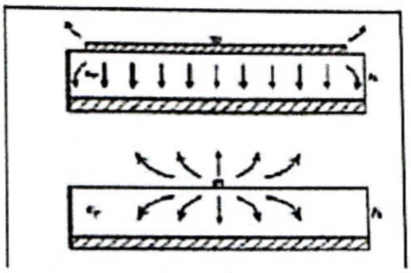


Figure 2.18 wide and narrow width microstrip Line [14]

The effective dielectric constant of the microstrip line can be approximated by [14]

$$\frac{1}{2}(\varepsilon_r + 1) \leq \varepsilon_{eff} \leq \varepsilon_r \qquad (2.8)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\left[1 + \frac{12}{w/h}\right]^{\frac{1}{2}} + +0.04\left[1 - \frac{w}{h}\right]\right] \; for \; \frac{w}{h} \leq 1 \quad (2.9)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1 + 12\frac{h}{w}\right) - \frac{1}{2} \text{ for } \frac{w}{h} \geq 1 \qquad (2.10)$$

2.5.9.2 Characteristic Impedance

The characteristic impedance, Z0 is defined as the ration of voltage and current of a travelling wave. The characteristic impedance can be calculated through the following two equations given the width of the microstrip line, W:

$$Z_0 = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{8h}{w} + \frac{w}{4h}\right) \; for \; \frac{w}{h} \leq 1 \; (2.11)$$

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}\left[\frac{W}{h} + 1.393 + 0.667 \ln\left(\frac{W}{h} + 1.444\right)\right]}} \; for \frac{W}{h} \geq 1$$

CHAPTER 3

METHODOLOGY

3.1 Introduction

The research was conducted by the method of this methodology. It plays an important role as implementing the appropriate research studies and will be described the detailed in this chapter. There a lot of tests and researches are required to get this project well done. A work flow is made from the beginning to make sure the project is done on time. Figure 3.1 below, shows the work flow of this project. The figure summarizes all the work that will be done throughout the process to complete the circular patch wearable antenna. First of all, research via internet, books, and IEEE paper are done on properties of circular patch antenna. This is to further understanding about fundamental, theory and properties of the antenna. The research on circular patch antenna has to be completed to know the overall designing process. Then, designing and simulation is done using CST Studio Suite. In the earlier stage, circular patch antenna is design. The two of fabric which is denim and felt as a substrate is used for this design. The value of permittivity of the substrate is get from the IEEE paper. The process is continued by altering the shape of the patch. To achieve the best performance of the antenna, the simulation result is optimized. The return loss of the circular antenna is being recorded in the CST software. The gain and far field is also recorded and being compared between two software. The gain and far field is also recorded and being compared between two different textiles materials in the software. The current distribution n the two different materials is being observed and recorded at the CST software's to determine the effectiveness of the antenna.

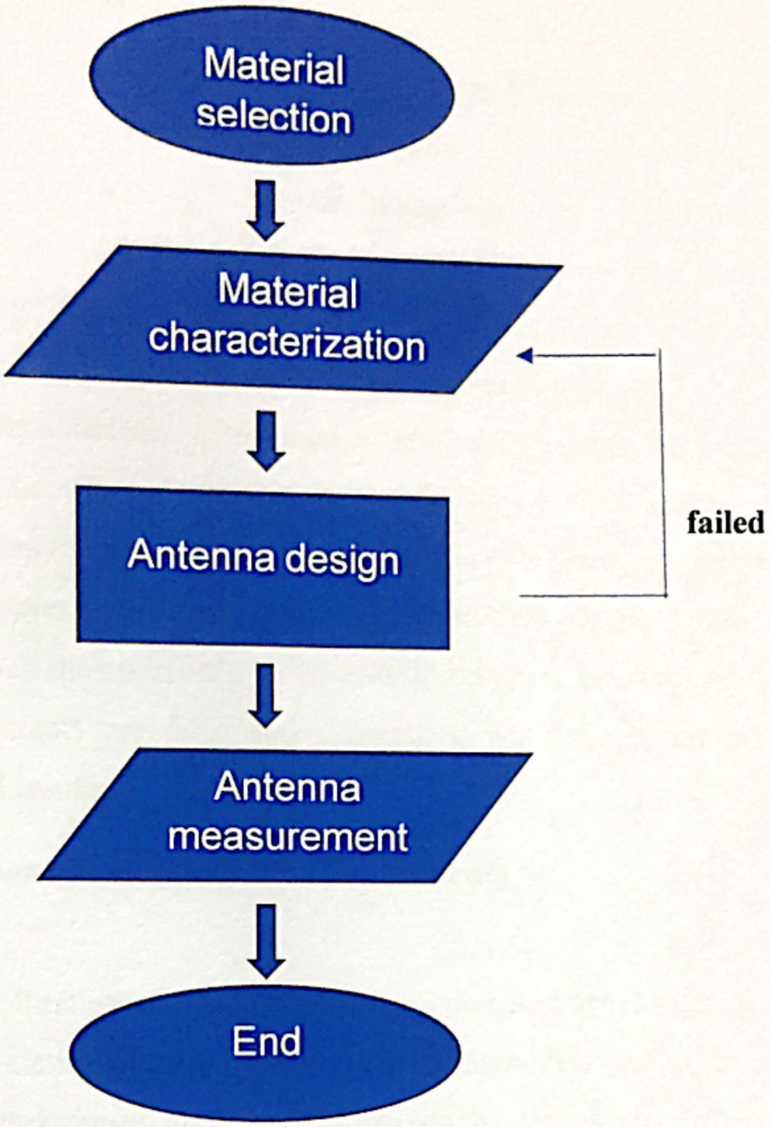


Figure 3.1 flow chart of the project

The researcher begins the project work by reviewing literature related to the fundamentals about patch antenna. This is to obtain information and insight relevant to this project work. The data collected from the research papers are categorized into design parameters for antenna design, methodology outcome, the antenna design parameters of the research and contribution to future work. This is followed by an investigation into the antenna design parameters, before proceeding to designing the antenna with CST software. The specification of the antenna design begins with determining the patch shape of the antenna. The rectangular patch shape is chosen for the design due to its simplicity. The patch length is obtained from Equation 4.5. The substrate utilized in the design are denim and felt textiles, with substrate thickness of

2mm and 1.5mm and its dielectric constant, are 1.69 and 1.38. Taking into account the fringing of electric field around the patch antenna, as described in Chapter 2, the effective dielectric constant is calculated using Equation 2.18, which yields ere f f = 3.994. The design begins with a basic rectangular microstrip patch antenna printed on one side of the denim, felt substrate and ground plane on the other side. Due to its narrowband characteristic, detailed investigations are conducted on antenna design parameters such as patch shape and feedline width. Each parameter is modified to allow the antenna to exhibit characteristics of rectangular patch antenna. Various parameters are used to investigate the effects on the return loss of antenna, S11 and impedance bandwidth. The generation of antenna designs and findings of the antenna performance are carried out in Computer Simulation Technology (CST) microwave studio, 2016. Suitable designs were then chosen in order to fabricate the antenna. Once the fabrication is completed, measurements are done and simulations are done to compare the simulated and measured results.

3.2 Simulation of Antennas Using CST Microwave Studio

CST Microwave Studio® (CST MWS) (Release version 2016) is a professional tool for the 3D EM simulation of high frequency components. It is one of the reliable computer-aided design techniques, many researchers use this technique to improve the characterization and modelling of microwave structures. The unparalleled performance of CST MWS makes it the first choice among researchers in technology leading departments of Research and Development (R&D). CST MWS is a full 3D high frequency 3D EM simulator that combines unbelievably fast and accurate high frequency 3D EM analysis and simulation in the time domain. Its intuitive, yet powerful solid modelling interface, provides brilliant graphics that quickly give the users the insight into EM behavior of the high frequency designs [13]. CST Microwave Studio® (CST MWS) offers users a choice of five powerful solver modules; Time Domain Solver, Frequency Domain Solver, Eigenmode Solver, Integral Equation Solver, Multilayer Solver and Asymptotic Solver. Each module offers distinct advantages in its own domains.

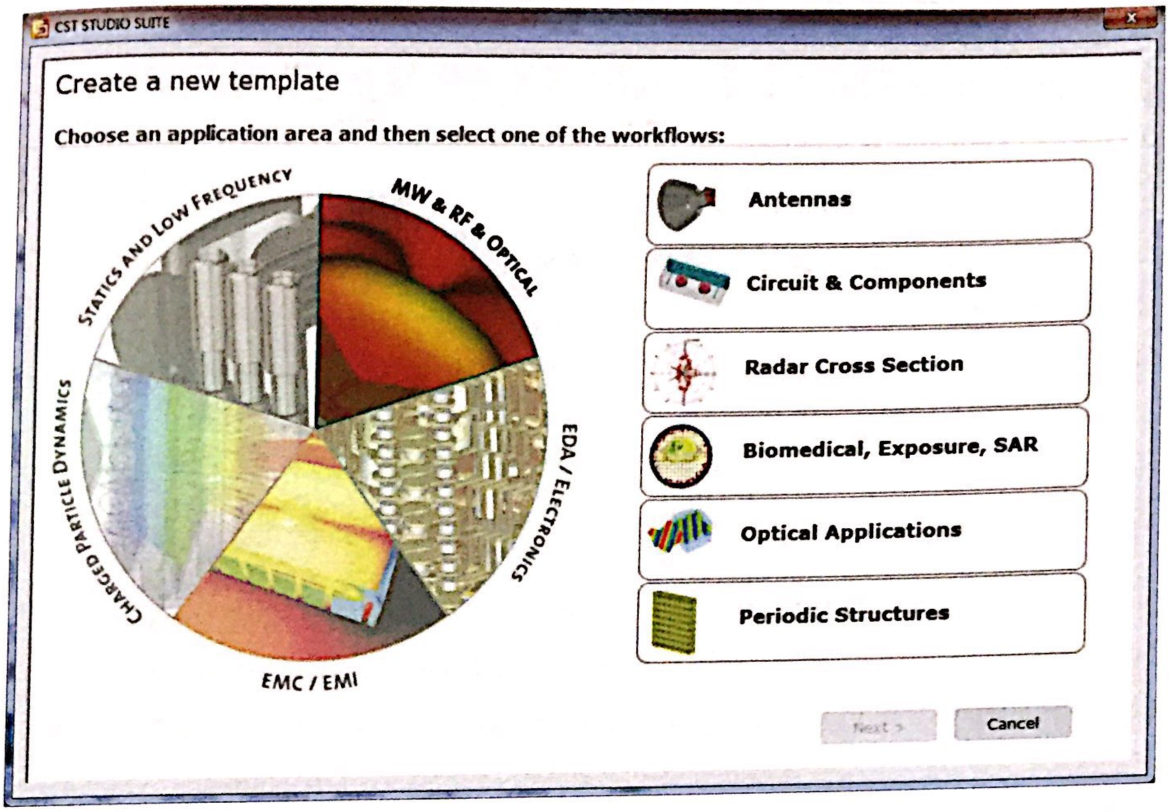


Figure 3.2 CST Studio suite environments

CST MWS is the first commercial high frequency EM simulation code that offers the advantages of both Cartesian and tetrahedral meshing in one 3D EM simulator. Users are able to choose the method (Method on demand TM) and the mesh (Mesh on demand TM) that best suits a particular structure. This beneficial feature allows the combination of innovations such as Perfect Boundary Approximation (PBA)® (1998) and the Thin Sheet Technique (TST)TM(2001). These techniques provide very accurate approximation and easy meshing. The PBA technique is applied to the Finite Integration Technique (FIT) algorithm that maintains all the advantages of structured Cartesian grids while allowing for accurate modelling of curved structures. Lately TST is used to improve the finite integration method whereby perfectly thin electric conducting sheets are used to enhance the model. CST MWS is used to perform all the simulations involving rectangular patch antennas in this project, because of its high frequency range time domain calculations. The Time Domain Solver is chosen for the antenna simulations, as it can be applied to solve most electromagnetic field problems. This solver allows users to monitor various results for radiation patterns, return loss (S11), input impedance and Smith's chart. In CST Microwave Studio, the structure of the both antenna are drawn on the two different chosen of substrate block, Denim textile with a dielectric constant of 1.69 while felt textile with dielectric constant of 1.38 . An appropriate mesh size is applied to obtain the approximation of the antenna parameters. After several tunings and simulations of the design structure is tuned and simulated several times to obtain desired results, when this happens the mesh cells is increased. The simulations are repeated with the new mesh size to obtain accurate sample results. This is because the increase in mesh size increases the simulation time, due to the complexity of the structure

3.2 rectangular patch Antenna Design

3.2.1 Design Specification

The essential parameter for the design of a rectangular patch antenna is the frequency of operation (f) of the antenna. It must be compatible for medical application which is 5.8GHz. The resonant frequency selected for the design of this research study is 5.8 GHz. The dielectric constant of the dielectric material selected for the design are denim and felt textiles substrate with a dielectric constant (er) of 1.69 and 1.38 . This substrate is selected because of its availability in the laboratory in UKM. The height of the dielectric (h) are 2mm and 1.5 mm and the height of the copper conductor (t) is 1 mm, hence, the three essential parameters for the design of this research study are:

- f = 5.8 GHz
- er = 1.69
- er =1.38
- h = 2 mm
- h=1.5mm
- t = 1mm

The design specifications are shown in table 3.1

Parameter	Value
Operating frequency range	2.5 - 6Ghz
Return loss	Less than 10dB
Radiation Pattern	Directional
Polarization	Linear
Gain	Low
Transmission Line	Microstrip line
Half power beam	Wide (>60%)
Physical profile	Small, compact, Planar

Table 3.1 Design Specification

3.2.2 Material Specification

The substrate use in this project which are denim jeans and Felt textile. The specifications of transmission line.

The substrate are listed in Table 3.2 and Table 3.3

Material	**Values**
Thickness(mm)	2
Dielectric Constant, ε_r	1.7
Loss Tangent	0.025

Table 3.2 Electrical Properties of Denim textile [5]

Material	Values
Thickness(mm)	1.5
Dielectric Constant, ε_r	1.38
Loss Tangent	0.025

Table 3.3 Electrical properties of Felt textile [6]

3.3 Design Procedure

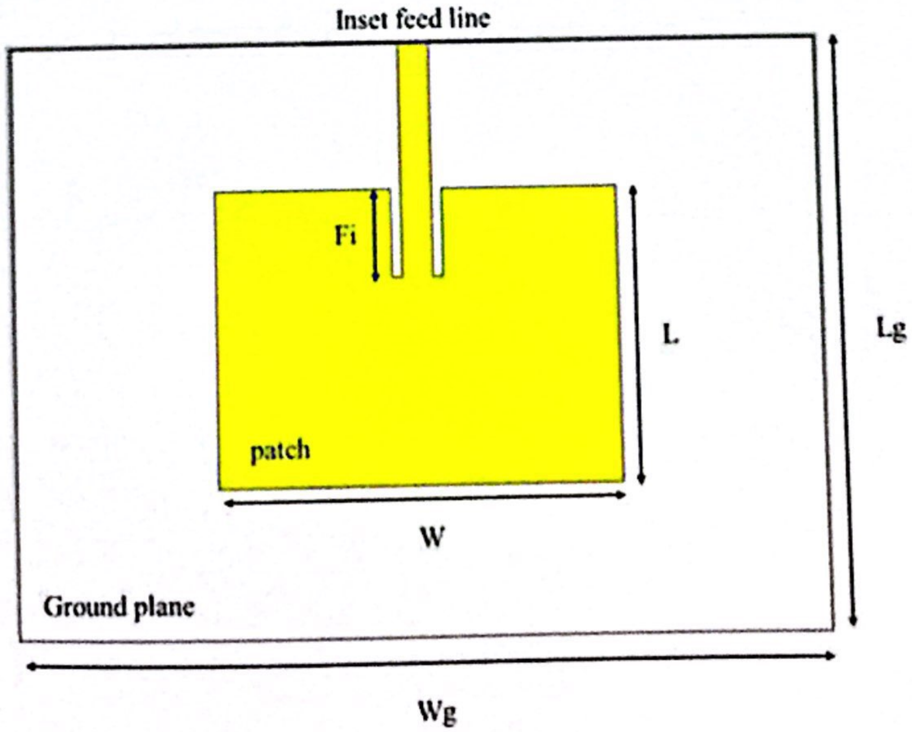


Figure 3.3 front view of rectangular patch antenna

3.3.1 Calculation 1st design of the rectangular patch antenna by using denim textile

Equation 3.1 shows the calculation of the width of the microstrip patch antenna for the 1st design

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_0+1}{2}}} \qquad (3.1)$$

By substituting C = 3×10^{8}m/s, f∘ = 5.8GHz and ε_r = 1.69,

W = 30.7mm.

The calculation of effective dielectric constant (ε_{reff}) can be obtained from equation 2.18 as:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r+1}{2}\left[1 + 12\left(\frac{h}{w}\right)\right] - 0.5 \qquad (3.2)$$

By substituting ε_r= 1.69 , W = 30.7 and h = 2mm,

$$\varepsilon_{reff} = 3.866$$

The calculation of the effective length (L_{eff}) can be obtained from Equation 2.21.

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \qquad (3.3)$$

By substituting C = 3×10^{8}m/s, f∘ = 5.8GHz and ε_{reff}= 3.866mm,

$Leff$= 25.27mm.

The calculation of the fringing length (ΔL) can be obtained from Equation 2.19.

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}-0.8\right)} \qquad (3.4)$$

By substituting = 30.7mm, ε_{reff}= 3.866mm and h = 2mm,

$$\Delta L = 0.751mm.$$

The calculation of actual length of the patch (L) can be calculated from Equation 2.20

$$L = Leff - 2\Delta L \qquad (3.5)$$

By substituting values of $Leff$= 25.27 mm, and ΔL = 0.751mm,

$$L = 23.77\text{mm}.$$

To calculate the length of ground planeL_g using Equation 4.6,

$$L_g = 2\text{L}. \qquad (3.6)$$

To calculate the width of ground plane, Wg using equation 4.7.

$$W_g = 2W \qquad (3.7)$$

Figure 3.1 illustrates the dimensions of the desired patch antenna

3.3.2 Determinations of the Inset-fed for 1st design by using denim textile

Figure 4.2 shows the inset-fed which was used for the designed antennas. It is placed on top of the patch lengthwise, where the input impedance is 50W for the resonance frequency with a gap (Gpf) between the patch and the inset-fed. The width of the inset-fed (wf) can be calculated using the following equation 2.23, is given by

$$Z_o = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln\left(\frac{5.98h}{0.8wf + t}\right) \text{h} < 0.8wf \qquad (3.8)$$

By substituting values of Z∘ = 50ohm, h = 2mm and ε_{reff}= 3.866,

The width of the inset-fed (wf) can also be obtained by using the CST Microwave Studio from the calculate tool.

The length inset of the patch for microstrip line (Fi) can be calculated using Equation 2.15,is given by.

$$Fi = \begin{pmatrix} 0.001699\times\varepsilon_r^7 + 0.13761\times\varepsilon_r^6 - 6.1783\times\varepsilon_r^5 + 93.187\times\varepsilon_r^4 \\ -682.69\times\varepsilon_r^3 + 2561.9\times\varepsilon_r^2 - 4043\times\varepsilon_r + 6697)\times\frac{L}{2} \end{pmatrix} \quad (3.9)$$

By substituting values of er = 1.69 and L = 23.77mm,

Fi = 6.29

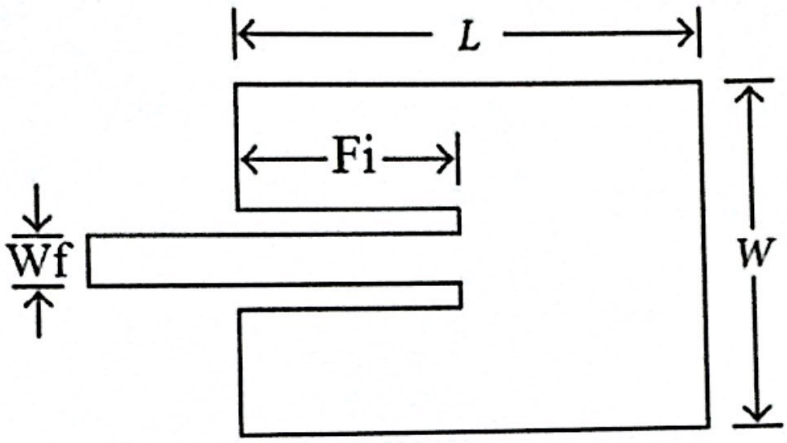


Figure 3.4: front view of rectangular patch with inset feed

The antenna is designed to operate at a resonance frequency (f_o = 5.8GHz) with denim textile dielectric substrate material, (ε_r = 1.69) which is suitable for ISM band for medical application

Table 4.1 shows as the initial parameters of the rectangular patch antenna design. The value of the parameters are obtained from the calculation of Equation 3.5, 3.1, 3.9 and 3.8.

Parameters	Value(mm)
L	23.7
W	30.7
Fi	6.29
Wf	5.5

Table 3.4 initial dimension of single patch antenna

3.3.3 Calculation 2nd design of the rectangular patch antenna by using felt textile

Equation 3.2 shows the calculation of the width of the microstrip patch antenna for the 2nd design

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_0+1}{2}}} \qquad (3.10)$$

By substituting C = 3×10^8m/s, f∘ = 5.8GHz and ε_r = 1.38,

W = 28.7mm.

The calculation of effective dielectric constant (ε_{reff}) can be obtained from equation 2.18 as:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r+1}{2}\left[1+12\left(\frac{h}{w}\right)\right](-0.5) \quad (3.12)$$

By substituting ε_r= 1.38, W = 30.7 and h = 1mm,

$$\varepsilon_{reff} = 3.566$$

The calculation of the effective length (L_{eff}) can be obtained from Equation 2.21.

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \qquad (3.13)$$

By substituting C = 3×10^8m/s, f∘ = 5.8GHz and ε_{reff}= 3.566mm,

$Leff$= 22.27mm.

The calculation of the fringing length (ΔL) can be obtained from Equation 2.19.

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}-0.8)} \qquad (3.14)$$

By substituting = 28.7mm, ε_{reff}= 3.566mm and h = 2mm,

$$\Delta L = 0.751mm.$$

The calculation of actual length of the patch (L) can be calculated from Equation 2.20

$$L = Le\,f\,f - 2\Delta L \qquad (3.15)$$

By substituting values of $Le\,ff$= 25.27 mm, and ΔL = 0.751mm,

$$L = 23.77\text{mm}.$$

To calculate the length of ground planeL_g using Equation 4.6,

$$L_g = 2\text{L}. \qquad (3.16)$$

To calculate the width of ground plane, Wg using equation 4.7.

$$W_g = 2W \qquad (3.17)$$

Figure 3.1 illustrates the dimensions of the desired patch antenna

3.3.4 Determinations of the Inset-fed for 2nd design by using felt textile

Figure 4.3 shows the inset-fed which was used for the designed antennas. It is placed on top of the patch lengthwise, where the input impedance is 50ohm for the resonance frequency with a gap (Gpf) between the patch and the inset-fed. The width of the inset-fed (wf) can be calculated using the following equation 2.23, is given by

$$Z_o = \frac{87}{\sqrt{\varepsilon_r+1.41}}\ln\left(\frac{5.98h}{0.8wf+t}\right) \text{h} < 0.8wf \qquad (3.18)$$

By substituting values of Z∘ = 50ohm, h = 1mm and ε_{reff}= 3.566, The width of the inset-fed (wf) can also be obtained by using the CST Microwave Studio from the calculate tool.

The length inset of the patch for microstrip line (Fi) can be calculated using Equation 2.15,is given by.

$$Fi = \begin{pmatrix} 0.001699\times\varepsilon_r^7 + 0.13761\times\varepsilon_r^6 - 6.1783\times\varepsilon_r^5 + 93.187\times\varepsilon_r^4 \\ -682.69\times\varepsilon_r^3 + 2561.9\times\varepsilon_r^2 - 4043\times\varepsilon_r + 6697)\times\frac{L}{2} \end{pmatrix} \quad (4.19)$$

By substituting values of ε_r = 1.69 and L = 23.77mm,

Fi = 6.14

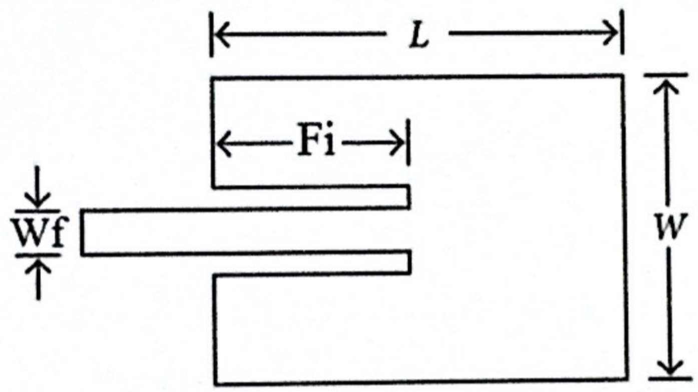


Figure 3.5: front view of rectangular patch with inset feed

The antenna is designed to operate at a resonance frequency (f_o = 5.8GHz) with denim textile dielectric substrate material, (ε_r = 1.38) which is suitable for ISM band for medical application

Table 4.1 shows as the initial parameters of the rectangular patch antenna design. The value of the parameters are obtained from the calculation of Equation 4.10, 4.12, 4.19 and 4.18.

parameters	Value(mm)
L	23.77
W	28.77
Fi	6.14
Wf	5.3

Table 3.5 initial dimensions of the 2nd rectangular patch

Both parameters were modified and optimized until get the accurate result for 5.8GHz

3.3.5 Modification from rectangular Patch (1st Design) for denim textile

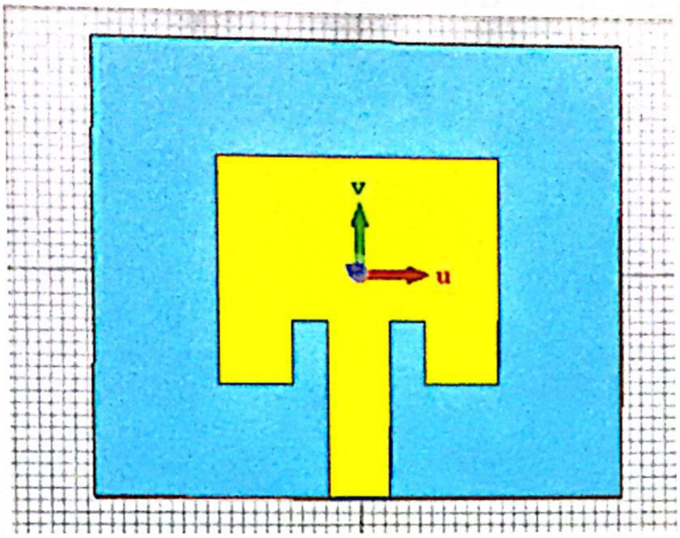


Figure 3.6(a) front of the rectangular microstrip patch

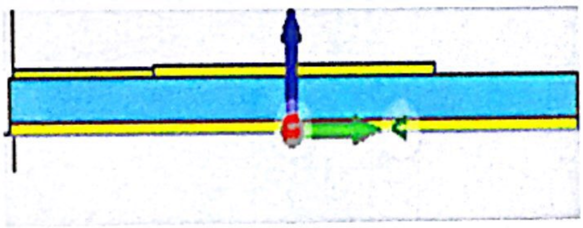


Figure 3.6(b) side view of the rectangular patch

Figures above show the front and side overview of the antenna. The dimension of the denim substrate is 40 x 40mm. the length of the patch of this antenna is 18.8mm.the dimension of the ground plane is 37.6mm x 44.6mm.The dimension of the microstrip patch is 22.7mm x 18.8mm. This antenna is more compact than the other antenna that have been designed in this project. The table below shows the parameters that been optimized in order to get the accurate value.

Parameters	Optimized value(mm)
W	22.7
L	18.8
Fi	5.29
Wf	5.1
Gpf	3

Table 3.6: optimized dimensions of the rectangular patch antenna

3.3.6 Modification from rectangular Patch (2nd Design) for felt textile

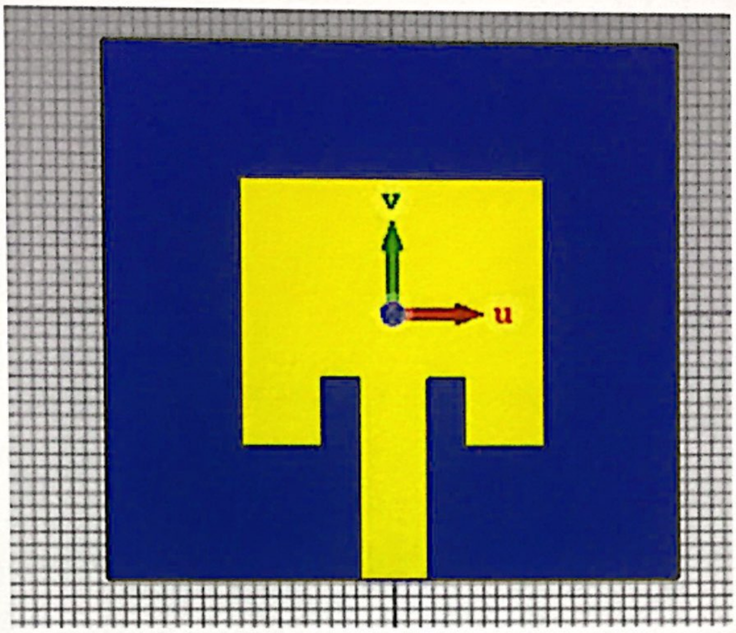


Figure 3.7(a) front view of the rectangular patch

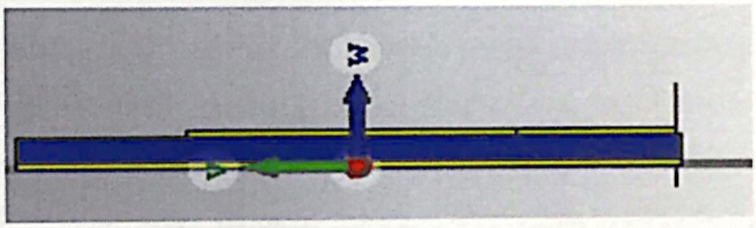


Figure 3.7(b) side view of the rectangular patch

Figures above show the front and side overview of the antenna. The dimension of the felt substrate is 23.7 x 20.6mm. The length of the patch of this antenna is 20.6 mm.the dimension of the ground plane is 23.7mm x 20.6mm.The dimension of the microstrip patch is 22.7mm x 18.8mm. This antenna is more compact than the first antenna that have been designed in this project. The table below shows the parameters that been optimized in order to get the accurate value in Simulation Process.

Parameters	Optimized value(mm)
W	23.7
L	20.6
Fi	5.29
Wf	5.2
Gpf	3

Table 3.7 the optimized value of the 2nd rectangular patch antenna

CHAPTER 4

RESULT, ANALYSIS AND DISCUSSION

4.1 Introduction

The fundamental aim for this is to develop a micro strip wearable antenna which can cover the frequency at 5.8GHz. The antenna designs were obtained previously. All the antennas remained methodical as previous chapter. The performances of the antenna were studied in two different methods; the first one is by simulation and after that by measurement. There are three types of results will be discussed in this chapter such as return loss, return loss and current distribution. The powerful simulation software, CST Microwave studio, is a specialized toll for the fast and accurate 3D EM simulation of high frequency problems. It can generate result of return loss and also the radiation pattern as well. The 3D polar plot of the antenna also can be observed.

4.2 1st design of rectangular antenna by using denim textile

4.2.1 Simulated the return loss

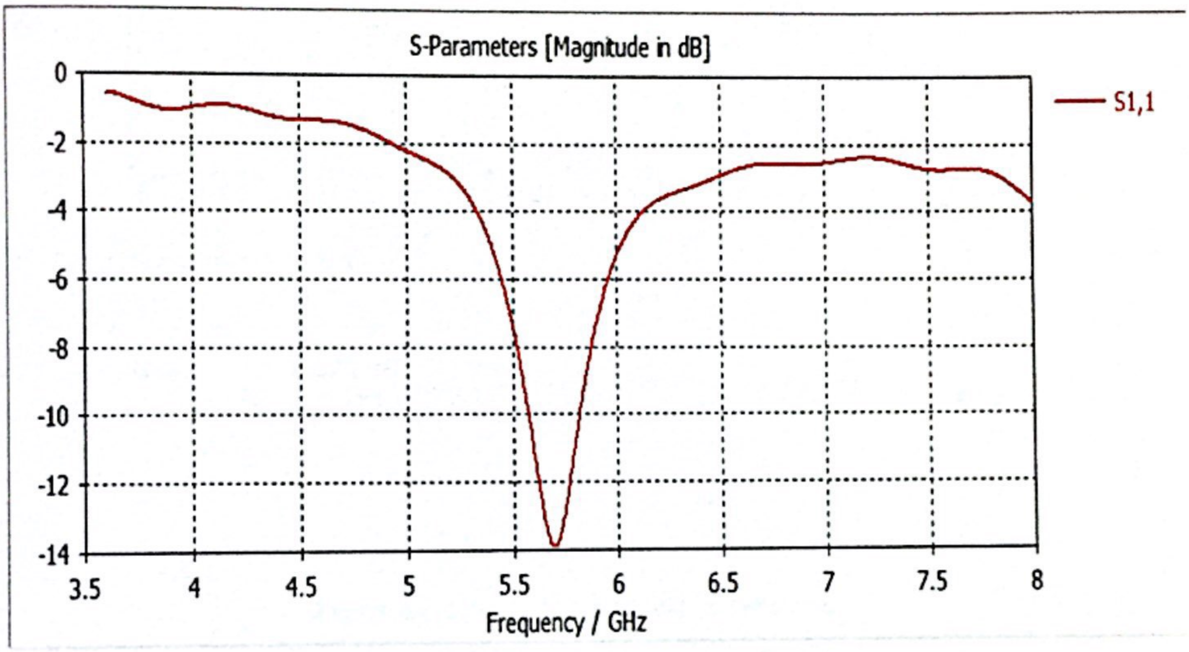


Figure 4.1 below shows the comparison between simulations for return loss

Figure above shows that the comparison between simulation results. For the simulation result, the antenna operates at 5.8 GHz. From the figure above. The bandwidth for measured result is 150MHz. Besides that, the gain for the measured result below -10dB which is -15.41db that follow the ISM band in medical application.

4.2.2 simulated gain

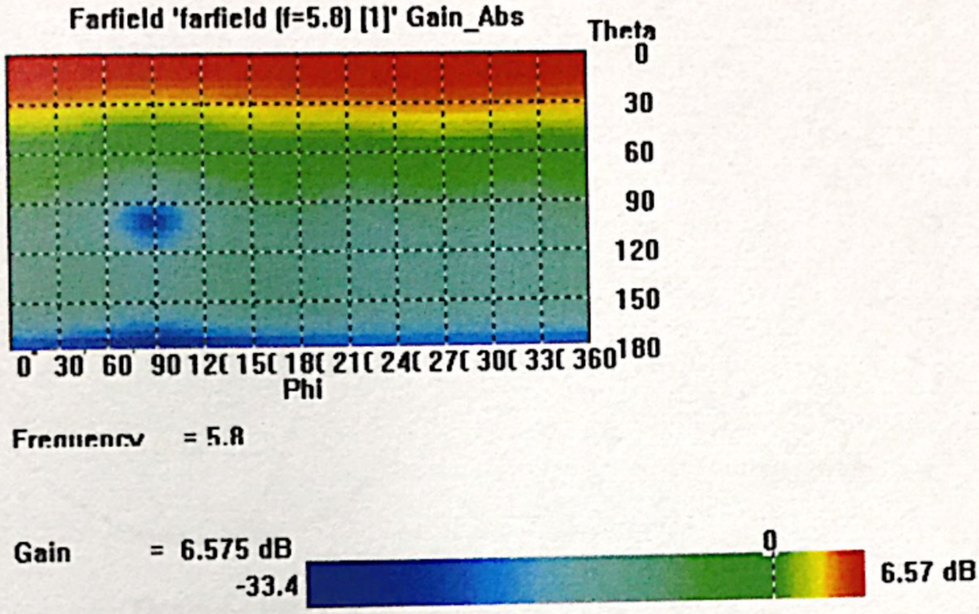


Figure 4.2 simulated gain for denim substrate

Figure above shows that the comparison between simulation results. For the simulation result, the antenna operates at 5.8Ghz. From the figure above.the gain of the denim substrate is 6.57db.

4.2.3 simulated radiation pattern for denim substrate

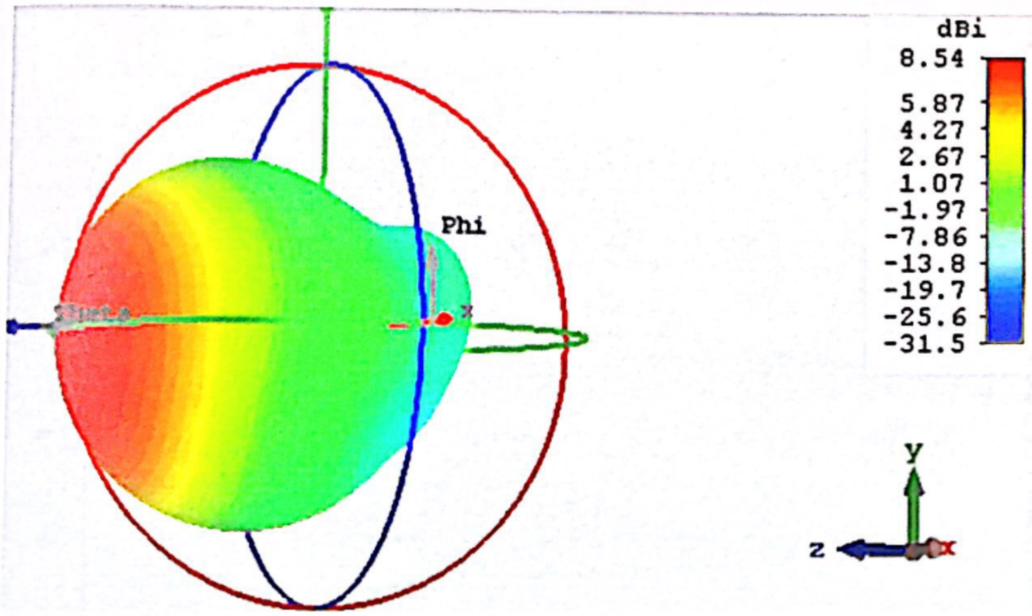


Figure 4.3 the radiation pattern for denim substrate in 3D

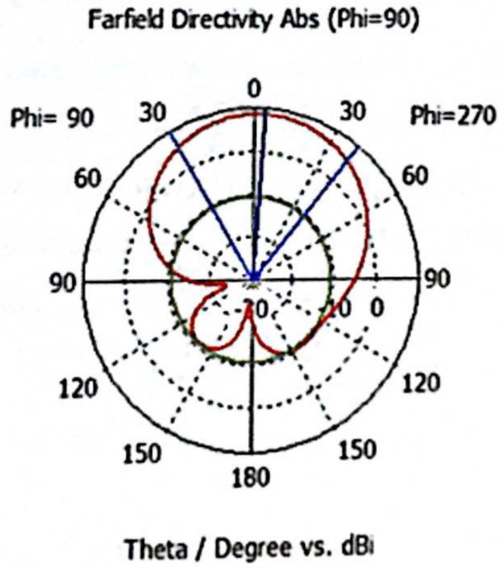


Figure 4.4 the radiation pattern in 2D

Figure above shows that the simulation results. For the simulation result, the antenna operates at 5.8Ghz. From the figure above.the gain of the denim substrate is 8.54db.The radiation pattern is quite orthogonal from the 360 axis.

4.3 2nd Antenna Design by using felt textile

4.3.1 simulated return loss

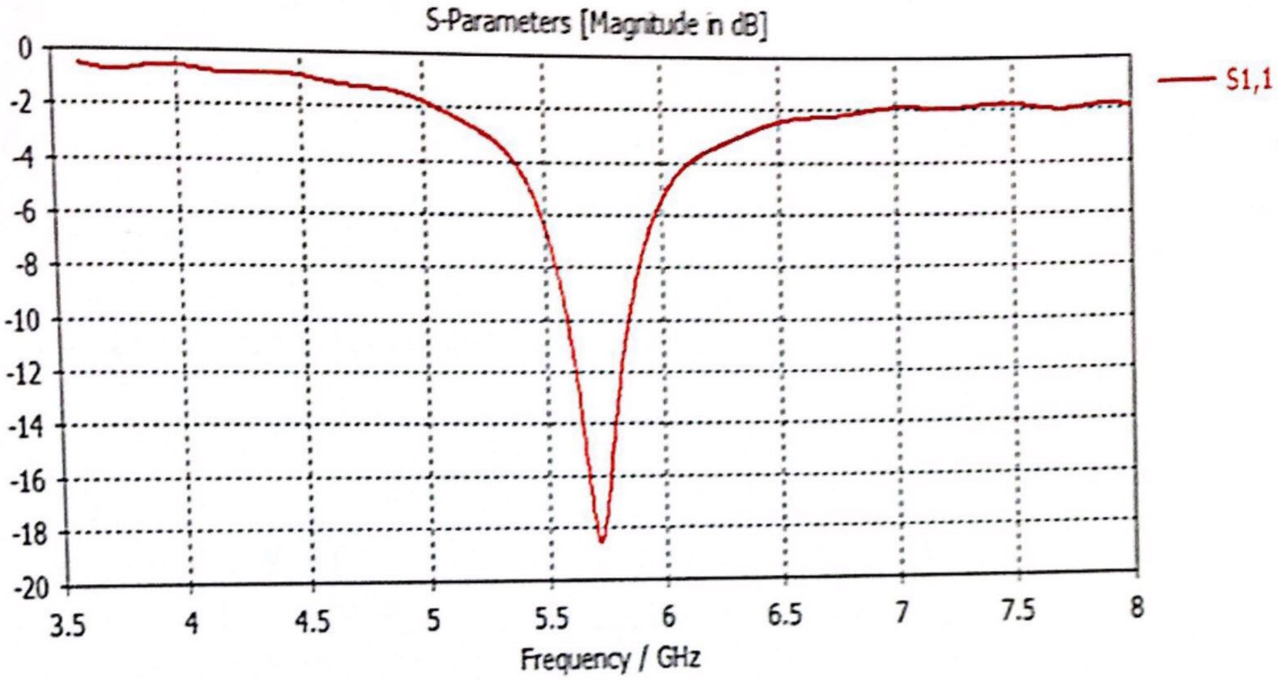


Figure 4.5 simulated retrun loss for felt textile

Figure above shows that the comparison between simulation results. For the simulation result, the antenna operates at 5.8GHz. From the figure above. The bandwidth for measured result is 90MHz lower than 1st design result which is 150MHz. Besides that, the gain for the measured result below -10dB which is -18.34 db that follow the ISM band in medical application

4.3.2 simulated gain

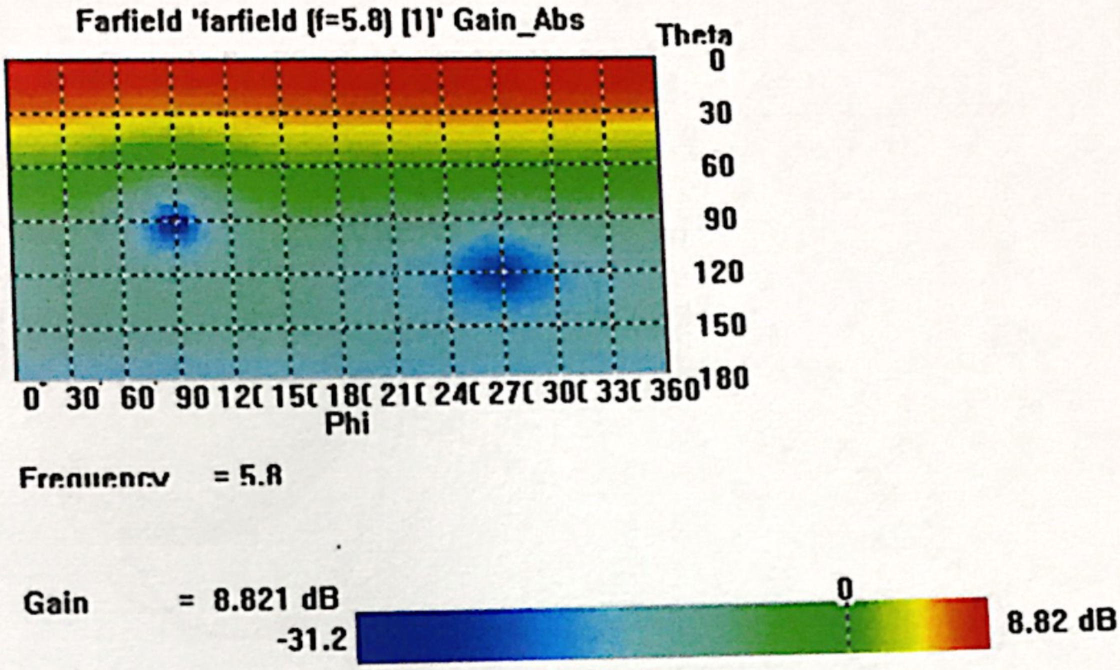


Figure 4.6 the simulated gain for felt textiles

Figure above shows that the comparison between simulation results. For the simulation result, the antenna operates at 5.8Ghz. From the figure above.the gain of the denim substrate is 8.82 db.

4.3.3 simulated raditaion pattern on felt textile

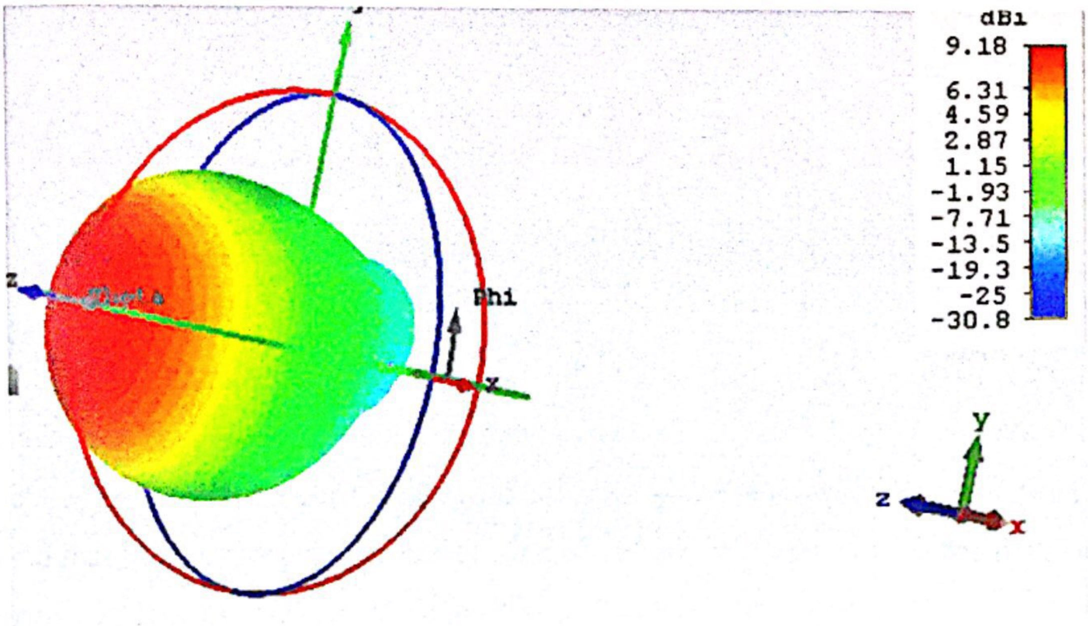


Figure 4.7 the simulated radiation pattern in 3D

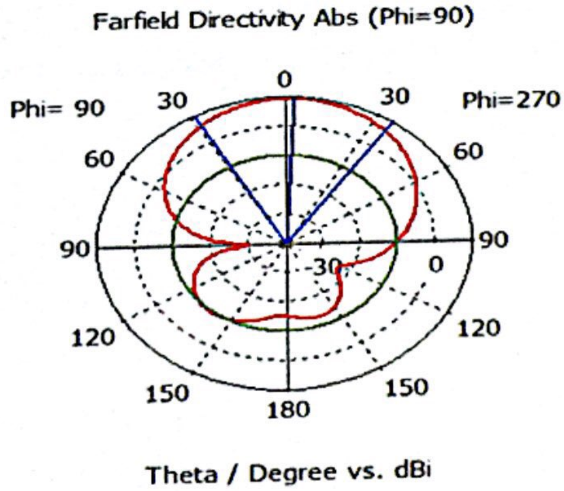


Figure 4.8 the radiation pattern in 2D

Figure above shows that the simulation results. For the simulation result, the antenna operates at 5.8Ghz. From the figure above.the gain of the denim substrate is 9.18db.The radiation pattern is more orthogonal from the 360 axis.

4.4 The comparison analaysis between denim and felt substrate

No	Parameters	Rectangular antenna with denim substrate	Rectangular antenna with felt substrate
1	Return loss(dB)	-18.34	-15.41
2	Gain(dB)	8.84	6.57
3	Resonant frequency	5.6	5.8

Table 4.1 the comparative analysis between denim and felt textiles

From the table above, The 1st antenna design is found to achieve return loss at frequency ranges at 5.2Ghz while the 2nd antenna design is found to have return loss at frequency ranges at 5.8GHz. In term of radiation patterns results, all the antennas are found that have almost similar results. For all the antennas, the radiation pattern at 1st design is less directional while on the 2nd design, the radiation pattern is more directional because it has an optimum frequency which is 5.8Ghz. the gain of the 1st design with denim substrate have a lower gain rather than 2nd design wit felt textiles which is higher gain and therefore, the felt textile efficiency is more accurate than the denim design. Besides that , in terms of gain and efficiency of the antennas, all of the antennas have low power consumption.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Introduction

The fundamental aim for this project is to develop the wearable rectangular textile antenna, which can cover the frequency at 5.8 GHz. The objective of this project is achieved whereby the antennas were successfully developed by using CST Microwave Studio and. The performance of all antennas were analysed and investigated by using simulation and measurement. All the measured results are agreed with the simulated results in term of return loss. The 1st antenna design is found to achieve return loss at frequency ranges at 5.2 GHz while the 2nd antenna design is found to have return loss at frequency ranges at 5.8GHz. a. In term of radiation patterns results, all the antennas are found that have almost similar results. Besides, in terms of gain and efficiency of the antennas, all of the antennas have low power consumption. In medical application, the felt textile is more suitable compared to denim textiles. This is because the felt textile have a good resturn loss, bandwidth, radiation pattern, resonant frequency and gain. These are great due to the design specification of microstrip patch antenna design. All the antennas also have high efficiency of data rate. This is good for microstrip patch antenna in wearable application that can be applied in medical application.

5.2 Recommendation for Future Work

To have better performance of the antenna, future work is needed. Human errors during the fabrication process are the major cause of the differences between simulated and measured results.. These antennas have partial ground plane. Subsequently, our body will suffer the power radiated from the antenna. Thus, the effect of the antenna to the body should be investigated. For the alternative, the antenna design can be matched using coaxial feed line. Basically, the microstrip is transmitting low power level which limits the area of coverage. In order to improve the quality of service, the UWB (ultra wideband) antenna system is needed to be designed. Therefore, the research on UWB should be carried out. Then, the fabrication of this circular antenna are needed because its more easier to to compared between the simulated and measured data. In this project, denim and felt fabric is used as a substrate. To have better performance, the other can attempt to research using the other fabric that have higher thickness than the denim fabric like leather textile. However, the dielectric permittivity also should take consideration to design the rectangular patch antenna.

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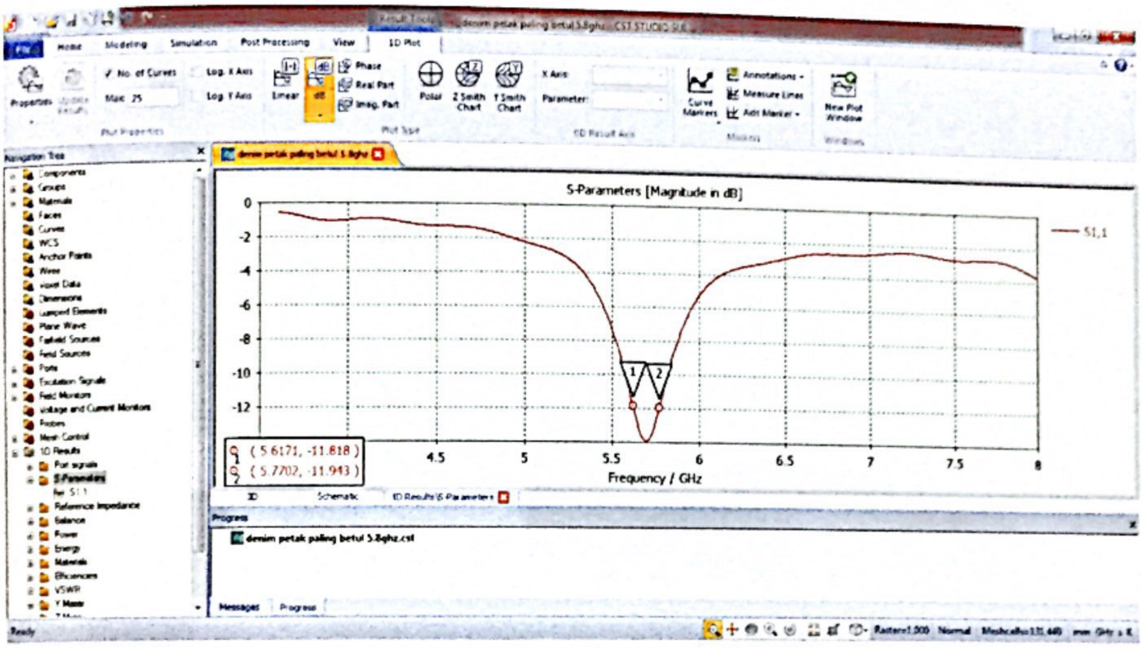
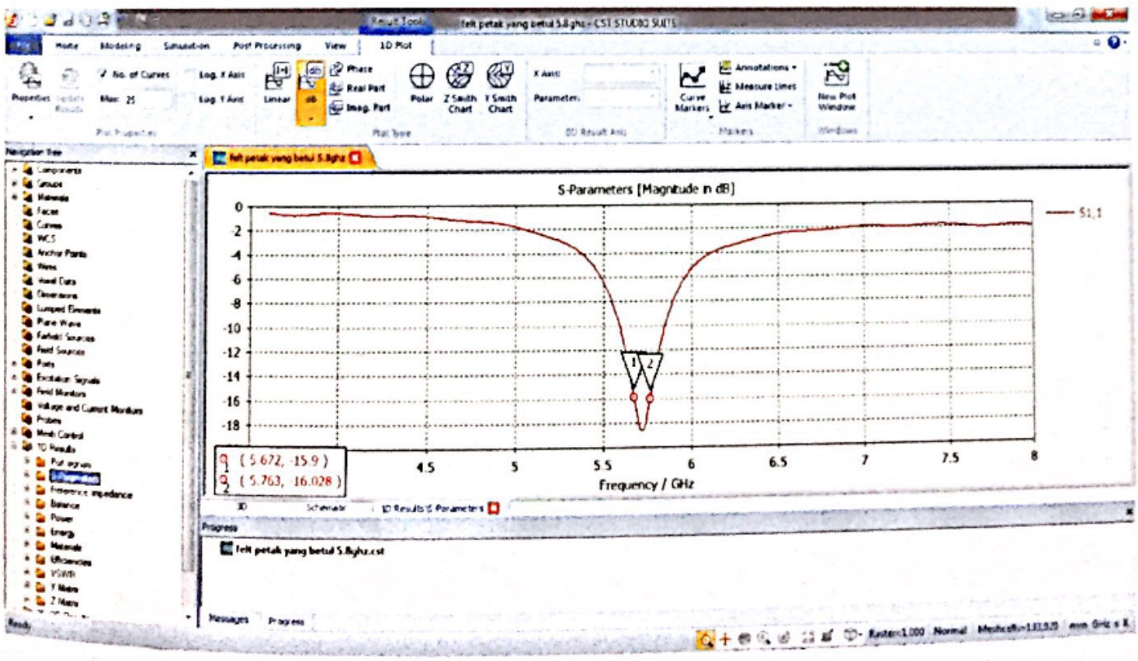
APPENDIX A

RETURN LOSS AND BANDWITDH OF SIMULATION RESULT



1st design by using denim textile



2nd design by using felt textile