BACHELOR OF SCIENCE IN ELECTRONIC AND TELECOMMUNICATIONS ENGINEERING

A simple 2.4 GHz Micro-strip Patch Antenna for Heart Rate Monitoring.

Submitted By:

Sushmoy Datta

T-181073

Sakibul Hoassain Sakib

T-181047

Supervised By:

Abu Zafar Md. Imran

Lecturer

Department of Electronic and Telecommunication Engineering
International Islamic University Chittagong
Kumira, Sitakund, Chattogram

Dedication

This thesis work is dedicated to all of our honorable teachers and our beloved parents for their prayers and support towards the achievement of our goal.

Certificate of Approval

The thesis entitled as "A simple 2.4 GHz micro-strip patch antenna for heart rate monitoring" submitted by Sushmoy Datta bearing ID No: T-181073, Sakibul Hossain Sakib bearing ID No: T-181047, to the Department of Electronic and Telecommunications Engineering(ETE) of International Islamic University Chittagong(IIUC) has been accepted as satisfactory to partially fulfill the bachelor's degree criteria in Electronic and Telecommunication Engineering and approved as to its style and contents for the examination held on 15Th October 2022.

Approved By:

Abu Zafar Md. Imran

Supervisor & Lecturer

Department of Electronic and Telecommunications Engineering

Faculty of Science and Engineering

International Islamic University Chittagong

Kumira, Sitakunda, Chattogram.

Candidates Declaration

The work presented in this thesis is hereby stated not to have been submitted elsewhere for the award of any degree or diploma and does not contain any illegitimate declaration.

Sushmoy Datta

T-181073

Sakibul Hossain Sakib

T-181047

Acknowledgements

In Allah's name, the Merciful One, the Merciful One. All praises and glory is to Allah (SWT), that He may bless us with abundant possibilities and shower us His compassion and guidance throughout our lives. And may peace and blessings of Allah be upon Prophet Muhammad (PBUH), a guidance and inspiration to our lives. To our thesis supervisor **Abu Zafar Md. Imran** we express our genuine appreciation and indebtedness, Valuable guidance, encouragement throughout the study period for his initiative in this field of studies. We convey our appreciation to **Syed Zahidur Rashid**, Chairman of Electronics and Telecommunications Engineering Department, IIUC to provide us with the finest department equipment and his prompt recommendations. We are also thankful to **Abdul Gafur**, Convener of our thesis for his dedication and sacrifice. We are also very grateful to all of our teacher for giving us the best effort throughout our entire academic years. And we remember our parents for their support in our life till now. And we also express gratitude our friends, well-wishers for their directly or indirectly involvement in the completion of this thesis work.

Abstract

Micro-strip patch antennas have several well-known advantages, including low profile, low cost, light weight, ease of manufacturing, and conformity. Micro-strip antennas have become an integral part of today's wireless communication world due to their low cost, low profile, and ease of manufacturing on circuit boards. However, poor performance characteristics such as low capacity handling, narrow bandwidth, low gain, and so on. Limit their application in some cases. In this research purpose, a 2.4 GHz Micro-strip Patch Antenna will be designed with the parameters which are useful for the antenna and the components materials such as FR4 Lossy and Copper which will be useful to measure the heart beat under the human muscle tissues. In real life, silicon is the best material to build a wearable antenna.

TABLE OF CONTENTS

S/N	Title	Page No.
	Acknowledgements	
	Abstract	
	List of Figures	
	List of Symbols	
	Chapter 1 Introduction	
1. 1	Antenna Basics	11
1.1.1	Bandwidth	12
1.1.2	Input Impedance	13
1.1.3	Impedance Matching	13
1.1.4	Directivity and Gain	14
1.1.5	Radiation Pattern	15
1.1.6	Voltage Standing Wave Ratio (VSWR)	16
1.1.7	Return Loss (RL)	17
1.1.8	Polarization	17
1.1.8.1	Linear polarization	18
1.1.8,2	Circular polarization	19
1.1.8.3	Elliptical polarization	21
1. 2	Micro-strip Patch Antenna	22
1.2.1	Advantages and Disadvantages of Microstrip Patch Antenna	24
1.2.2	Microstrip Antenna Feed Techniques	26
1.2.3	Microstrip Line Feeding	26
1.2.4	Coaxial / Probe feeding	27
1.2.5	Aperture Coupled Feed	28
1.2.6	Proximity Coupled Feed	29
1. 3	Biomedical Antenna	
1.3.1	Introduction	30
1.3.2	Types of Biomedical Antennas	30
1.3.3	Importance of Biomedical Antennas	31

1.3.4 Applicatios of wireless technologies in medical & it's advantages 32
1.3.5 Microstrip Patch Antenna for Biomedical use 33
1. 4 Heart Rate Monitoring using Microstrip Patch Antenna 34
1. 5 Problem Statement 34
1. 6 Aims & Objectives 36
1. 7 Design Tool (CST Microwave Studio) 36

Chapter 2 Literature Review
2.1 Introduction 38
2.2 Paper Review 38
2.3 Summary 53
2.4 Objectives 54
Chapter 3 Methodology
3.1 Methodology 55
3.2 Research Design 56
3.3 Pilot Study 57
3.4 Software 58
3.5 Design procedure 59
3.6 Designed Antenna 60
Chapter 4 Results' Analysis
4.1 Voltage Standing Wave Ratio (VSWR) 63
4.2 Return Loss Graph 64
4.3 Total Efficiency 66
4.4 The Specific Absorption Rate (SAR) 67
4.5 2D Radiation Pattern 68
4.6 3D Radiation Pattern 69
Chapter 5 Conclusion
5.1 Achievements 71
5.2 Limitations 72
5.3 Future Work Field 72
References 73

LIST OF FIGURES

Figure No	Title	Page No
Figure1.1:	Transmitting & Receiving Antenna	11
Figure1.2:	Different types of Polarization	18
Figure1.3:	Linear Polarization	19
Figure 1.4:	Circular Polarization	20
Figure 1.5:	Elliptical Polarization	22
Figure 1.6:	Structure of Micro-strip Patch Antenna	23
Figure 1.7:	Micro-strip Line Feeding	27
Figure 1.8:	Coaxial/Probe Feeding	28
Figure 1.9:	Aperture Coupled Feed	28
Figure 1.10:	Proximity Coupled Feed	29
Fig 3.1:	2.4 GHz Micro-strip Patch Antenna	60-61
Fig 3.2:	Bottom view	61
Fig 3.3:	Antenna Layer Specifications	62
Fig 4.1:	VSWR Plot	64
Fig 4.2:	Return Graph Loss (s11 parameter)	65
Fig 4.3:	Total Efficiency	67
Fig 4.4:	Efficiency Percentage	67
Fig 4.5:	Specific Absorption Rate (SAR)	68
Fig 4.6:	2D radiation pattern	69
Fig 4.7:	3D Radiation pattern for 2.4 GHz with directivity	70
Fig 4.8:	3D Radiation Pattern for 2.4 GHz with Gain (IEEE) value	70

LIST OF SYMBOLS

Hertz	Hz
Kilo Hertz	KHz
Mega Hertz	MHz
Giga Hertz	GHz
Millimeter	mm
Centimeter	cm
Meter	m
Relative permitivity	ε
Length	L
Width	W
Speed of light	C
Decibel	dB
Lambda	λ
Ohm	Ω

Chapter One

Introduction

1.1: Antenna Basics

An antenna is a particular transducer that transforms radio frequency (RF) or alternating current (AC) areas to one another. There are two basic types: the transmitting antenna, which receives AC from electronic machinery and generates an RF field, and the receiving antenna, which intercepts RF power and delivers it to it. In radio and electronics, an antenna or aerial is a device that converts electrical power into radio waves and typically used with transmitter or receiver.

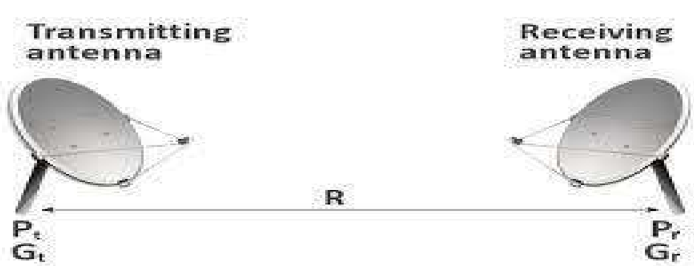


Figure 1.1: Transmitting and Receiving Antenna

In the typical sense, frequency refers to how frequently an event occurs over a specific time period. Frequency is essentially the number of times an event occurs over a specific period of time. According to the standard definition, frequency is the number of times a signal occurs more than a specified time period (one second). Every 'T' seconds, referred to as the period of time, the periodic signal cycles itself. The frequency of a periodic signal is only the inverse of its duration (T). Frequency is a term used in engineering to describe the frequency of oscillatory and vibratory phenomena, such as radio waves, audio signals (sound), mechanical vibrations, and light. Heinrich Hertz, a German physicist, gave the unit of frequency hertz in the SI (International System) (Hz).

1.1.1: Bandwidth

The terms "bandwidth" and "half-powered, -3dB bandwidth" are widely used in electrical devices. The bandwidth of half-power is the frequency range in which the resonant device operates at half or less of its maximum energy. The most common way to describe bandwidth in antenna design is in terms of VSWR or bandwidth impedance. The impedance bandwidth is commonly defined as the frequency range when the VSWR is less than 2, resulting in a power loss of 11%.

1.1.2: Input Impedance

The voltage-to-current ratio in an antenna's terminals is referred to as the input impedance of the antenna. The input impedance of the antenna depends on its size and length. Impedance Z has a true part that accounts for the antenna's Rrad radiation resistance and R ohmic losses, and a reactive part that accounts for energy from the antenna's surroundings. [1]

1.1.3: Impedance Matching

The usual definition states that "Impedance matching" occurs when the approximate values of the impedances of a transmitter and receiver are equal or when they are opposite. Impedance matching is important for wireless communication between the circuitry and the antenna. According to the idea, the antenna impedance, transmission line, and circuitry should correlate to the antenna's ability to transfer the most energy to the receiver or transmitter. Tuning or antenna matching is the process of impedance matching of the antenna with the circuitry over a range of frequencies. The bandwidth of a game is the frequency range where the antenna impedance for a certain VSWR is near to 50 Ohms. VSWR describes the quality of the game.

<u>Necessity of Matching</u>:

A resonant unit is one that at certain small frequency bands produces better performance. Antennas are resonant devices whose impedance provides a better output if matched.

1-If the impedance of the feedline matches that of the source, the power from the source will be efficiently transmitted to the feedline.

2-If the feedline and antenna impedances match, the feedline's power will be efficiently transmitted to the antenna.

3-The receiver antenna's output impedance and the receiver amplifier circuit's input impedance should be the same.

For a transmitter antenna, its input impedance should match the output impedance of the transmitter amplifier and the transmission line's impedance. [2]

1.1.4: Directivity and Gain

Directivity refers to an antenna's capacity to emit energy in a certain direction when transmitting or to better receive energy coming from a specific direction when receiving. Gain is typically defined as the energy ratio produced by the antenna from a far-off source on the antenna's beam axis to the energy produced by a fictitious isotropic lossless antenna that is equally susceptible to all directions of signals. Gain and directionality are related. When comparing a light bulb to a spotlight, the phenomena of greater directivity makes this connection obvious. A 100 watt light bulb will provide more light in some directions than a 100 watt spotlight will in others. One could argue that the lightbulb has less. The gain-directivity relationship involves a fresh parameter (π) known as the antenna efficiency.[3]

1.1.5: Radiation Pattern

Antenna power density in space is represented graphically by the radiation pattern of the antenna. The theoretical isotropic antenna has a spherical radiation characteristics, but there isn't a real one. A half-wave dipole radiates in all directions other than the direction of the axis on which it is located, exhibiting a doughnut-shaped radiation pattern. The radiation pattern also serves as the antenna's receiving characteristics, constituting it a "reception pattern." Three-dimensional radiation patterns do exist, but they are difficult to demonstrate in a meaningful way. It takes a bit of time to measure a three-dimensional radiation pattern. Often, recorded radiation patterns represent a two-dimensional slice of a three-dimensional radiation pattern.an easily visible pattern on a screen or piece of paper. These pattern measurements are offered in both rectangular and polar formats. [4]

1.1.6: Voltage Standing Wave Ratio (VSWR)

The standing wave ratio, which may be calculated by dividing maximum wave power by minimum wave power (SWR). Typically, the VSWR voltage proportion is used to describe the SWR. The term "VSWR" refers to the ratio of the reflected voltage to the voltage incident.

An antenna's VSWR is always a real, positive quantity. The closer the transmission line matches the antenna and the lower the VSWR, the more energy the antenna gets. The VSWR's base value is one. In this situation, the ideal antenna does not reflect any power. As the VSWR increases, there are 2 significant downsides. The first is obvious: more energy is reflected by the antenna and is not transferred. But there's still another problem. The radio transmission reflects more energy as VSWR increases. Large amounts of reflected energy have the potential to destroy the radio. Antennas are typically suitable with VSWR values up to 2.[4]

1.1.7: Return Loss (RL)

An alternative technique to represent mismatch is through the return loss (RL). The algorithmic ratio, expressed in decibels (dB), compares the energy the antenna reflects to the energy fed into the antenna from the transmission line. The VSWR is directly connected to the RL.

In general, S11 is the antenna parameter that is quoted the most. S11 is actually nothing more than the loss of return (RL). S11=0 dB means that nothing radiates because the antenna reflects all forces. If the antenna is supplied with 3 dB of energy and S11 = -10 dB, then the reflected energy is -7 dB. A -9.5 dB or lower RL or S11 corresponds to the allowed upper 2 VSWR. In this thesis, an acceptable RL is one of -10 dB. [4]

1.1.8: Polarization

An antenna's polarization in a particular direction exposes the polarization of the wave it radiates within this direction. If no direction is given, the polarization in the direction of greatest profit is assumed to exist.

The property of an electromagnetic wave known as polarization, which may be detected along a propagation path, describes the direction and relative amplitude of the electric field vector at a fixed space position as well as how it changes over time.The polarization is indicated by the vector that represents the electrical field at a certain location in space as a function of moment. There are three types of antenna polarization: elliptical, circular, and linear. Circular and linear polarization are special examples of elliptical polarization. In both circularly polarized waves and elliptical waves, the electric field's sensation of rotation is referred to as a right-hand polarization if it is traced in a straight (CW) direction, and a left-hand polarization if it is traced in the opposite direction (clockwise counter) (in Figure 1.2).

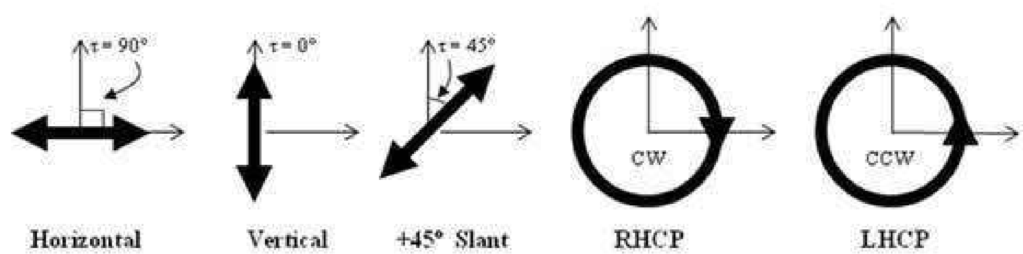


Figure 1.2: Different types of Polarization

1.1.8.1: Linear Polarization

The time-harmonic wave is said to be linearly polarized at a place in space if, at any given time, the electrical field vector is always orientated along the same straight line. This is accomplished if the electric field vector possesses the properties listed below:

1. A single component,
2. Two orthogonal linear components that are 180 (or multiples of 180) out of phase with respect to time, or in phase.

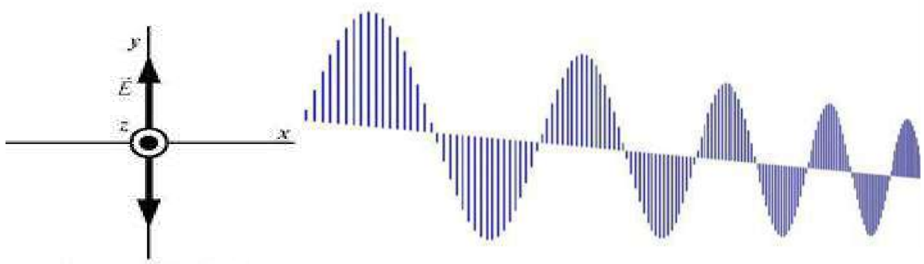


Figure 1.3: Linear Polarization

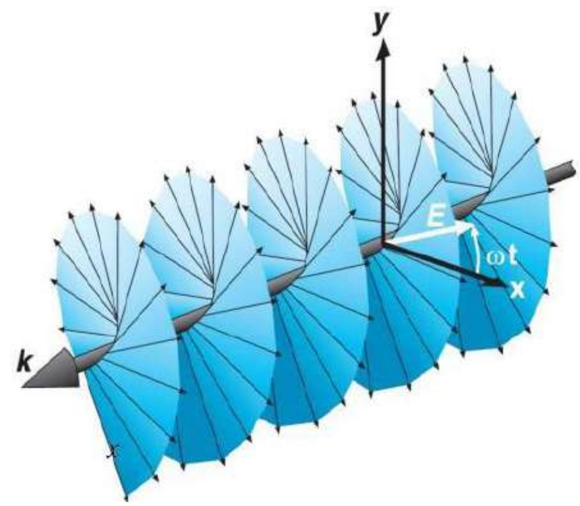
1.1.8.2: Circular Polarization

We are referring to the circular polarization of the time-harmonic wave if the electric field vector at a particular location in space follows a circle as a function of time. The following conditions must all be met by the electrical field's vector in order to accomplish this:

1. The field must have two linear orthogonal elements.

2. The magnitude of both components must be equal.

3. There must be an uncommon 900 multiple time-phase divergence between the two portions.



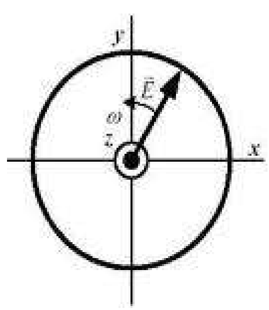


Figure 1.4: Circular Polarization

All three of these qualities must be encountered. Circular polarization is a desired property for many of the antennas in Figure. 9. Signal loss caused by polarization mismatch between two circularly polarized antennas is nonexistent. Circular polarization also converts RHCP waves into LHCP waves when they reflect off of surfaces. This is useful because it will reduce the effects of reflected waves that interfere with the desired wave on antennas designed to receive RHCP waves and cause signal fading. These are some of the causes of RHCP in satellite GPS signals

1.1.8.3: Elliptical Polarization

The time-harmonic wave is elliptically polarized if the point of the electric field vector traces an elliptical locus in space. When a wave is more or less elliptical in shape rather than linear or circular and when there isn't a perfectly linear or circularly polarized antenna in reality, the wave is said to be elliptically polarized. The following are the necessary and sufficient requirements if the electric field vector is the only factor involved:

1. There must be two linear orthogonal elements in the field, and
2. The two components can be of the same magnitude or difference.
3. (a) The time-phase difference between the two portions shouldn't be between 0 and 180 if the magnitude of the two parts differs, as this results in linear polarization.

(b) Because this will be a circular polarization if the two sections are of the same magnitude, the time-phase difference between the two parts shouldn't be exceptional multiples of 90.

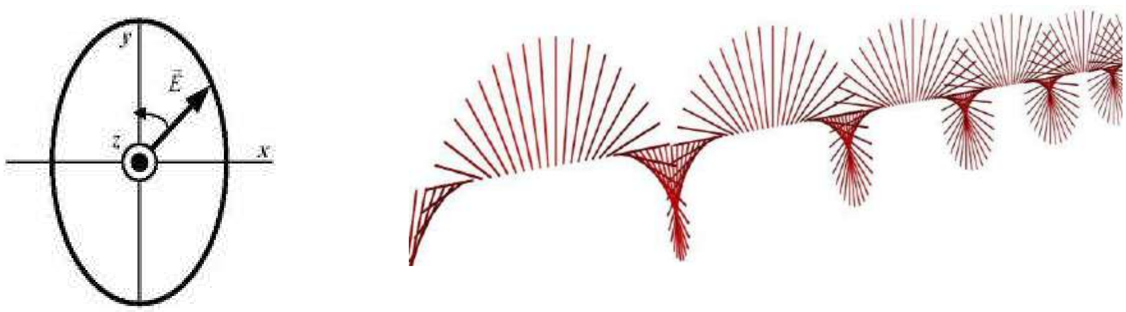


Figure 1.5: Elliptical Polarization

1.2: Micro-strip Patch Antenna

A micro-strip patch antenna consists of a ground plane on one side and a radiating patch on the other of a dielectric substrate. The patch can take any shape and is typically made of material like copper or gold. The radiating patch and the feed lines on the dielectric substrate are typically photographed. A patch antenna is an antenna that is created by etching away an area of conductive material from a dielectric surface. The ground plane, which serves as the foundation for the entire construction, is where the dielectric material is installed. Feed wires connecting through the patch are also used to excite the antenna.

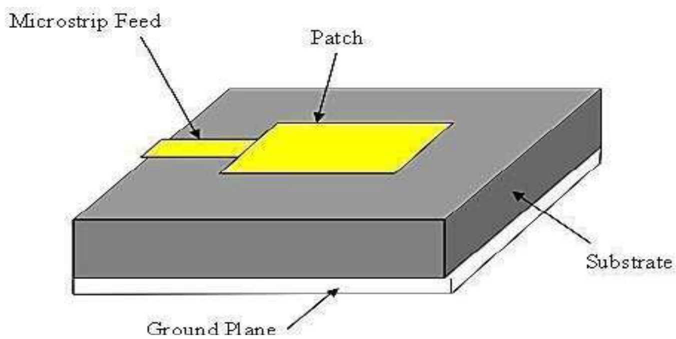


Figure 1.6: Structure of Micro-strip Patch Antenna

To make assessment and performance prediction easier, the patch is typically square, rectangular, circular, triangular, or another common shape. The typical patch length (L) for a rectangular patch is 0.3333 0L 0.5 0, where 0 is the wavelength of empty space. The patch is made to be extremely thin so that t 0 (where the patch thickness is this). The height h of the dielectric substrate is typically 0.003 / 0.05 0. The substratum's (r) dielectric constant typically falls between the values of 2.2 and 12.

Due of the fringing zones, micro-strip patch antennas mostly radiate between the patch edge and the ground plane. For optimal antenna performance, a thick dielectric substratum with a low dielectric constant is preferred because it provides better efficiency, more bandwidth, and better radiation. However, such a configuration leads to a larger antenna size. To create a small Micro-strip patch antenna, higher dielectric constants that are less efficient and have a lower bandwidth must be used.

1.2.1: Advantages and Disadvantages of Micro-strip Antenna

Micro-strip patch antennas are becoming more and more common for usage in wireless applications because of their low profile design. As a result, they are quite compatible with integrated antennas in portable wireless devices like cell phones and pagers. The communication and telemetry antennas for missiles must be compact and conformal, and they frequently serve as antennae for micro-strip patches.

Some advantages of the micro-strip antenna are given below:

1. Micro-strip antennas are compact and light-weight.

2. They can be made cheaply, which allows for large-scale production.

3. They have a low profile planar design that is simple to adjust to the host's

surface.

4. Supports both linear and circular polarization.

5. Micro-strip antennas can be easily included into integrated circuits (MICs).

6. They can work with dual and triple frequencies, respectively.

7. They are mechanically durable when put on solid surfaces.

Some disadvantages of the Micro-strip antenna are given below:

1. The bandwidth of a micro-strip antenna is limited.

2. They are not very effective.

3. They have little gain.

4. They are harmed by interaction and feed radiation from alien life.

5. Poor fire radiator, with the exception of tapered slot antennas.

6. Their capacity for energy management is limited.

7. The surface wave's eagerness.

A very high quality factor (Q) antenna is included in micro-strip patch antennas. A high Q indicates significant antenna-related losses, which leads to a small effective bandwidth. By increasing the dielectric substratum thickness, Q can be reduced. However, as the thickness increases, an increasing amount of the source's total energy is converted into a surface wave. This surface wave contribution might be viewed as an unintended energy loss because it finally dissipates at the dielectric bends and degrades the antenna's characteristics.

1.2.2: Micro-strip antenna Feed Techniques

1. Microscopic Line Feed
2. Coaxial/Positron Feed
3. Coupled Feed via Aperture
4. Closely Coupled Feeds

1.2.3: Micro-strip Line Feeding

A micro-strip transmission line is etched right up to the patch's edge in this sort of feeding, keeping the entire structure in the same plan. In this design, as depicted in Fig. 2, a conducting strip is directly attached to the Microstrip patch's edge. The conducting strip is thinner than the patch. In order to achieve a flat structure, the feed can therefore be etched on the same substrate.

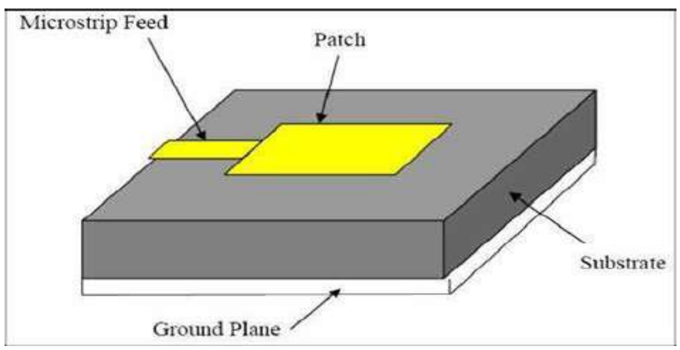
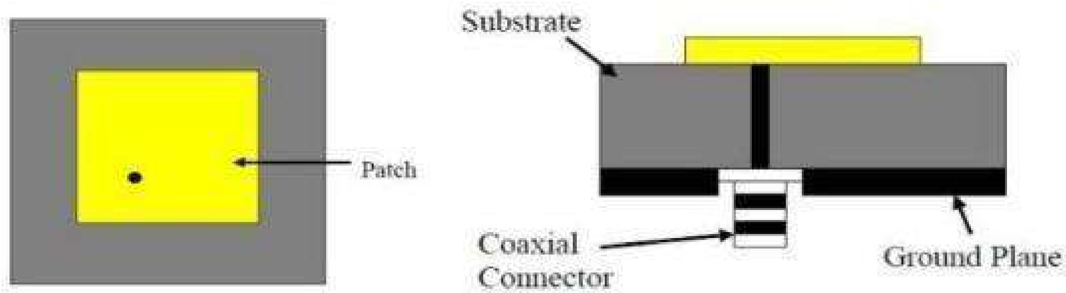


Figure 1.7: Micro-strip Line Feeding

1.2.4: Coaxial/Probe Feeding

The exterior conductor of the coaxial connector is joined to the ground plane, while the interior conductor of the connector goes through the substratum and is soldered to the radiating patch. A very popular method of connecting when feeding patch antennas is the coaxial feed, often known as the probe feed. The core probe conductor of the coaxial probe feed technique is directly connected to the patch antenna, which supplies the technique's power source. The ground plane is attached to the coax, which serves as the probe's outside connector, completing



the circuit.

Figure 1.8: Coaxial/Probe Feeding

1.2.5: Aperture Coupled Feed

In this type of feed, the opening connection consists of two substrates divided by a ground plane. The ground plane is separated from the radiating patch and micro-strip line at the bottom of the decreased substratum. Cutting a very small aperture or slot in the ground plane allows for the connection to take place.

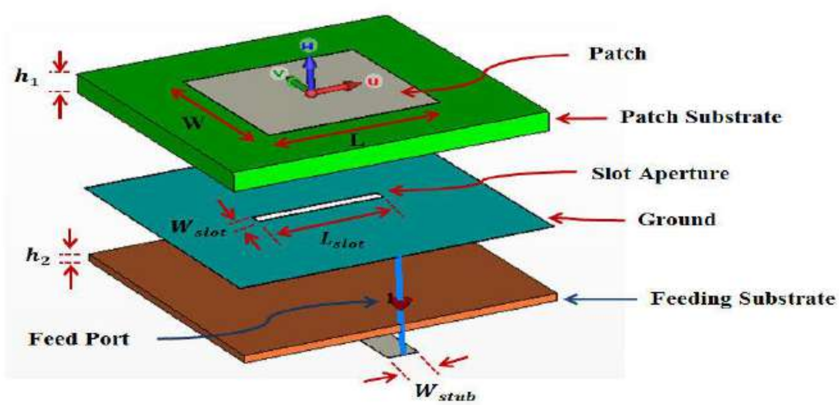


Figure 1.9: Aperture Coupled Feed

1.2.6: Proximity Coupled Feed

Electromagnetically Coupled ECMSA is another name for it. Additionally, it includes two substrates. The radiating patch is situated in the top of the upper substrate, and the micro-strip feed line is situated between two substrates. The electromagnetic coupling strategy is another name for the proximity linked feed technology. The feed line is placed between the two dielectric substrates, and the radiating patch is placed on top of the lower substrate. This feed technique's primary benefit is the extremely high bandwidth it offers. In order to enhance each user's performance, this system also offers options between two alternative dielectric media, one for the patch and one for the feed line.

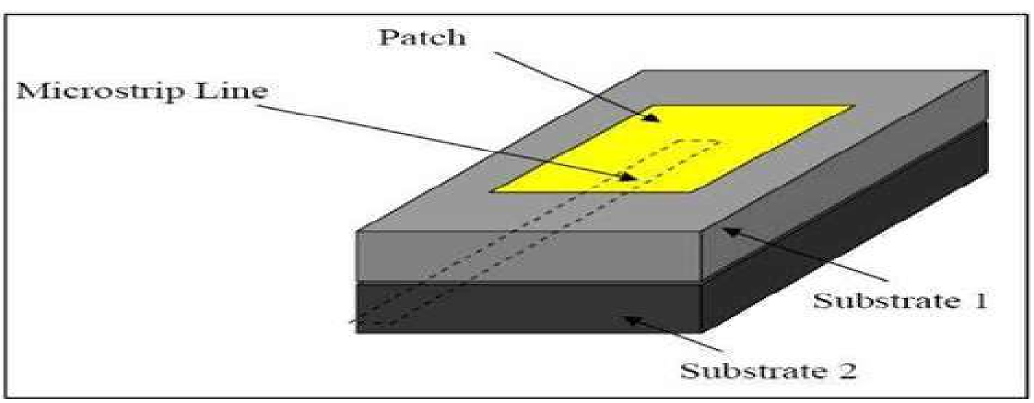


Figure 1.10: Proximity Coupled Feed

1.3: Biomedical Antenna

1.3.1: Introduction

Biomedical wireless devices employ biomedical antennas. On-body, in-body, and off-body devices are the different categories of this type of antennas. The antenna requirements, the propagation environment, and the surroundings for traditional wireless communication are all very different in each of these groups.

The devices that are worn or implanted inside the body to improve or monitor our health are now receiving a lot of attention thanks to technological advancements. Wireless connectivity is therefore necessary for these gadgets to operate. The construction of antennas for these devices needs extensive knowledge of electromagnetism, propagation, antenna design, and interactions of the electromagnetic field with the body because the body is thought of as a harsh environment for antennas. These gadgets could be utilized in daily life or in carefully controlled settings like hospitals or treatment facilities.

1.3.2: Types of Biomedical antennas:

They are divided into three categories:

(i) Off-body

(ii) In-body,

(iii) On-body devices.

Micro-strip or planar-inverted F antennas (PIF A), which operate in the Medical Implant Communications Service (MICS) band between 402-405 MHz, are one of the most popular types of biomedical antennas. However, this type of antennas' biggest issue is their larger wavelength due to their narrower frequency range.

1.3.3: Importance of Biomedical antenna:

The need for biomedical telemetry is growing every day in the modern society. We are proposing an "Implantable antenna for biomedical application." The main issue with implanted antennas in biomedical applications is miniaturization**.**

An implantable antenna has been shown to significantly improve patients' health and longevity in recent biomedical research studies. The MICS band (401-406 MHz) and the ISM band (2.45 GHz), where the implanted antennas are used, are just a few examples of electromagnetic fields and radio frequency applications.

1.3.4: Applications of wireless technologies in medical science and it's advantages:

Wireless technologies have a wide range of medical applications, including diagnostics and monitoring, treatments and imaging, as well as wellness and fitness. In order to assist the delivery of healthcare, radio frequency (RF) wireless medical devices carry out at least one function that makes use of wireless RF communication, such as Wi-Fi, Bluetooth, and cellular/mobile phone. A medical device can be programmed and controlled wirelessly, patients can be monitored from a distance, and patient data can be sent from the medical device to another platform, like a cell phone. As RF wireless technology develops further, it will be used more and more in the creation of medical equipment.

The use of wireless technology in medical devices can have a variety of advantages, such as increasing patient mobility by doing away with the wires that tether patients to medical beds, allowing medical professionals to remotely program devices, and enabling doctors to access and monitor patient's data from anywhere (a hospital, home, office, etc.). By giving doctors access to patient data in real-time while they are not present in the hospital and enabling real-time treatment modification, these advantages can have a significant impact on patient outcomes. Through home monitoring of chronic conditions, remote monitoring can also benefit special populations, such as elderly, by enabling the early detection of changes before more significant effects arise.

1.3.5: Micro-strip Patch antenna for biomedical use

Due to its modest profile, micro strip patch antennas are essential in biological applications. There are innumerable biomedical applications for these antennas. Patch antennas are increasingly used for health monitoring these days.

Many writers have developed micro-strip antennas for use in biomedical use. An ultra-wideband (UWB) antenna is being designed to find lung cancer. In an active microwave imaging system for noninvasive breast cancer screening, straightforward narrow band monopoles made of coaxial cables are placed in a tank filled with liquid that closely resembles breast tissues. Additionally, a number of planner antennas have been reported. In addition to telemetry applications, the micro-strip antenna array is also developed for biomedical applications. For the purpose of finding breast cancer, a micro-strip patch antenna operating between 4 and 9.5 GHz has been created. A biomedical application for a planer on-body wide band slot antenna has been created. The gains are demonstrated via a straightforward triple-band antenna for implantable biomedical applications.

1.4: Heart rate monitoring using micro-strip patch antenna.

Due to their distinctive qualities, including as low profile and flexibility in terms of resonant frequency, propagation, far-field pattern, and impedance matching when the precise radiator shape and mode are specified, micro-strip antennas are preferred over other types of antenna layouts. They may be made inexpensively by utilizing cutting-edge printed-circuit engineering, flexible to planar and nonplanar surfaces, and mechanically powerful when mounted on rigid surfaces, making them compatible with MMIC designs.

Despite having a straightforward structure, a low profile, and a moderate size, micro-strip patch antennas have a number of disadvantages. Low power, low efficiency, difficult to achieve polarization purity, surface wave excitation, and a small frequency bandwidth are the drawbacks.

1.5: Problem statement

When communicating with the body, wireless technology is intended to be more flexible and comfortable for the user than a bulky cable link. Multiple sensor nodes that are in-body or on-body are used in Wireless Body Area Network (WBAN) technology to make it easier to monitor the surroundings. By using antennas, the data from the sensors will be wirelessly transmitted to a computing center outside of the building. Body-centric communication antennas should have a low profile, be small, and be indifferent to the user's closeness to their bodies.

Although a single element micro-strip patch antenna has been a promising choice for body-centric communication, it has a number of disadvantages including a limited bandwidth and low gain. Thus, multi-elements known as an array of single patch antenna can be built to increase the bandwidth and gain of the antenna. Furthermore, because every person's body anatomy is different, it is essential to research how the human body affects antenna performance. The thickness and makeup of biological tissue affect how electromagnetic waves behave when they pass close to the human body. This is because variations in tissue thickness will affect how the waves are reflected and absorbed because each body tissue has its unique electrical characteristic. The 2.4 GHz applications are intended to be used with the single element and array antennas described in this research. The performance of the antenna for different tissue thicknesses is also studied, both in free space and while mounted on the body.

1.6: Aims and objectives

Designing on-body antennas for the 2.4 GHz Industrial, Scientific, and Medical (ISM) band is the primary goal of this project. The goals of this thesis include the following in order to achieve this goal:

1. Design a 2.4 GHz micro-strip patch antenna for heart rate monitoring at CST Studio Suite 2019.
2. To look into how different tissue thicknesses affect how well an antenna performs.
3. To employ straightforward gain enhancement approaches to increase the gain of on-body antennas.

1.7: Design Tool (CST Studio Suite)

The electromagnetic simulation program CST STUDIO SUITE® from CST has the capabilities for designing and optimizing devices that operate in a wide range of frequencies, from static to optical. Thermal and mechanical analysis, as well as circuit modeling, are both options. The CST Studio Suite was developed by Dassault Systèmes Simulia as a computational electromagnetics tool. Particle-in-cell (PIC), transmission line matrix (TLM), multilevel fast multiple method (MLFMM), finite element method (FEM), finite integration technique (FIT), and finite element method with finite elements are only a few examples of the simulation techniques it uses (FEM). In addition, multi-physics solutions for other branches of physics having electromagnetic linkages are included. The predecessor to CST Studio Suite, MAFIA [de] ("solving Maxwell's equations with the Finite Integration Algorithm"), was made available for purchase.

Chapter Two

Literature review

2.1: Introduction

The fundamental idea of a microstrip antenna is discussed here. Wireless standards for body-centric communication antennas have been examined at the beginning of the chapter as well. Characterization of the antenna material, feeding mechanisms, the idea of multi-elements, and its feeding method have all been taken into consideration. Not least among others, the significance of establishing tissue layer parameters is also covered.

2.2: Paper Review

In this section the works by other researchers that are related to this thesis "A simple 2.4 GHz microstrip patch antenna for heart rate monitoring " will be reviewed, which is vital element to successful research for the biomedical applications with the existing antenna. Hence, for the design and simulation of an antenna with better performance and easy fabrication.

1.

Research paper on "A review on antennas for biomedical implants used for IOT based health care "

This document provides information on microwave sensors, IMDs, their application, various antenna types, requirements for an implantable antenna, and design specifications. Microwave sensors are useful for IOT-based technology-based healthcare information. Because it is feasible to continuously monitor your health. IMDs are utilized nowadays for monitoring and diagnosis, and they can connect to IOT-based systems. The significance of human body traits in the antenna's qualities has been taken into account in all the research cited, and size reduction is another factor that has been taken into account. The MICS and ISM bands are used by the majority of the antennas covered here. Miniaturization, biocompatibility, wireless communication capability, patient safety, and biocompatibility are the primary design factors for implantable antennas. Certain requirements must be met while testing an implanted antenna; for example, it is difficult to prepare skin-impersonating gel since it must closely match the spectra of human skin for the intended frequency ranges. The creation of the next generation of miniaturized antennas requires the intricate and dense integration of a sensor, a power source, and electronics. The challenge of testing the constructed antenna in vitro and in vivo requires continued attention. The requirement of biocompatibility makes testing of these antenna in vivo challenging. Another area of focus is the compromise between the SAR and the power needed for communication. [5]

2.

Research paper on "Design of a Dual-Band implantable antenna and development of skin mimicking gels for continuous glucose monitoring "

In this study, the author described a small-size dual implantable antenna for continuous glucose monitoring that operates in the industrial, scientific, and medical (ISM) (2.4-2.48 GHz) and medical implant communications service (MICS) bands. An internal finite-element boundary integral electromagnetic simulation system and a particle swarm optimization algorithm are combined to improve the antenna for dual-band operation. The designed antenna was put to the test in vitro. Additionally, gels that mirror the electrical characteristics of human skin have been created. The gel is used to create and measure the optimal antenna. It is discovered that the simulated and measured bandwidths are

20.4% MICS, 4.2% ISM, 35.3% MICS, and 7.1% ISM, respectively. Although continuous glucose monitoring has been emphasized throughout this research, the antenna and skin-impersonating gels described here can be employed for a wide variety of wireless telemetry applications. [6]

3.

Research paper on "Human implanted spiral antenna for 2.45 GHz wireless temperature and pressure spiral SAW sensor system "

In this paper the author described a novel method in this research for optimizing a spiral antenna implanted in a person for a wireless temperature and pressure SAW sensor system operating at 2.45 GHz. The antenna was made to work best when placed close to the human heart. We have demonstrated that it is possible to improve matching and minimize antenna dimensions by simply connecting the two arms of a conventional dipole in a homogenous phantom. [7]

4.Research paper on "Human body effects on implantable antennas for ISM bands applications: Models comparison and propagation losses study"

The propagation losses of body-implanted antennas at the ISM bands of 433MHz, 915MHz, 2450MHz, and 5800MHz are examined in this study. The benefits and drawbacks of each of the two body models—one based on a single equivalent layer and the other on a three-layer structure—are demonstrated. The analysis of the antenna pair gain at various implanted antenna depths comes first. The effects of the thickness of the various layers of bodily tissue are then displayed. Finally, we go over the effects of isolating the antenna from the hostile environment of the human body via a coating layer. [8]

5. Research paper on "New patch antenna for ISM band at 2.45 GHz"

The proposed patch antenna in this paper is a hexagonal patch that operates at 2.45 GHz in the Industrial Scientific Medical (ISM) frequency band. It is verified using different numerical techniques, including the Finite Element Method (FEM) and the Method of Moments (MoM), and the compression results show good agreement. The results show that the novel antenna has minimal impact compared to that of the rectangular patch antenna when human body is placed near the antenna, which affects antenna performance such as S11 and bandwidth. [9]

6. Research paper on "Antenna and propagation for body centric wireless communications"

In this research, various numerical computational techniques have been used to investigate on-body propagation modeling. For the purpose of characterizing narrowband communication channels, 2.4 GHz propagation experiments with body-worn antennas have been made both inside and outside an anechoic chamber. At the UWB (ultra wide-band) band, data from simulation and measurement have also been obtained. [10]

7. Research paper on "Design and performance analysis of a multiband micro-strip patch antenna Ku and K band"

Satellite and space-borne radar applications frequently use microstrip patch array antennas. This research presents a Ku band (12 GHz to 18 GHz) and K band (18 GHz to 27 GHz) array antenna for radar and cube-sat applications. 64 dual feed radiating elements are grouped in a 2X2 sub-array to make up the planned antenna. Four 2X2 sub-arrays making up a block of 16 elements are excited by a single feed line that is coupled to the central feed. The analysis includes both 2X2, 4X4, and 8X8 arrays, with the 8X8 array demonstrating a larger bandwidth, high gain, and significant return loss with multiple output. High gain, high bandwidth, and multiple output are required to create the antenna for radar and/or cube-sat applications. [11]

8. Research paper on "Design of a miniaturized implantable PIFA with DGS for the investigation of uterus fibroids"

Continuous monitoring of irregular uterine fibroid growth is essential to reducing the unneeded complications of specific female health conditions. This article showcases an implantable multi-facet circular device. PIFA for early uterine fibroids detection. The circular antenna's diameter Its 7.5 mm and has the following dimensions(7.5) 21.58 mm3 The antenna possesses for use in the ISM band, a maximum return loss of 37 dB at 2.43 GHz is acceptable. It can completely be implanted in the uterus because to its modest profile. To increase the two dielectric substrates that improve the bandwidth and radiation efficiency. Both FR-4 and Rogers RO 3210, both 0.79 mm thick, are used. Top and Teflon has been applied to the antenna's bottom sides to ensure biocompatibility. The utilization of deformed ground structure. [12]

9. Research paper on "Subcutaneous Fat Distribution in the Human Torso"

With obesity recently becoming as a significant health concern and a topic of focus in the automotive. In order to create accurate models of the human body for the purpose of occupant safety, thorough descriptions of the distribution of body fat are required. More than 17,000 CT scans were used to quantify the subcutaneous fat in this investigation scans from skin surface locations to the facial envelope utilizing planar distance maps There were actions conducted as a Vertebral level (from T6 to L5, extending to the sacrum) and body position on the map are recorded body's exterior. The individual impact of demographics was assessed using multivariate regression mapping on the thickness of the subcutaneous layer. Results showed that regression coefficients were statistically significant. The migration that comes with turning 20 years old. [13]

10. Research paper on "A study of different feeding mechanisms in micro-strip patch antenna"

The feeding methods for several Micro-strip patch antennas are discussed in this study. The Micro-strip patch antennas are fed via a variety of techniques. These techniques are separated into contacting and non-contacting groups. Co-axial plane feed and micro-strip line feed are the two most common contacting techniques. In contrast, non-contacting solutions include proximity coupled feed and aperture coupled feed. VSWR, bandwidth, resonant frequency, and return losses are just a few of the features of an antenna that can be better understood using these methodologies. By altering the feed point in this investigation, perfect matching can be achieved. Coaxial feeding approach, micro-strip line feed, and aperture couple feed are utilized to provide maximum bandwidth, while proximity coupled gives the least amount of return losses and is dependable and simple to manufacture. [14]

11. Research paper on "Electromagnetic modelling of human tissues and it's application on the interaction between antenna and human body"

Body Area Networks (BAN) are revolutionizing patient care and health monitoring in this era of wireless technology. BAN gives people a good assessment of their physical and mental health at any time and from any location. Phantoms that can imitate the electrical characteristics of a real human body are now important due to the rising interest in creating effective body (in, on & off) communication systems. Wearable antennas, a crucial component of BAN, must be low profile and immune to the effects of the human body. Additionally, a method to lessen the impact of antennas on human health—specific absorption rate—should exist (SAR). The goal of this endeavor was to create phantoms that could be used for both in-person and on-body communication. When antennas come into contact with or are located near a human body, they suffer greatly in terms of efficiency and matching. This is a significant obstacle to establishing a reliable body communication network. This work includes a variety of methods used to keep bodily interferences to a minimum. Techniques such backing ground planes, high impedance surfaces, and polymeric ferrite sheets were used, and they were successful in reducing the sway in antenna characteristics when placed on bodies. [15]

12. Research paper on "2.4 GHz plaster antennas for health monitoring"

The author of this work discussed the usage of poly-acrylate, a common commercial plaster material, as an antenna substrate. Introduced are two patch antennas operating at 2.45 GHz that can be fastened to the skin. The measured efficiencies are 60% on-body and 70% in free space. Each antenna's measured on-body gains are 6.2 and 1.4 dBi. The two antennas' simulated 1 g specific absorption rates (SAR) at 1 W input power are 2.3 W/kg and 1.6 W/kg, respectively. SAR values for 10 g are

0.6 and 1.2 W/kg. Snap-on buttons are being researched for use in antenna feeding. [16]

13. Research paper on "Design and development of Micro-strip Patch Antenna at 2.4 GHz for wireless applications"

The development of low-cost, lightweight, highly dependable, and low-profile antennas for wireless devices has increased, which presents a new challenge for antenna design in wireless communications. In this study, a rectangular micro strip patch array antenna for 2.4 GHz wireless communications is designed and simulated. It has a wide beam radiation pattern and a gain of 11.6 dBi. Using Ansof/Ansys HFSS, the rectangular micro strip patch antenna was analyzed. Additionally, comparisons between the various substrates, showing varied outcomes based on the same parameters, were made. [17]

14. Research paper on "Design and analysis of square micro-strip patch antenna at 2.4 GHz band used for IOT based health care monitoring"

In this work, a quick development in the field of wireless communication was made to an antenna design for the ISM band for medical applications. The design and installation of a square micro-strip patch antenna (SMP) for the ISM band are the main topics of this research. Three areas are covered by this antenna: the patch and ground are made of copper material, and the substrate is composed of FR4 material. This antenna has good return loss of -20.84 dB, VSWR of 1.2, impedance of 43.1 ohm, gain of 4.96382 dBi, directivity of 5.36308 dBi, efficiency of 91.217%, bandwidth of 0.06 GHz, and fractional bandwidth of 0.025 GHz. This kind of antenna is better suited for biological applications that monitor patient health and transfer bio-information to distant locations. [18]

15. Research paper on "Design and fabrication of micro-strip patch antenna at 2.4 GHz for WLAN application using HFSS"

In this paper, HFSS software is used to create a rectangular micro-strip patch antenna. The 2.4 GHz resonant frequency of the developed antenna makes it suitable for Wireless Local Area Networks (WLAN). This study presents the suggested antenna's design considerations as well as its simulated performance. The design is created using FR-4 Epoxy, which has a dielectric constant of 4.4 and a 1.5mm thickness, and is employed as a dielectric material. The proposed antenna is then built based on the HFSS simulation software's modeling of the design. The manufactured results were obtained by manufacturing the MSA, and they are displayed in the report. The suggested antenna's low profile and straightforward structural design make construction simple and appropriate for the application in the WLAN. [19]

16. Research paper on "Comparison of the performance of micro-strip antenna at 2.4 GHz using different substrate materials"

The performance of several dielectric substrates with dielectric constants ranging from 2 to 5 is discussed in this work. These designs are essentially 2.4 GHz resonant rectangular micro strip patch antennas for wireless communication. They are simulated with the software IE3D used by the evaluator, and their performances are contrasted in terms of the parameters "return loss v/s frequency" and "VSWR v/s frequency." Four dielectric substrates are compared: FR4, RO-3003, PTFE (Teflon), and Polyguide. MATLAB is used to analyze each and compile the results to demonstrate relative performance. [20]

17. Research paper on "Micro-strip parallel coupled bandpass filter design for applications at 2.4 GHz"

The main prerequisite for the best and most effective operation of next-generation communication systems is the design of micro-strip filters. The parallel coupled micro-strip band pass filter's design, mathematical and numerical analysis, electrical responses obtained through iterative numerical electromagnetic simulations, and discussions of the outcomes measured and tested following fabrication using FR4 substrate are all covered in this research article. In using Ansoft Designer Software to compare this filter's performance to international industry standards for its 2.4 GHz operational frequency applications, we discovered satisfactory parameters like insertion loss above 5.00 dB, reflection loss below -20 dB, negligible energy loss, and frequency bandwidth of 6.25%. In the RF and microwave communication band, the volumetric downsizing and sustained compatibility we investigated are crucial, resulting in the lowest production cost and a step towards. [21]

18. Research paper on “Design and implementation of textile antenna and their comparative analysis of performance parameters with off and on body condition”

A wearable antenna is a crucial component of the body area network (BAN), which transmits protected information and healthcare data to the central hub. This study compares several conductive textile materials and conductive non-textile materials used in rectangular micro-strip patch textile antennas. The industrial, scientific, and medical (ISM) band application's textile antenna is created, assessed using ADS 2013.06 software, and measured using a N9926A 14 GHz field fox handheld vector network analyzer. The textile antenna operates at a resonant frequency of 2.4-2.485 GHz. Performance metrics like VSWR, reflection coefficient, bandwidth, impedance, directivity, and gain are examined and compared for these textile antennas. The return loss of the suggested design is 53.32 dB, the VSWR is 1, and the efficiency is 100%. [22]

19. Research paper on “Analysis of thickness variation in biological tissues using microwave sensors for health monitoring applications”

For medical diagnostic applications, the microwave sensing approach offers a potential and alluring modality alternative to conventional X-rays, magnetic resonance imaging, and computed tomography. This method is advantageous since it employs non-ionizing radiation, which may be employed in the microwave healthcare system. This paper's primary objective is to offer a microwave sensing method for analyzing variations in biological tissue thickness while taking into account how physiological and biological factors affect microwave signals. We have created a two-port non-invasive sensor system made up of two split ring resonators (SRRs) that operate at the 2.45 GHz Industrial, Scientific, and Medical (ISM) frequency band in order to achieve this objective. The sent signal's amplitude and phase are used to verify the system. [23]

20. Research paper on “Design and evaluation of a button sensor antenna for on-body monitoring activity in healthcare applications”

In wireless body area network (WBAN) systems, a button sensor antenna for on-body monitoring is provided. Because of the intimate interaction between the human body and the sensor antenna, devices for sensor antenna design are quite difficult. In this article, a mechanically reliable system is a wireless sensor module constructed with an integrated dual-band button antenna is proposed on an electronic circuit board (PCB). The device has a tiny footprint and good radiation resistance qualities and effectiveness. The measured and simulated findings are accurate despite this being a fabrication agreement. In free space, the design provides a variety of omnidirectional radiation patterns, including a maximum gain of 1.75 (5.65) dB, a reflection coefficient (S11) of 29.30 (30.97) dB, and radiation. [24]

2.3 Summary

The design of micro-strip patch antenna for biomedical applications by monitoring heart at millimeter wave bands including 2.4 GHz and others has been conducted in several research. From the current research, it is clear that the most potential and important candidate for monitoring heart is among the 2.4 GHz millimeter wave bands, as many research has been carried out that encompasses this frequency band and to use FR4 lossy and copper materials. Again, the most challenging task in deploying the antenna to overcome serious path-loss for the lossy characteristics of body tissues, sufficient miniature to be able to integrate efficiently and easily manufacture into the human body.

2.4 Objectives

- ❖ To design and simulate an array antenna for future biomedical applications.
- ❖ To optimize the antenna parameters.
- ❖ This antennas will be modelled by using CST software.

Chapter Three

Methodology

3.1: Methodology

A methodology is a group of steps. This term can be used to describe procedures employed in a given research study, methods used to complete a specific project, or practices that are often used across an industry or scientific area. When discussing the study of such procedures, the word "methodology" may be used in place of the techniques themselves.

Methodology can be thought of as a collection of procedures, each of which is applied to a distinct set of facts over the full methodology spectrum. The two parts of research are qualitative research and quantitative research. The systematic approach to solving a research topic through the collection of data using various approaches, the provision of an interpretation of the data collected, and the drawing of inferences from the study data is known as methodology in research. A research technique is essentially the design of a research or study.

3.2: Research Design

Research design is characterized as the framework created to address the research questions. A research project's design identifies the research tools, including the study topic, dependent and independent variables, experimental design, and, if necessary, data collection techniques and a plan for statistical analysis.

The research's methodology was as follows:

- Study on biomedical uses of microstrip patch antenna.
- Study on antenna requirements for heartbeat monitoring.
- Study literature to select the design parameters for the antenna.
- Study the procedures of designing a smooth antenna for maximum result.
- Study the antenna design procedure in CST Microwave Studio.
- Implement the procedure.

3.3: Pilot Study

A research study carried out earlier than the one intended is called a pilot study. Typically, pilot studies are carried out on a lower size than the original investigation. A pilot study lessens the possibility of making a Type I or Type II error, however it cannot completely eliminate all systemic errors or unforeseen difficulties. The primary study is a time, money, and effort waste due to both sorts of errors.

Before launching the main investigation, a pilot study should be conducted for a variety of reasons. Here are a few motivating factors:

- ❖ To test the research process.

- ❖ To identify variables of interest and decide how to operationalize each one.

- ❖ To evaluate an intervention plan and determine the elements that will be most helpful in facilitating the intervention.

- ❖ To create or evaluate the performance of research tools and procedures.

- ❖ To estimate statistical parameters for later analyses.

3.4: Software

The CST MWS from Microwave Studio is a powerful tool for electromagnetic 3D simulation of high frequency components. Quick and precise evaluation of HF systems, including filters, couplers, antennas, single- and multi-layer constructions, as well as SI and EMC consequences, is made possible by CST MWS.

CST MWS is the top choice for R&D departments leading in technology because of its unmatched output. CST MWS, which is incredibly user-friendly, gives the user a brief review of the EM conduct of high frequency designs.

The result of many years of research and development into the most precise and effective computational solutions for electromagnetic designs is the electromagnetic simulation program CST STUDIO SUITE®.

3.5: Design procedure

Step 1: Firstly, all the selected parameters must be stored to use during the design. Such as:

- ❖ The operating frequency.
- ❖ Dielectric constant of substrate (FR4 material= 4.3).
- ❖ The width of the substrate (Ws=46.6).
- ❖ The height of the dielectric substrate (Hs=1.6).
- ❖ The length of the substrate (Ls=38).
- ❖ The width of the patch (Wp=38.5).
- ❖ The length of the patch (Lp=30).
- ❖ The height of the patch (Hp=0.035).
- ❖ Other parameters (DL=0.78,Wf=2.88,Yo=4,y=6).
- ❖ Evaluate the air,skin,fat,muscle layers properties

Step 2: Design the substrate.

Step 3: Design the ground.

Step 4: Design the patch.

Step 5: Design the transmission line.

Step 6: Design the air layer.

Step 7: Design the skin layer.

Step 8: Design the fat layer.

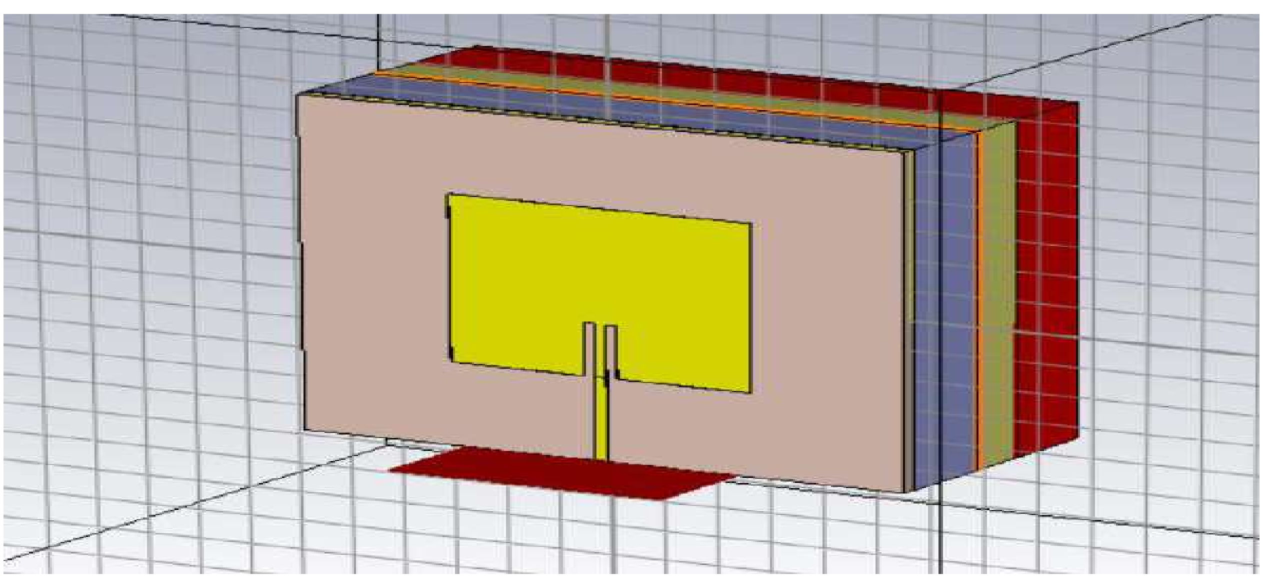
Step 9: Design the muscle layer.

Step 10: Design the waveguide port using picks, macros solver.

Step 11: Start simulation.

Step 12: Check the results of (VSWR, S11 parameters, e & h fields, Line Impedance, Power accepted, Total efficiency, Loss in Dielectrics, Power radiated etc.) and save the design of antenna if it meets the criteria.

3.6: Designed Antenna



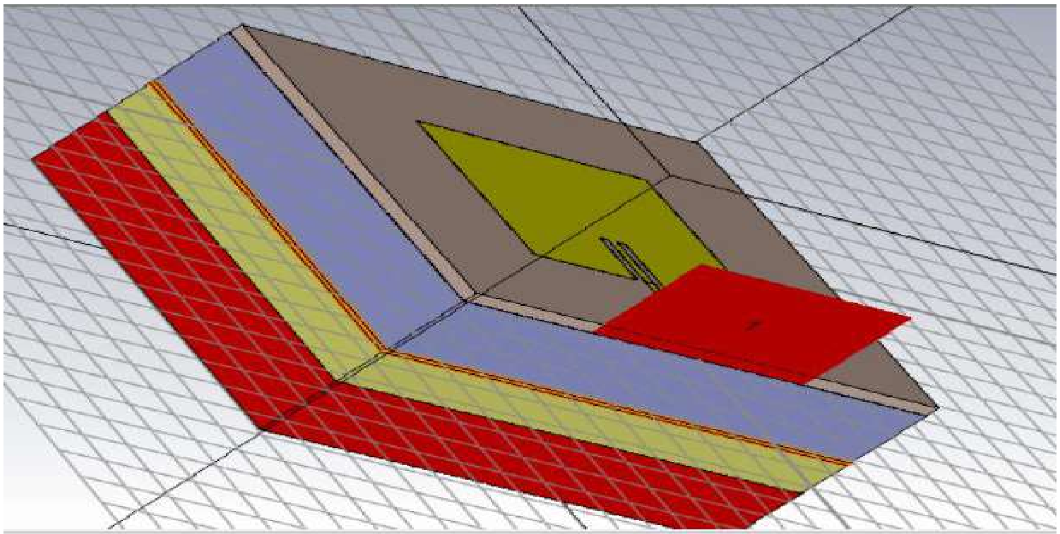


Fig 3.1: 2.4 GHz Micro-strip Patch Antenna

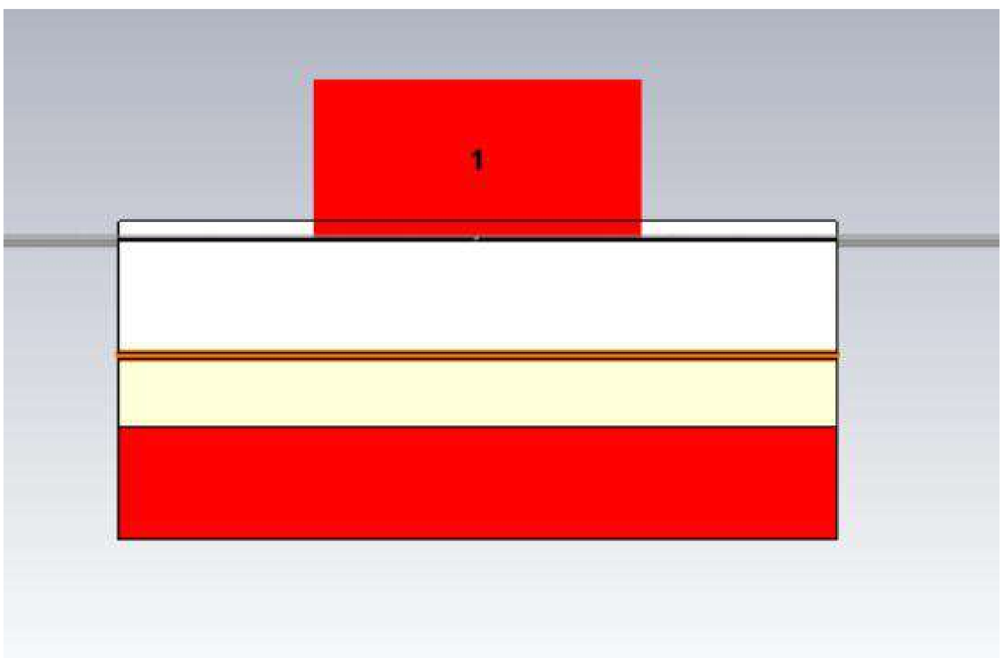


Fig 3.2: Bottom view

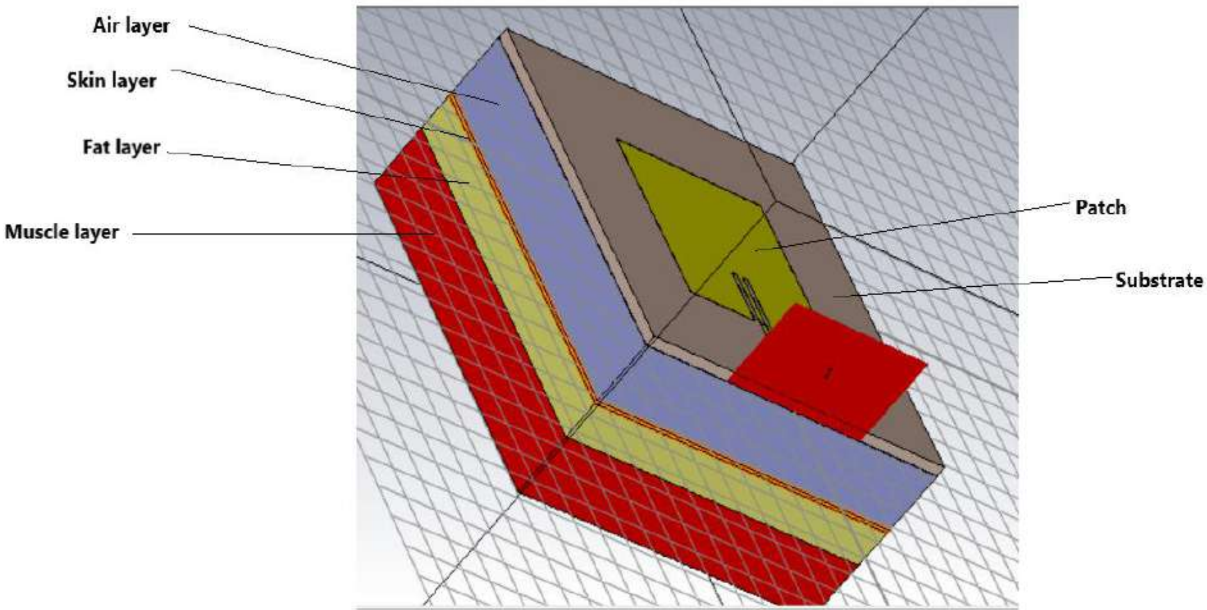


Fig 3.3: Antenna layer specifications

Chapter Four

Result Analysis

This section provides and analyzes the results obtained after simulating the built antenna.

4.1: Voltage Standing Wave Ratio (VSWR)

The voltage standing wave ratio (VSWR), which runs the length of a transmission line construction, is defined as the ratio of the maximum voltage to the minimum voltage.

It is consistently positive and ranges from 1 to (plus) infinity. This term is difficult to apply unless you have a piece of slotted line-test equipment, especially given that the idea of voltage in a microwave structure has several different meanings. In order to avoid using the word voltage and instead refer to the idea of power waves, VSWR is occasionally referred to as SWR. The mathematical definition of VSWR in terms of a reflection coefficient follows from this. The proportion of the reflected wave to the incident wave at a reference plane is known as the reflection coefficient.

VSWR value under 2 is considered suitable for most antenna applications. The graph below shows that the value of VSWR is 1.6532 which is within the normal limit of the working frequency range.

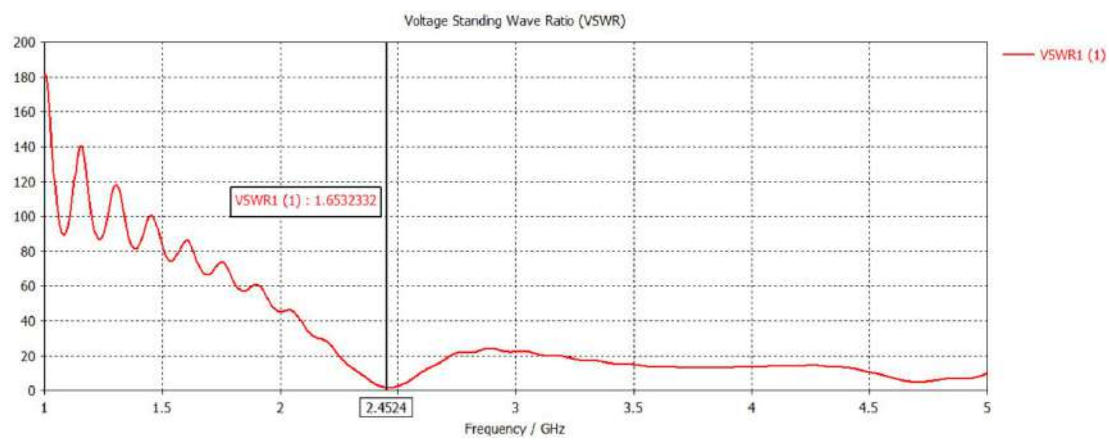


Fig 4.1: VSWR Plot

4.2: Return Loss Graph

The return loss of an antenna is a measurement of how many radio waves arrive at the antenna input and are rejected as compared to how many are accepted. In relation to a short circuit, the decibels (dB) are stated. The amount of light that is reflected back toward the source is measured by return loss, which is likewise given in dBs and is always a positive number. A high return loss is advantageous since it typically leads to a low insertion loss. A high return loss value indicates a higher quality signal.

The return loss or S11 parameter value in this following graph is under -10 dB which is sufficient. The graph below shows that our s11 parameter value is -12.750

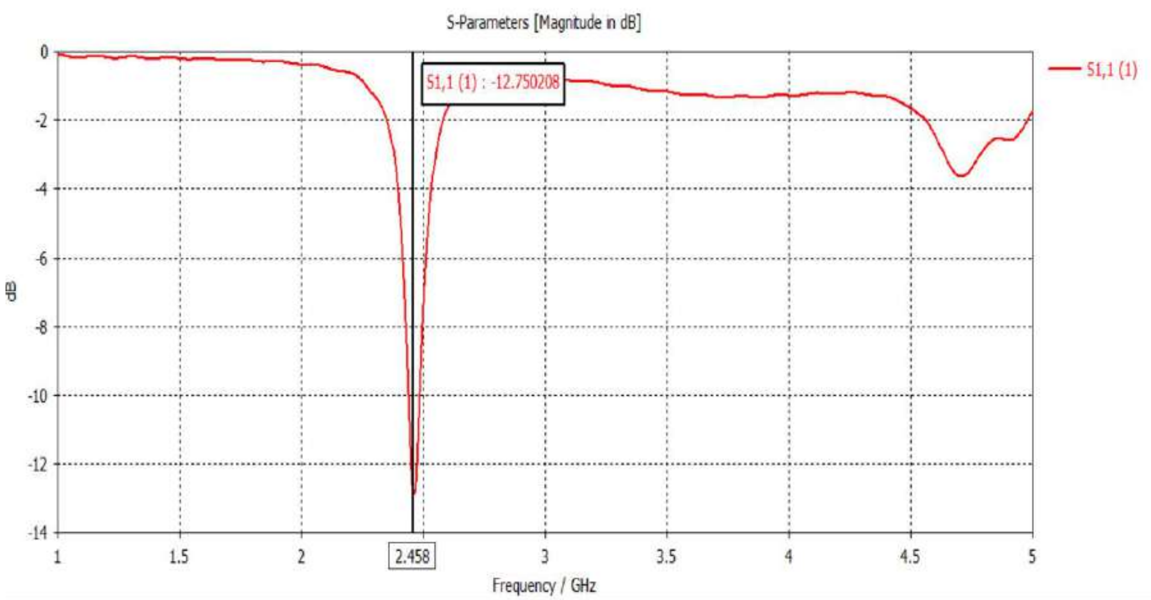


Fig 4.2: Return Loss Graph (s1 1 Parameter)

4.3: Total Efficiency

Total efficiency, which accounts for both reflection loss and energy loss in the antenna, is the ratio of power incident from the network to power incident on the antenna. Antenna effectiveness is the effectiveness with which the antenna transmits or receives a signal. Most often, it is the proportion between total input power and total radiated power at the transmitting side, and vice versa at the receiving side.

An ideal antenna transmits all of the power applied to it, or has a 100% antenna efficiency. A decent antenna, however, only transmits between 50 and 60 percent of the power applied to it in reality.

By applying some power to the antenna feed pads and measuring the strength of the radiated electromagnetic field in the surrounding area, the antenna efficiency is determined in an anechoic chamber.

A good antenna typically transmits between 50 and 60 percent of the energy it receives (-3 to -2.2dB). The following graph shows the total efficiency value is -4.622 dB, which is a perfect result for a simulated antenna. In real life if this antenna is fabricated it will show the decent results required.

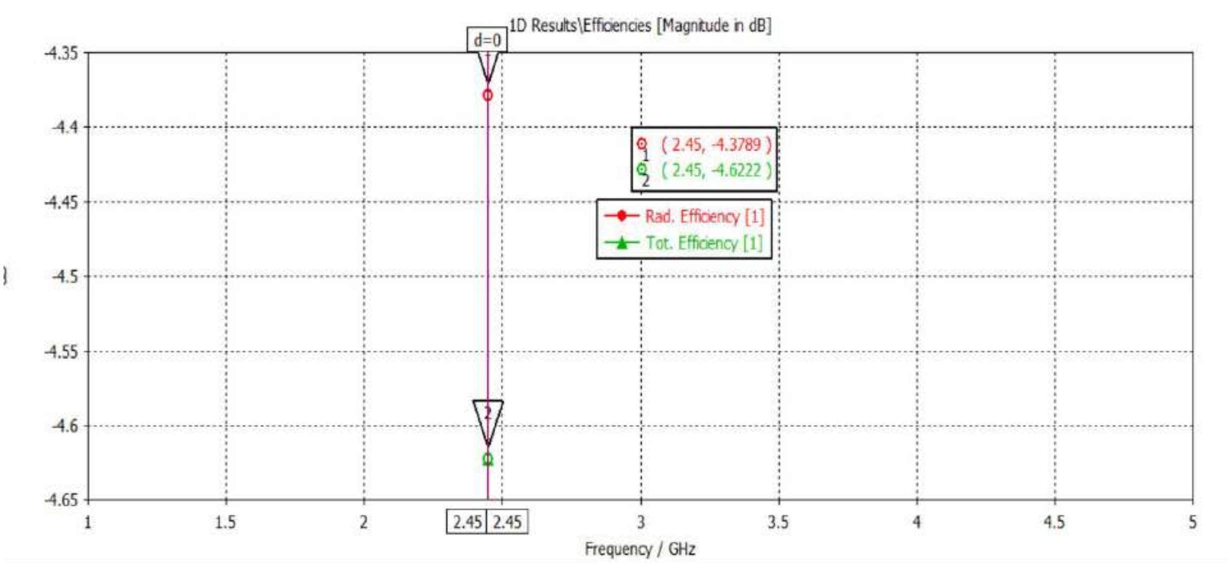


Fig 4.3: Total Efficiency

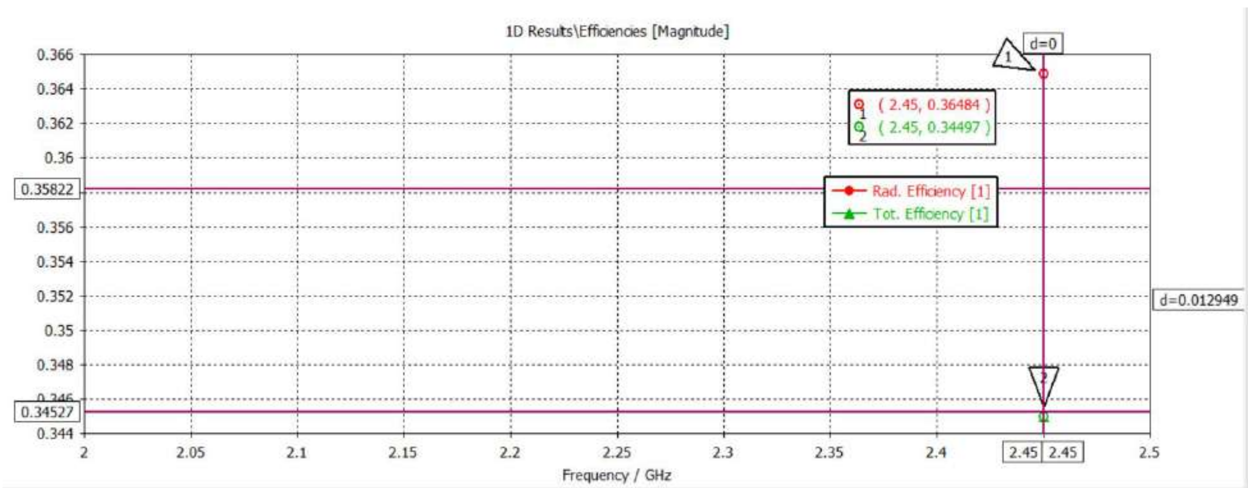


Fig 4.4: Efficiency Percentage

4.4: The Specific Absorption Rate (SAR)

The Specific Absorption Rate (SAR) is important for biomedical implantable antennas. It gives the measure of absorbed power within a unit mass of biological tissue. The SAR value should be within the range set by IEEE C95. 1-1999 standard. For safety the average SAR should be less than 1.6 W/Kg for a 1g- body model. Specific absorption rate

(SAR) is the measure of the allowable level of EM radiation to be produced by communication antenna in wireless devices. Our antenna has an SAR value 0.279 W/Kg for a 1g body model which a very good result as an biomedical antenna.

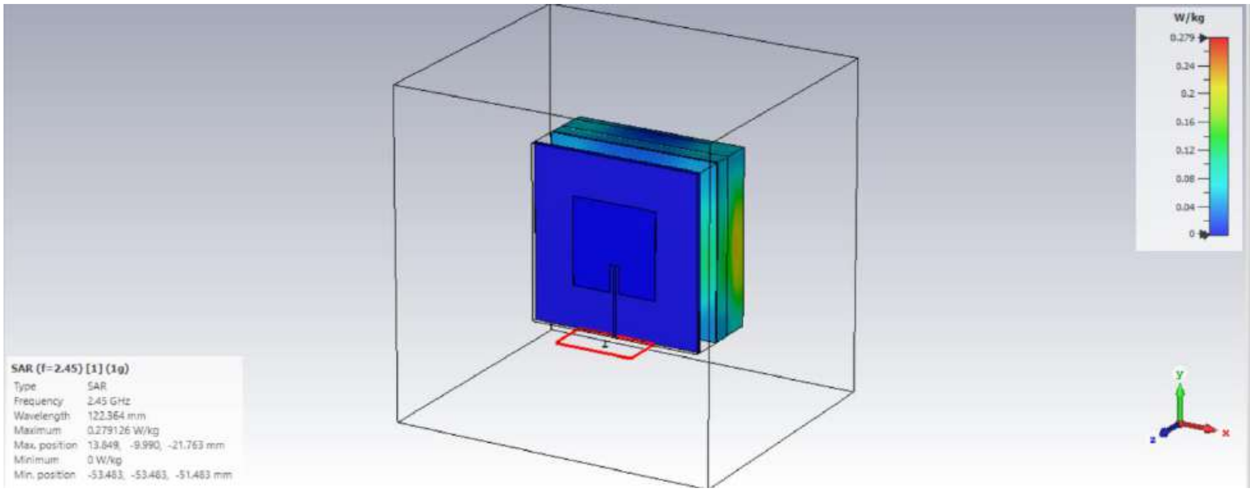


Fig 4.5: Specific Absorption Rate (SAR)

4.5: 2D Radiation Pattern

In the realm of antenna design, the term radiation pattern refers to the directional reliance on the antenna radio waves' intensity. A respectable radiation pattern and a narrow beam width for the constructed antenna are shown in the 2D radiation pattern of a single element. Micro-strip patch antennas have a half-circular radiation pattern, and our radiation pattern exactly matches the standard, which is also nearly half-circular.

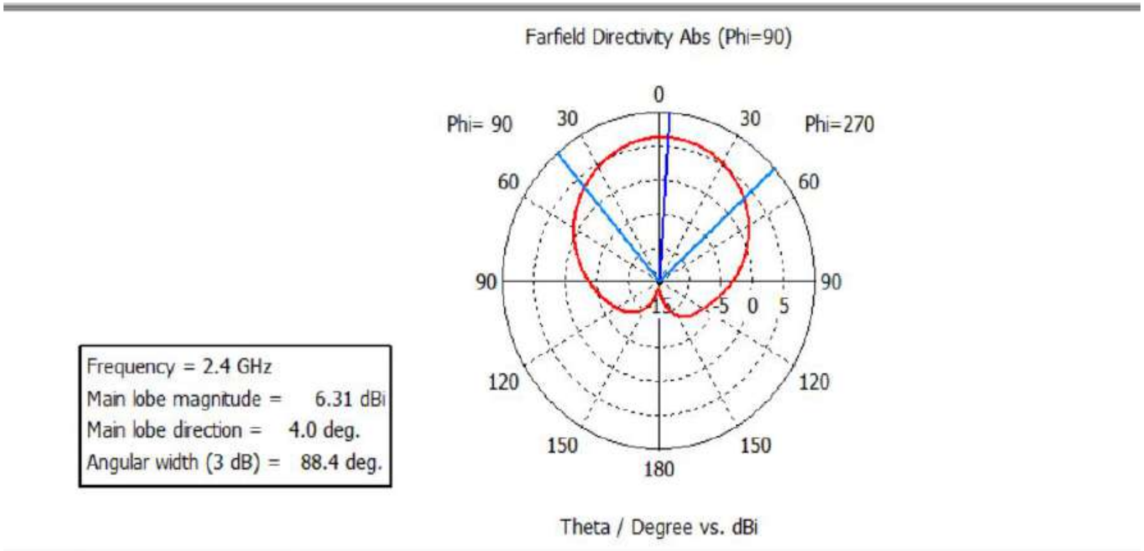


Fig 4.6: 2D Radiation Pattern

4.6: 3D Radiation Pattern

A 3D radiation pattern is a three-dimensional view of how an antenna radiates energy in the surrounding room. This pattern is typically measured at a sufficient distance from the known farfield antenna.

Simply put, it is the energy that radiates from an isotropic antenna in some direction (a theoretical antenna that radiates in all directions equally). A healthy antenna, like the 2D radiation pattern, should maintain its 3D radiation pattern throughout the operating frequency range. The energy supplied in a specific direction from the 3D radiation pattern is very easy to observe.

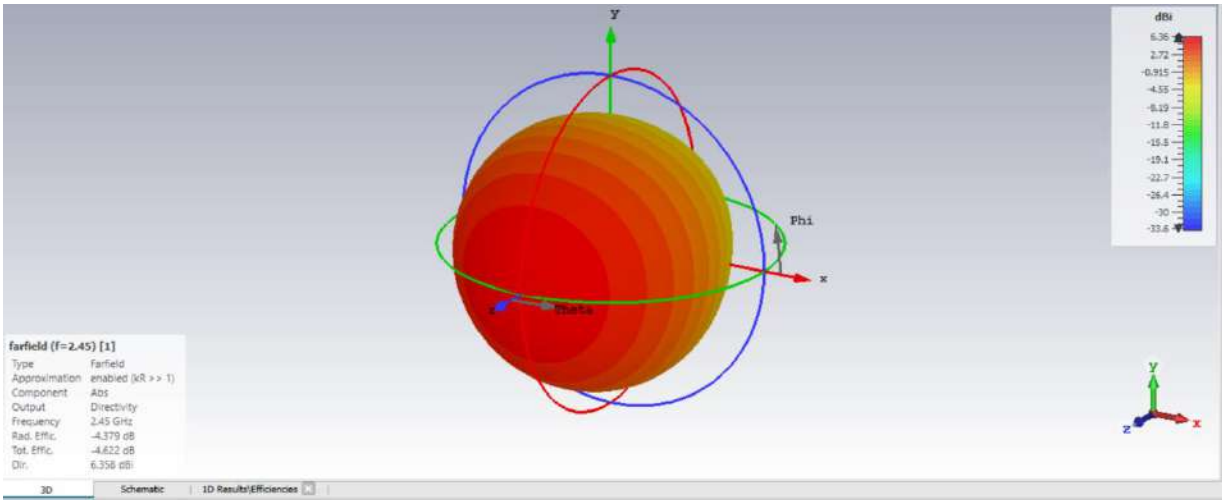


Fig 4.7: 3D Radiation pattern for 2.4 GHz with directivity

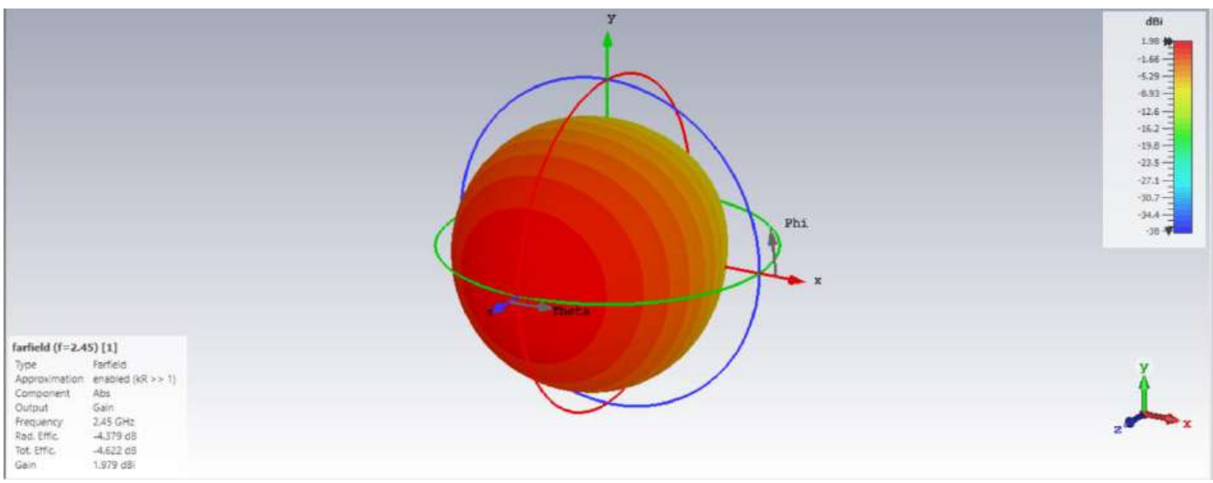


Fig 4.8: 3D Radiation Pattern for 2.4 GHz with Gain (IEEE) value.

Chapter Five

Conclusion

The findings of this research work reveals that a high gain Micro-strip Patch Antenna is intended to function on a 2.4 GHz band using CST Microwave Studio. The findings are very much positive according to the values of desired specturms. Our antenna is much reliable to monitor heart beat on a regular basis checkup for any diseased patients.

5.1: Achievements

In this thesis work, a high gain 2.4 GHz single micro-strip antenna is designed. The parameters we used to design this is measured by analyzing many research papers to find out the proper values of the elements length, width, height. The VSWR value is under 2 which is a proper amount for a good working antenna.The return loss graph or s11 parameter value is -12dB, which is good amount for a resonating biomedical antenna. The efficiency is showing -4.6dB which is slightly good amount according to previous researches on this similar topic. The researchers have managed to gain efficiency about -3.8dB. Ours value is slightly higher than them but is a good number as there are many obstacles for resonating the power. The skin,fat,muscle layer will block the radiation of power but if we can manage to provide the proper amount of power without any loss our antenna will show proper result.We can say it because the SAR value is 0.279 which is much better for biomedical antennas like this, as they need SAR value 1.6. Other results are also in good shape as this which makes our designed antenna as a suitable antenna for monitoring heart-beat.

So, the proposed antenna is a strong candidate to be used in health monitoring tools.

5.2: Limitations

The proposed antenna is somehow needed some more proper efficiency value as an simulated antenna, though the value we got is also perfect but if it can be increased slightly it will be 100% reliable for doctors.

5.3: Future Work Field

Wearable antennas are the future of health monitoring tools for doctors. It will save a lot of times which will help the doctors to treat patients more easily as it is very handy and easy to use.

References

[1]M. M. M. Ali and A. Sebak, "Directive antennas for future 5G mobile wireless communications," *2017 32th General Assembly and Scientific Symposium of the International Union of Radio Science (URSI GASS)*, Montreal, QC, 2017, pp. 1-4.

[2]W. Hong; K. Baek; Y. Lee; Y. Kim; S. Ko, "Study and prototyping of practically large-scale mmWave antenna systems for 5G cellular devices," in *IEEE Communication Magazine*, 2014

[3]G. Guo, L. Wu, Y. Zhang and J. Mao, "Stacked patch array in LTCC for 28 GHz antenna- in-package applications," 2017 IEEE Electrical Design of Advanced Packaging and

[4]H. Jaafar, M. T. Ali, S. Subahri, A. L. Yusof and M. K. M. Salleh, "Improving gain performance by using air substrate at 5.8GHz," *2012 International Conference on Computer and Communication Engineering (ICCCE)*, Kuala Lumpur, 2012, pp. 95-98.

[5]Kasturi Sudam Patil,Elizabeth Rufus, “A review on antennas for biomedical implants used for IoT based health care,August,2019

[6]T. Karacolak, A. Z. Hood, and E. Topsakal, "Design of a dual-band implantable antenna and development of skin mimicking gels for continuous glucose monitoring," Microwave Theory and Techniques, IEEE Transactions on, vol. 56, pp. 1001-1008, 2008.

[7]Collin-Chami/G. Collin, A. Chami, +2 authors R. Staraj paper/Human-implanted-spiral-antenna-for-a-2.45GHz-and Published 5 July 2008 2008 IEEE Antennas and Propagation Society International Symposium

[8]J. Gemio, J. P. o., and J. Soler (2010).Human Body Effects on Implantable Antennas for ISM Bands Applications: Models Comparison and Propagation Losses Study. Progress In Electromagnetics Research, 110,437-452

[9]Al-Shaheen, A. (2012). New Patch Antenna for ISM Band at 2.45 GHz. ARPN Journal of Engineering and Applied Sciences 7(1), 1-9.

[10]Peter S.Hall, Y. H. (2012). Antennas and Propagation for Body-Centric Wireless Communications.

[11]Design and Performance Analysis of a Multiband Microstrip Patch Array Antenna at Ku and K Band October 2018 Conference: 2018 International Conference on Innovations in Science, Engineering and TechnologyAt: Chittagong, Bangladesh

[12]Design of a Miniaturized Implantable PIFA with DGS for the Investigation of Uterus Fibroids Mousume Samad Md. Mostafizur Rahman

[13]S. Holcombe and S.Wang (2014), Subcutaneous fat distribution in the human torso, pp. 389-396

[14]Author Narinder Sharma A Study Of Different Feeding Mechanisms In Microstrip Patch Antenna February 2017

[15]Robin Augustine. Electromagnetic modelling of human tissues and its application on the interaction between antenna and human body in the BAN context. Universit´e Paris-Est, 2009.

[16]2.4 GHz Plaster Antennas for Health MonitoringTiiti Kellom¨aki #1, William G. Whittow ∗ 2, Jouko Heikkinen #3, Lauri Kettunen #4

[17]Kukunuri Suraj and M. Neelaveni Amma Design and Development of Microstrip Patch Antenna at 2.4 GHz for Wireless Applicationsl Indian Journal of Science and Technology, Vol 11(23), DOI: 10.17485/ijst/2018/v11i23/125651, June 2018

[18]K. Ravi Kiran2, E. Thangaselvi1, S. Karthikeyan1, and T. Chelladurai1

Published Online: 24 May 2022 Design and analysis of square microstrip patch antenna at 2.4 GHz band used for iot based health care monitoring AIP Conference Proceedings K. Ramamoorthy1,a),

[19]Shera Prabjyot Singh1, Ashish Singh2, Deepak Upadhyay3, Sunilkumar Pal4, Mahesh Munde5, 'Design and Fabrication of Microstrip Patch Antenna at 2.4 Ghz for WLAN Application using HFSS', IOSR Journal Of Electronics and Communication Engineering(ISOR-JECE)e-ISSN:2278-2834,p-ISSN-2278-8735.

[20]Nandini Ammanagi, Rahul Khadilkar, Akash Harwani, Disha Budhlani, Disha Dembla; "Comparison of the performance of Microstrip Antenna at 2.4GHz Using Different Substrate Materials", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3, Issue-4, April 2014.

[21]Vipul, Ved Vyas Microstrip Parallel Coupled Bandpass Filter Design for Applications at 2.4 GHz M. Published 24 March 2017 Business Communications on Applied Electronics

[22]Thangaselvi E & Meena alias JeyanthiK, "Design and Implementation of Textile Antenna and their Comparative Analysis of Performance Parameters with Off and On Body Condition", International Journal of Biomedical Engineering and Technology, vol.30, no.4, pp. 295–328, 2019

[23]Syaiful Redzwan, Noor Badariah Binti Asan, Jacob Velander, Javad Ebrahimizadeh Analysis of Thickness Variation in Biological Tissues Using Microwave Sensors for Health Monitoring Applications October 2019

[24]Ali, S.M.;Ali, S.M.; Sovuthy, C.; Noghanian, S.; Saeidi, T.; Majeed, M.F.; Hussain, A.; Masood, F.; Khan, S.M.; Shah, S.A.; Abbasi, Q.H. Design and Evaluation of a Button Sensor Antenna for On-Body Monitoring Activity in Healthcare Applications. Micromachines 2022, 13, 475.

[25] Kaul, N., et al. (2015). Effect of parasitic patch configurations on multi-banding of

microstrip antenna. 2015 4th International Conference on Reliability, Infocom Technologies and Optimization (ICRITO)
[26] A. K. Skrivervik, "Implantable antennas: The challenge of efficiency," in Antennas and Propagation (EuCAP), 2013 7th European Conference on, 2013, pp. 3627-3631.
[27] K. Gosalia, M. S. Humayun, and G. Lazzi, "Impedance matching and implementation of planar space-filling dipoles as intraocular implanted antennas in a retinal prosthesis," Antennas and Propagation, IEEE Transactions on, vol. 53, pp. 2365-2373, 2005.
[28] L.Thuc,"Human implanted spiral antenna for a 2.45 GHz wireless temperature and pressure SAW sensor system,"in 2008 IEEE Antennas & Propagation Society International Symposium, 2008, pp.1-4.
[29] R. D. Beach, R. W. Conlan, M. C. Godwin, and F. Moussy, "Towards a miniature implantable in vivo telemetry monitoring system dynamically configurable as a potentiostat or galvanostat for two-and three-electrode biosensors," Instrumentation and Measurement, IEEE Transactions on, vol. 54, pp. 61-72, 2005.
[30] M., et al. (2016). Implantable ferrite antenna for biomedical applications. Microwave and Optical Technology Letters 58(11), 2745-2749.
[31] Peter S.Hall, Y. H. (2012). Antennas and Propagation for Body-Centric Wireless Communications
[32] Yeboah-Akowuah, B., et al. (2015). A low profile microstrip patch antenna for bodycentric communications at 2.45GHz band. 2015 9th European Conference on Antennas and Propagation (EuCAP).
[33] P. Hasgall, F. Di Gennaro, C. Baumgartner, E. Neufeld, M. Gosselin, A. Payne, D. Klingenbck, and N. Kuster, "Itis database for thermal and electromagnetic parameters of biological tissues, v3.0," 2015. [Online]. Available: http://dx.doi.org/10.13099/VIP21000-03-0
[34] Fazeli, M., et al. (2016). Implantable ferrite antenna for biomedical applications. Microwave and Optical Technology Letters 58(11), 2745-2749.
[35] M. Teja, K. R. D. (2016). Design of Compact Dual Band Slot Antenna at MICS and ISM for Bio-Medical Applications. International Journal of Innovative Research in Computer and Communication Engineering 4(8), 15362 - 15368.
[36] Vidal, N. and J. M. López-Villegas (2010). Changes in Electromagnetic Field Absorption in the Presence of Subcutaneous Implanted Devices: Minimizing Increases in Absorption. IEEE Transactions on Electromagnetic Compatibility 52(3), 545-555.
[37] Bouazizi, A., et al. (2016). Parametric study of implantable planar inverted-F antenna for wireless body area network application. 2016 2nd International Conference on Advanced Technologies for Signal and Image Processing (ATSIP).

[38] J. Gemio, J. P. o., and J. Soler (2010).Human Body Effects on Implantable Antennas for ISM Bands Applications: Models Comparison and Propagation Losses Study. Progress In Electromagnetics Research, 110,437-452.
[39] Christ, A., et al. (2006). The dependence of electromagnetic far-field absorption on body tissue composition in the frequency range from 300 MHz to 6 GHz. IEEE Transactions on Microwave Theory and Techniques 54(5), 2188-2195.
[40] Hossain, T., et al. (2015). Design and performance analysis of a biomedical implantable patch antenna. 2015 International Conference on Advances in Electrical Engineering (ICAEE).
[41]Constantine A. Balanis, Antenna theory third edition analysis and designing, 3rd Edition, Willey Interscience