

DESIGN OF MINIATURIZED DUAL BAND MICROSTRIP ANTENNA FOR WLAN APPLICATION

A Project Report Phase – II

Submitted in partial fulfillment of the requirements for the award of

**Bachelor of Engineering degree in
Electronics and Communication Engineering**

by

K.TINU SAHITH (39130237)

L.LIBIN(39130258)



**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade “A” by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119.

APRIL 2023



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with "A" grade by NAAC
Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai - 600 119

www.sathyabama.ac.in

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **K.TINU SAHITH (39130237)** and **L.LIBIN (39130258)** who carried out the project entitled "**DESIGN OF MINIATURIZED DUAL BAND MICROSTRIP ANTENNA FOR WLAN APPLICATION**" under our supervision from November 2022 to April 2023.

Internal Guide

Dr. S. LAKSHMI, M.E., Ph.D.

Head of the Department

Dr. T. RAVI, M.E., Ph.D.

Submitted for Viva Voce Examination held on 24.04.2023

Internal Examiner

External Examiner

DECLARATION

We, **K.TINU SAHITH (39130237)** and **L.LIBIN (39130258)** hereby declare that the project report entitled “**DESIGN OF MINIATURIZED DUAL BAND MICROSTRIP ANTENNA FOR WLAN APPLICATION**” done by us under the guidance of **Dr. S. LAKSHMI M.E., Ph.D.** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

DATE: 24.04.2023

1. 

2. 

PLACE: CHENNAI

SIGNATURE OF CANDIDATES

ACKNOWLEDGEMENT

We are pleased to acknowledge our sincere thanks to the **Board of Management** of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

We convey our thanks to **Dr. N. M. Nandhitha, M.E., Ph.D., Dean, School of Electronics and Communication Engineering** and **Dr. T. Ravi, M.E., Ph.D., Head of the Department, Department of Electronics and Communication Engineering** for providing me necessary support and details at the right time during the progressive reviews.

We would like to express our sincere and deep sense of gratitude to our project guide **Dr.S.Lakshmi, M.E., Ph.D.** for her valuable guidance, suggestions and constant encouragement paved way for the successful completion of our project work.

We wish to express our thanks to all teaching and non-teaching staff members of the **Department of Electronics and Communication Engineering** who were helpful in many ways for the completion of the project.

ABSTRACT

Wireless local area network (WLAN) is a technology which combines the computer network with wireless communication technology. In this method a new design approach has been presented for achieving the miniaturized dual band microstrip patch antenna suitable to be used for the 2.4GHz, 5GHz and 8.2GHz frequency bands in the industrial scientific medical (ISM) band can be used in the WLAN development. Because of the development of wireless communication technology and the use of the frequency bands without any need of authorization, the application of WLAN is becoming more and more extensive. This paper designs two new dual-frequency microstrip antennas with the use of electromagnetic simulation software- High Frequency Structure Simulation (HFSS). The two antennas adopt ordinary FR4 material as a dielectric substrate, with the advantages of low cost and small size. The first antenna adopts microstrip line feeding, and the antenna radiation patch is composed of a folded T-shaped radiating dipole which reduces the antenna size, and two symmetrical rectangular patches located on both sides of the T-shaped radiating patch. The second antenna is a microstrip patch antenna fed by coaxial line, and the size of the antenna is diminished by opening a stepped groove on the two edges of the patch and a folded slot inside the patch.

TABLE OF CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
	ABSTRACT	v
	LIST OF FIGURES	viii
	LIST OF TABLES	ix
	LIST OF ABBREVIATIONS	x
1	INTRODUCTION	1
	1.1 INTRODUCTION	1
	1.2 ANTENNAS	1
	1.3 ANTENNA PARAMETERS	1
	1.4 TYPES OF ANTENNAS	3
	1.5 INTRODUCTION TO MICROSTRIP ANTENNAS	6
	1.6 DESIGN THEORY	7
	1.7 INTRODUCTION ABOUT WLAN	9
	1.8 TYPES OF WLAN	10
	1.9 APPLICATION OF WLAN	11
	1.10 ANALYSIS MATHOD OF MICROSTRIP PATCH ANTENNA	12
	1.11 SUMMARY	15
2	LITERATURE SURVEY	
	2.1 INTRODUCTION	16
	2.2 LITERATURE REVIEW	16
	2.3 SUMMARY	20
3	EXISTING METHODOLOGY	21
	3.1 INTRODUCTION	21
	3.2 MINIATURIZATION OF AN ANTENNA	21

	3.3 KEY TYPES OF DUAL BAND WIFI ANTENNAS	24
	3.4 RADIO FREQUENCY CONNECTOR FOR DUAL BAND WIFI ANTENNAS	25
	3.5 SUMMARY	26
4	PROPOSED METHODOLOGY	27
	4.1 INTRODUCTION	27
	4.2 BLOCK DIAGRAM	27
	4.3 MICROSTRIP PATCH ANTENNA FORMULAS	28
	4.4 DIMENSIONS TABLE OF THE MICROSTRIP PATCH ANTENNA	31
	4.5 ANSYS HFSS SOFTWARE	34
	4.6 SUMMARY	35
5	RESULTS AND DISCUSSION	37
	5.1 INTRODUCTION	37
	5.2 FABRICATION WORK	49
	5.3 TESTING RESULTS OF FABRICATED ANTENNA	51
	5.4 MAXIMUM AND MINIMUM VALUE OF SIMULATED ANTENNA DESIGN	53
	5.5 SUMMARY	53
6	CONCLUSION AND FUTURE WORK	53
	6.1 INTRODUCTION	55
	6.2 CONCLUSION	55
	6.3 FUTURE SCOPE	55
	6.4 SUMMARY	56
	REFERENCES	57

LIST OF FIGURES

FIGURE NO	TITLE	PAGE NO
1.1	Dipole Antenna circuit diagram	3
1.2	Horn antenna	4
1.3	Reflector antenna	4
1.4	Lens antenna	5
1.5	Yagi – uda antenna	5
1.6	Structure of microstrip antenna	6
1.7	Structure chart of printed microstrip antenna	7
1.8	Microstrip feed line	13
1.9	Coaxial probe feed	14
1.10	Proximity coupling	14
1.11	Aperture coupling	15
4.1	Fabrication measurement diagram	27
5.1	Simulated structure of an antenna	37
5.2	Gain of the antenna	38
5.3	Directivity of an antenna	39
5.4	Return loss	40
5.5	Electric field of an antenna	41
5.6	Magnetic field of an antenna	41
5.7	Reflection coefficient	42
5.8	VSWR	43
5.9	Radiation efficiency	44
5.10	Radiation intensity	45
5.11	Front to back ratio	46
5.12	Radiation pattern at 2.4GHz	47

5.13	Radiation pattern at 5.2GHz	47
5.14	Smith chart	48
5.15	Fabricated antenna-front side	50
5.16	Fabricated antenna-back side	50
5.17	S-parameter plot	51
5.18	Vswr plot	52
5.19	Smith chart	52

LIST OF TABLES`

TABLE NO.	TITLE	PAGE NO.
4.1	DIMENSIONS AND POSITION OF THE MICROSTRIP PATCH ANTENNA	31
5.1	MAXIMUM AND MINIMUM VALUES OF SIMULATED ANTENNA DESIGN	53

LIST OF ABBREVIATIONS

SIW Antenna	Substrate Integrated Waveguide Antenna
ANSYS HFSS	ANSYS High Frequency Structure Simulator
VSWR	Voltage Standing Wave Ratio
ISW	Integrated Substrate Waveguide
PO	Physical Optics
RFID	Radio Frequency Identification
Wi-Max	Worldwide Interoperability for Microwave Access
ANN	Artificial Neural Network
MSE	Mean Square Error
ADAS	Advance driver Assistance systems
WLAN	Wireless Local Area Network
SRR Antenna	Split Ring Resonator Antenna
SBR	Shooting and bouncing rays
GSM	Global System for Mobile Communication
FEM	Finite Element Method
MoM	Method of moments

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Antenna are major part of any wireless communication system. In today's scenario, although, antenna as a device is not new to common man, but the level of understanding the background concept involved in the working of this device will certainly help in designing new types of antennas, in order to meet the necessary requirements in wireless domain.

1.2 ANTENNAS

In any wireless communication system, after a radio frequency (rf) signal has been generated in a transmitter, some means must be used to radiate this signal through space to a receiver. The device that does this job is the antenna. The transmitter signal energy is sent into space by a transmitting antenna, the rf signal is then picked up from space by a receiving antenna.

The Rf energy is transmitted into space in the form of an electromagnetic field. As the travelling electromagnetic field arrives at the receiving antenna, a voltage is induced into the antenna (usually a conductor). The rf voltages induced into the receiving antenna are then passed into the receiver and converted back into the transmitted rf information. So, antennas can be thought of as a "transducer" that converts radio waves into electrical currents and voltages and vice versa. More specifically, these are devices designed to radiate or receive electromagnetic energy efficiently in a prescribed manner.

1.3 ANTENNA PARAMETERS

An antenna is an electrical conductor or system of conductors
Transmitter – Radiates electromagnetic energy into space
Receiver – Collects electromagnetic energy from space.

1.3.1 Power Gain

Power gain (or simply gain) is a measure of the ability of the antenna to direct the input power into radiation in a particular direction and is measured at the peak radiation intensity. Consider the power density radiated by an isotropic antenna with input power P_0 at a distance R which is given by $S = P_0/4\pi R^2$. An isotropic antenna radiates

equally in all directions, and its radiated power density S is found by dividing the radiated power by the area of the sphere $4\pi R^2$. An isotropic radiator is considered to be 100% efficient and also measure that combines an antenna's efficiency Σ antenna and directivity D :

$$G = \Sigma \text{ antenna} \cdot D \quad (1.1)$$

1.3.2 Efficiency

The efficiency Σ antenna of an antenna is the total radiated power P_0 divided by the input power at the feed point.

$$\Sigma \text{ antenna} = \frac{p_0}{p_{in}} \quad (1.2)$$

A transmitting antenna is supplied power by a feed line, a transmission line connecting the antenna to a radio transmitter. The input power P_{in} to the antenna is typically defined to be the power supplied to the antenna's terminals (the feed point), so antenna power losses do not include power lost due to joule heating in the feed line and reflections back down the feed line due to antenna/line impedance mismatches.

The electromagnetic reciprocity theorem guarantees that the electrical properties of an antenna, such as efficiency, directivity, and gain, are the same when the antenna is used for receiving as when it is transmitting.

1.3.3 Directivity

An antenna's directivity is determined by its radiation pattern, how the radiated power is distributed with direction in three dimensions. All antennas are directional to a greater or lesser extent, meaning that they radiate more power in some directions than others. The direction is specified here in spherical coordinates (θ, ϕ) where θ is the altitude or angle above a specified reference plane (such as the ground), while ϕ is the azimuth as the angle between the projection of the given direction onto the reference plane and a specified reference direction (such as north or east) in that plane with specified sign (either clockwise or counterclockwise).

The distribution of output power as a function of the possible directions (θ, ϕ) is given by its radiation intensity $U(\theta, \phi)$ (in SI units: watts per steradian, $W \cdot sr^{-1}$). The output power is obtained from the radiation intensity by integrating the latter over all solid angles $d\Omega = \cos\theta \, d\theta \, d\phi$

1.3.4 Path loss

Path loss normally includes propagation losses caused by the natural expansion of the radio wave front in free space (which usually takes the shape of an ever- increasing sphere), absorption losses (sometimes called penetration losses), when the signal passes through media not transparent to electromagnetic waves, diffraction losses when part of the radio wave front is obstructed by an opaque obstacle, and losses caused by other phenomena.

1.3.5 Return Loss

Return loss is an important parameter when testing an antenna. It is related to impedance matching and the maximum transfer of power theory. It is also a measure of the effectiveness of an antenna to deliver of power from source to antenna. The return loss (RL) is defined by the ratio of the incident power of the antenna (P_{in}) to the power reflected back from the antenna of the source (P_{ref}) the mathematical expression is $R = 10\log_{10}(P_i/P_r)$.

1.4 TYPES OF ANTENNA

1.4.1 Dipole Antenna

Wire antennas are Dipole, monopole, loop antenna, helix. Usually used in personal applications, auto mobiles, buildings, ships, aircrafts and spacecrafts.

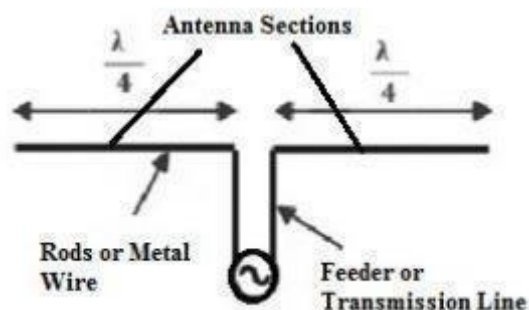


Fig 1.1: Dipole Antenna Circuit Diagram

1.4.2. Horn Antennas

Aperture antennas are Horn antennas, waveguide opening. Usually used in air crafts and spacecrafts because these antennas can be flush mounted.

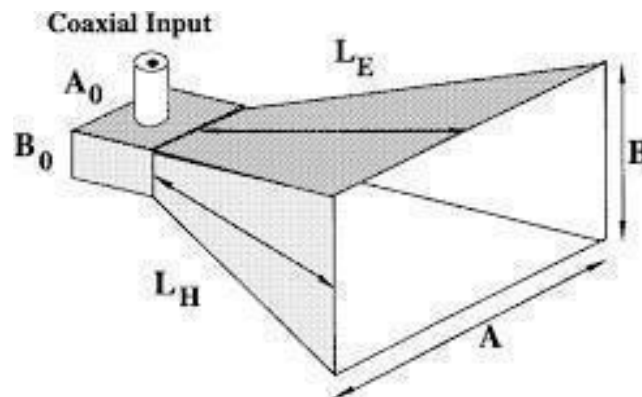


Fig 1.2: Horn Antenna Diagram

1.4.3 Reflector Antennas

Reflector Antennas Parabolic, corner reflectors. These are high gain antennas usually used in Radio astronomy, Microwave communication and satellite trafficking.

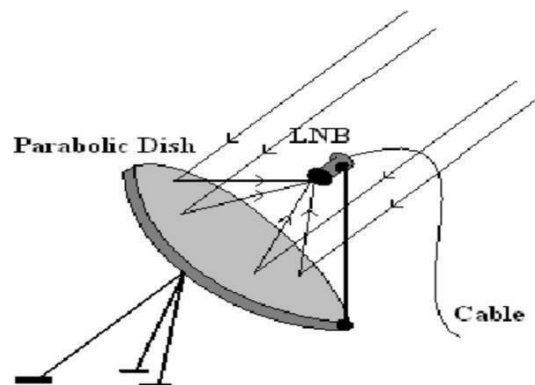


Fig 1.3: Reflector Antenna Diagram

1.4.4 Lens Antenna

Lens Antennas are Convex plane, convex-convex, concave-convex and concave plane lenses. These antennas are usually used for very high frequency applications.

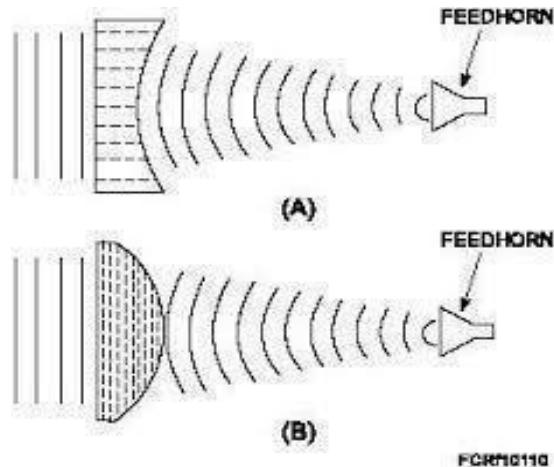


Fig 1.4: Lens Antenna Diagram

1.4.5 Yagi – Uda Antenna

Microstrip Antennas are rectangular, Circular etc shaped metallic patches above a ground plane. Used in aircraft, spacecraft, satellites, cars, mobile phones etc. Yagi Uda antenna, Microstrip patch array, 0 Aperture array, Slotted wave guide array. Used for high gain applications with added advantage such as controllable radiation.

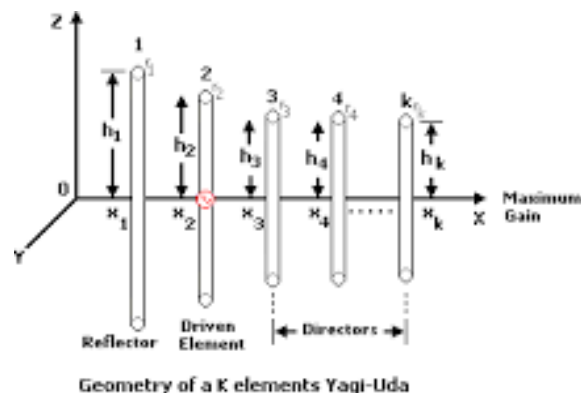


Fig 1.5: Yagi-uda Antenna Diagram

1.5 INTRODUCTION TO MICROSTRIP ANTENNAS

In recent years, with the rapid development of wireless communication technology, the WLAN communication system has also flourished, and the applied range in the market is increasingly wide. WLAN communication systems generally require two-way sending and receiving data in a fast, high-efficiency and reliable way, which is reflected in the antenna subsystem. The antenna is an important part of the wireless communication system. Modern society has entered into the information age, and people present higher requirements for the antenna, that is, the antenna not only has a wider frequency band, smaller size and is easier to install, but also has a high radiation efficiency and anti-interference performance, and other characteristics. Therefore, the study of multiband and miniaturized antennas becomes an important issue in the field of antennas. Compared with the traditional microwave antenna, the microstrip antennas are low profile, small size, low cost and light weight, which can meet the demands of miniaturization. However, microstrip antennas inherently have narrow bandwidth; hence, the study of dual-band microstrip antennas is necessary. At present, extensive studies of dual-band microstrip antennas applied in WLAN have been carried out, and a lot of antenna types which work in a dual-band have been put forward, such as Dipole antennas, Planar Inverted-F antennas [8], Planar Monopole antennas [9] and Quasi-Yagi antennas. These antennas are simple in structure and low in production cost, which are suitable for the use of WLAN devices.

The research of microstrip antennas is mainly focused on small scale, broadband, multi-polarization, multi-band and high gain, etc. For example, Heng-Tung Hsu et al. have designed a microstrip antenna for dual band operation, as shown in Figure 1.6

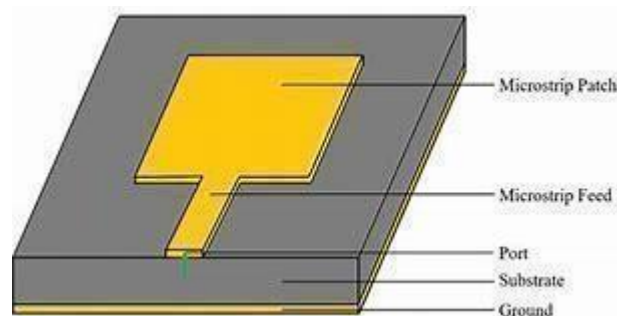


Fig 1.6: Structure of microstrip antenna

1.6 DESIGN THEORY

A microstrip antenna is a resonant radiator, whose radiation field is produced by the electromagnetic field of mutual-motivation between the upper radiation patch edges of microstrip antenna and the grounding plate, and constantly radiates out electromagnetic waves through the gap between them. The parameters of the antenna are the measure of the quality of the antenna. The microstrip antenna designed in this paper will mainly study the bandwidth and the gain. The bandwidth is the frequency range of the antenna when the antenna is off the center of the operating frequency; meanwhile, the antenna's performance parameter is reduced to the allowable value. Generally, the bandwidth of the microstrip antenna is in 0.7%–7%. The gain of the antenna is the ratio of the radiation power intensity generated by the actual designed antenna to the ideal radiation unit at the same point in space as the same input power is equal.

1.6.1 The feeding of the Antenna , Miniaturization and Dual-Band Technology:

The typical structure of printed microstrip antenna is shown in Figure 1.7. It has advantages of small size, light weight, easy to integrate and mass production. The feed means of the antenna is microstrip line feeding. The manufacturing process of microstrip line is simple, easy to integrate with other active and passive circuit components, which is conducive to realizing the miniaturization of the circuit system and improving the degree of integration.

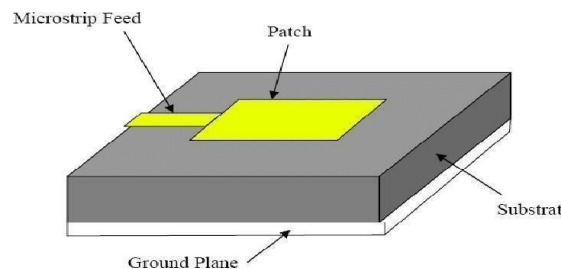


Fig 1.7: Structure chart of a printed microstrip antenna

When using coaxial feed, the probe used for feeding is stretched into the resonant cavity to motivate the patch antenna. The advantages of the coaxial feed is that the feeding points can be selected at any desired position of the patch, and the coaxial feeder located in below

the ground plane and the patch antenna located in the ground floor avoid the effect of the feeder on the antenna radiation. The band width and gain of the antenna are closely related to the structure and size of the antenna. Reducing the size of the antenna will reduce the efficiency of the antenna and narrow the bandwidth. In many cases, especially in aerospace satellite communication and mobile communication, due to the limitation of physical space, small antennas are urgently needed.

Therefore, it is necessary to reduce the size of the antenna while improving the performance of the antenna. With the development of WLAN technology and other communication technologies, the demand for dual-frequency and multi-frequency antennas is increasing. In light of this situation, the multi-frequency operation method of the microstrip antenna has been studied extensively. There are two kinds of basic methods: monolithic chip method and multichip method. Monolithic chip method can be divided into monolithic multi mode method and monolithic loading method. Monolithic multi mode method works in different modes of patch simultaneously, while monolithic loading method adopts loading to form different resonance frequencies. For monolithic microstrip patch antenna, in addition to the use of multi mode method, the load method can also be employed to achieve multi-frequency work. In addition, low frequency ratio of the two working frequencies can be obtained by using the loading method. Commonly used forms of loading slots include rectangular slots, U-shaped grooves and L-shaped grooves. Through the adjustment of the length and width of the gap, the antenna can achieve excellent matching characteristics and multi-frequency characteristics.

Demand for wireless networks has soared due to technological innovation and rapid expansion of wireless services. Government and commercial applications highly require cost effective, low-profile antennas. As microstrip patch antennas are simple and inexpensive to manufacture, these low — profile antennas are used for wide range of wireless applications. Patch antennas are conformable to planar and non-planar surfaces and when a particular patch shape and mode are selected, they are very versatile in terms of resonant frequency, polarization pattern and impedance. Polarization diversity is the major advantage of patch antenna. These antennas can easily be designed to have linear, left-hand circular, right hand circular and horizontal polarization. This unique property allows patch antenna to play a significant role in communication industry. In this present work a simple microstrip patch

antenna based on coaxial feed configuration is designed to resonate at 2.45GHz center frequency with a bandwidth of 100MHz ranging from 2.40-2.50GHz. Further, to achieve dual band operation a notch is etched in the patch parallel to the current lines, this is based on reactive loading technique. Due to strong interaction between the notch resonant frequency and main patch, the antenna resonates at two different frequencies. The proffered design tends the antenna to resonate at 2.4GHz band ranging from 2.40 to 2.50GHz and 4.96Ghzband ranging from 4.87 to 5.06GHz). Nowadays, with an expeditious development of wireless communication technology where the WLAN communication systems has also developed and the applied range in the market is increasing at a wide range. Modern society has entered the information age, and people present higher requirements for the antenna, that is, the antenna not only has a wider frequency band, smaller size and is easier to install, but also has a high radiation efficiency and anti-interference performance, and other characteristics. Therefore, the study of the multiband and miniaturized antennas becomes an important part in the field of antennas. Compared with the traditional microwave antenna, the microstrip antennas are low profile, small size, low cost and light weight, which can meet the demands of miniaturization.

1.7 INTRODUCTION ABOUT WLAN

Wireless LAN stands for Wireless Local Area Network. It is also called LAWN(Local Area Wireless Network). WLAN is one in which a mobile user can connect to a Local Area Network(LAN) through a wireless connection. The IEEE 802.11 group of standards define the technologies for wireless LANs. For path sharing, 802.11 standard uses the Ethernet protocol and CSMA/CA(carrier sense multiple access with collision avoidance). It also uses an encryption method i.e. wired equivalent privacy algorithm. Wireless LANs provide high speed data communication in small areas such as building or an office. WLANs allow users to move around in a confined area while they area while they are still connected to the network.

In some instance wireless LAN technology is used to save costs and avoid laying cable, while in other cases, it is the only option for providing high- speed internet access to the public. Whatever the reason, wireless solutions are popping up everywhere. Wireless LANs based on the IEEE 802.11 standards are the most widely used computer networks in the world. These

are commonly called Wi-Fi, which is a trademark belonging to the Wi-Fi Alliance. They are used for home and small office networks that link together laptop ,computers, printers, smart phones, Web TVs and gaming devices with a wireless router, which links them to the internet. Hotspots provided by routers at restaurants, coffee shops, hotels, libraries and airports allow consumers to access the internet with portable wireless devices.

1.8 TYPES OF WLANs

The IEEE 802.11 has two basic modes of operation : infrastructure and ad hoc mode. In adhoc mode , mobile units communicate directly peer-to-peer. In infrastructure mode, mobile units communicate through a wireless access point(WAP) that also serves as a bridge to other networks such as a local area network or the Internet.

Since wireless communication uses a more open medium for communication in comparison to wired LANs, the 802.11 designers also included encryption mechanisms: Wired Equivalent Privacy(WEP), no longer considered secure, Wi-Fi Protected Access(WPA,WPA2,WPA3), to secure wireless computer networks. Many access points will also offer Wi-Fi Protected Setup, a quick, but no longer considered secure, method of joining a new device to an encrypted network.

1.8.1 Infrastructure

Most Wi-Fi networks are deployed in infrastructure mode. In infrastructure mode, wireless clients, such as laptops and smart phones, connect to the WAP to join the network. The WAP usually has a wired network connection and may have permanent wireless connections to other WAPs.

Waps are usually fixed and provide service to their client nodes within range. Some networks will have multiple WAPs using the same SSID and security arrangement. In the case, connecting to any WAP on that network joins the client to the network, and the client software will try to choose the WAP that gives the best service, such as the WAP with the strongest signal.

1.8.2 Peer-to-peer

An ad hoc network is a network where stations communicate only peer-to- peer (P2P).

There is no base and no one gives permission to talk. This is accomplished using the Independent Basic Service Set (IBSS). A Wi-Fi Direct network is different types of wireless network where stations communicate peer-to-peer. In a peer-to-peer network wireless devices within range of each other can discover and communicate directly without involving central access points. In a Wi-Fi P2P group, the group owner operates as an access point and all other devices are clients. There are two main methods to establish a group owner in the Wi-Fi Direct group. In one approach, the user sets up a P2P group owner manually. This method is also known as autonomous group owner (autonomous GO). In the second method, called negotiation-based group creation, two devices compete based on the group owner intent value. The device with higher intent value becomes a group owner and the second device becomes a client. Group owner intent value can depend on whether the wireless device performs a cross-section between an infrastructure WLAN service and a P2P group, available power in the wireless device, whether the wireless device is already a group owner in another group or a received signal Strength of the first wireless device.

1.9 APPLICATIONS OF WLAN

- Modern implementations of WLANs range from small in-home networks to large, campus sized ones to completely mobile networks on airplanes and trains.
- Users can access the Internet from WLAN hotspots in restaurants Hotels and now with portable devices that connect to 3G or 4G networks. Often times these types of public access points require no registration or password to join the network. Others can be accessed once registration has occurred and/or a fee is paid.
- Wireless networking is applicable to all industries with a need for mobile computer usage or when the installation of physical media is not feasible. Such networking is especially useful when employees must process information on the spot, directly in front of customers, via electronic-based forms and interactive menus.
- Wireless LAN makes it possible to place portable computers in the hands of mobile “front-line” workers, such as doctors, nurses, warehouse clerks, inspectors, claims adjusters, real estate agents, and insurance salespeople.
- Retail: Retail organizations need to order, price, sell and keep inventories of merchandise. A wireless LAN in a retail environment enables clerks and storeroom personnel to perform their functions directly from the sales floor.

- Healthcare: Healthcare centers, such as hospitals and doctors' offices, must maintain accurate records to ensure effective patient care. Also doctors and nurses are also extremely mobile, going from room to room caring for patients. The use of electronic patient records, with the capability to input, view and update patient data from anywhere in the hospital, increases the accuracy and speed of healthcare. This improvement is possible by providing each nurse and doctor with a wireless pen based computer, couples with a wireless LAN to databases that store critical medical information about the patients.

1.10 ANALYSIS METHOD OF MICROSTRIP PATCH ANTENNA

1.10.1 Transmission Line Model

This model represents the microstrip antenna by two slots of width 'W' and height 'h', separated by transmission line of length 'L'. The microstrip is essentially a non-homogeneous line of two dielectrics, typically substrate and air.

As seen from the figure , most of the electric field lines lies reside in the substrate and parts of some line in air. As a result, this transmission line cannot support pure transverse electromagnetic(TEM) Mode of transmission, since phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence an effective dielectric constant must be obtained in order to account for the fringing and the wave propagation in the line. The value of ϵ_{eff} is slightly less than ϵ_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spreads in the air. The expression for ϵ_{eff} is given by,

$$\epsilon_{eff} = \frac{(\epsilon_r + 1)}{2} + \frac{(\epsilon_r - 1)}{2} \left[1 + 12 \frac{h}{W} \right]^{-1} \quad (1.3)$$

Where ϵ_{eff} = Effective dielectric constant

ϵ_r = Dielectric constant of substrate

h = Height of the dielectric substrate

1.10.2 Types of feeding in microstrip patch array antenna

There are many methods of feeding a microstrip antenna. The most popular methods are:

- 1) Microstrip Line Feed.
- 2) Coaxial Probe (coplanar feed) Feed.
- 3) Proximity Coupling.
- 4) Aperture Coupling

1.10.2.1 Microstrip line feed

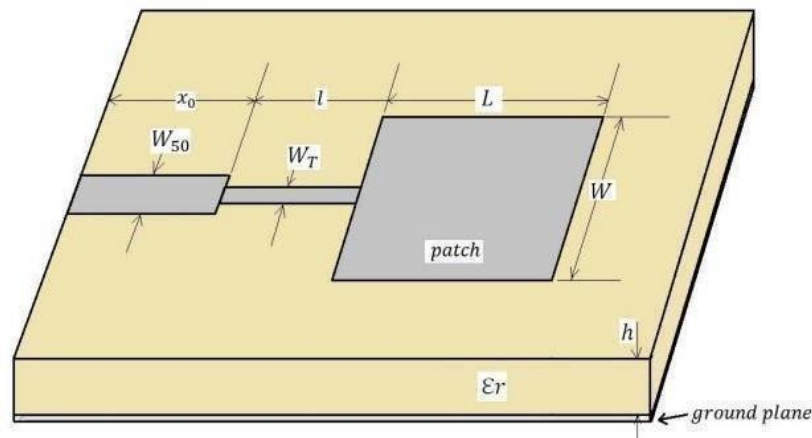


Fig 1.8: Microstrip Line Feed

It is a feeding technique, in which the microstrip patch is directly connected with the conducting microstrip feed line. The dimensions of the feed line are different than microstrip patch. It is easy to fabricate and match. In this feeding method, inner conductor of coaxial cable is connected to the microstrip patch of an antenna and outer one is connected with ground plane. Mostly, the feed networks are isolated from the microstrip patch, but in this mechanism, it is not like that. Spurious radiation minimization, easy fabrication and efficient feeding are the advantages of coaxial feeding method.

1.10.2.2 coaxial probe feed

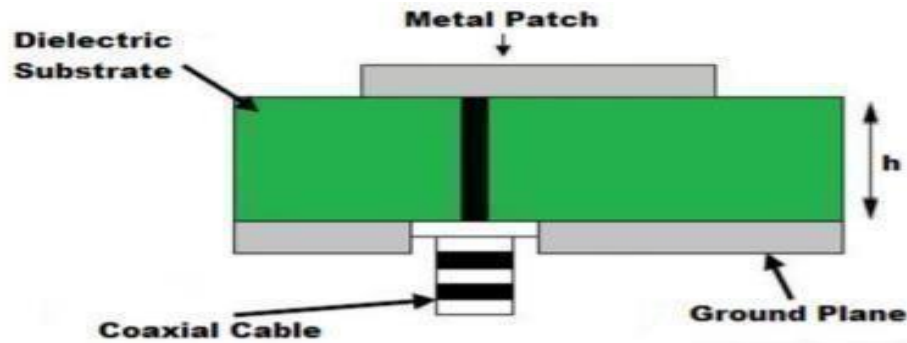


Fig 1.9: Coaxial Probe Feed

In this feeding method, the inner conductor of coaxial cable is connected to the microstrip patch of an antenna and outer one relates to ground plane. Mostly, the feed networks are isolated from the microstrip patch, but in this mechanism. Spurious radiation minimization, easy fabrication and efficient feeding are the advantages of coaxial feeding method. The coaxial connector is coupled to the back side of the microstrip antenna (the ground plane) and the center connector of the coaxial will be passed through the substrate and soldered to the patch.

1.10.2.3 Proximity coupling

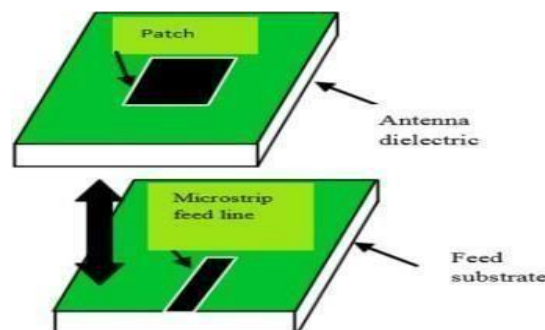


Fig 1.10: Proximity Coupling

Proximity coupled feed technique is also called as the electromagnetic coupling scheme. Two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. Proximity coupled microstrip patch antennas offer various advantages over conventional edge or probe fed patches.

The fabrication of this feeding method is a bit complicated comparatively. Two dielectric substrates are used in this technique. The microstrip patch is there at the upper surface of the upper dielectric substrate and the feed line is there between two substrates. It provides the highest bandwidth and avoids spurious radiation.

1.10.2.4 Aperture coupling

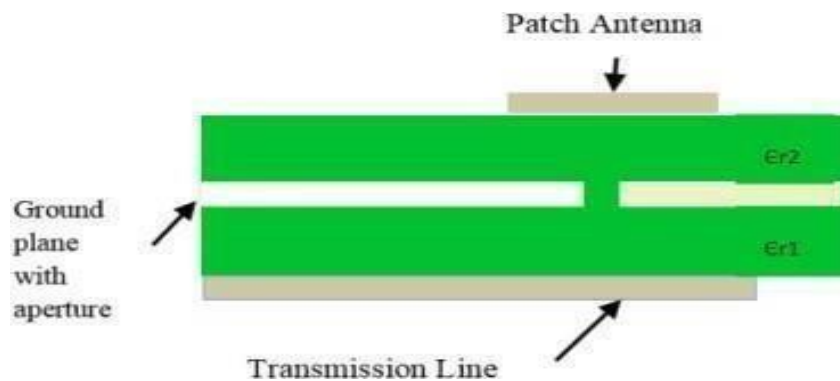


Fig 1.11: Aperture Coupling

This feed has two substrates, which are different from each other and are separated by a ground plane. In this method, the microstrip patch and feed line are coupled through a slot in the ground plane. Minimization in interference and pure polarization are the advantages of aperture coupled feeding method

1.11 SUMMARY

This chapter introduces the problem statement, objectives and motivation for a project aimed at developing a miniaturized antenna for WLAN applications. Wireless Local Area Networks (WLANs) use wireless connections to allow mobile users to connect to a Local Area Network (LAN). The IEEE 802.11 standards define WLAN technologies, using Ethernet protocol and CSMA/CA for path sharing, and wired equivalent privacy for encryption. WLANs provide high-speed data communication in small areas, allowing users to move around while still being connected. WLANs are used to save costs, avoid cable laying, or provide high-speed internet access to the public. Wi-Fi is a widely used WLAN based on IEEE 802.11 standards, used in home and small office networks, and in hotspots at public places.

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

Many people done projects on antenna different ways. Here we have collected some references. And we came up with a project which implements the Dual -band integrated substrate antenna for wireless LAN application. Here we listed some of the references related to microstrip patch antenna for wireless LAN application.

2.2 LITERATURE REVIEW

Byungje Lee et al(2002) have designed “Miniature microstrip antenna with a partially filled high-permittivity substrate”. A new technique to reduce the overall dimension of a microstrip antenna using a partially filled high-permittivity substrate is proposed. The miniaturized microstrip antenna for a repeater system in a mobile communication cellular band (824-894 MHz) is designed with the proposed technique and manufactured with light weight and small size. The disadvantage of the published paper is high return loss.

Aditya s et al(2004), proposed on the topic “Is High-gain 24- GHz CPW- fed microstrip patch antennas on high-permittivity substrates”. Simulation and measurement results are presented for two designs of high-gain linearly polarized microstrip patch antennas, operating at 24 GHz on two high- permittivity substrates: Taconic CER-10 and high-resistivity silicon. In both designs, a multilayer construction is used and the patch is coupled to a coplanar waveguide (CPW) feed through a slot. The problem of surface waves is avoided by introducing an air gap between the slot and the patch with the help of micromachining or spacer layer in one of the designs, the superstrate effect is also employed. For the design, the measured gain value in the forward direction exceeds 6 dBi. The disadvantage of the published paper is it is not cost effective.

Nasimuddin et al(2005) have designed “Compact circularly polarized enhanced gain microstrip antenna on high permittivity substrate” . A new combination of proximity coupled

circular microstrip antenna and a square quasi-planar surface mounted short horn is proposed on the high permittivity substrate (10.2) to increase the gain of a compact circularly polarized patch by 4.46 dB. This antenna structure has gain 9.0 dBi and over 3 dB beam width (70/spl deg/) the axial ratio (AR) is 0.11 dB. The AR bandwidth is 1.31%. The surface mounted horn provides flat gain over AR ratio bandwidth. The horn improves the side lobe level and the back lobe level between 7 dB to 10 dB. The patch structure has 12% area reduction over normal circular microstrip patch antenna. Total thickness of structure is only 13 mm. The disadvantage of the published paper is high directivity.

Dey s et al(2011), proposed on the topic “Design and performance analysis of narrow band textile antenna for three different substrate permittivity materials and bending consequence”. In this paper the design of textile antennas for materials with three different substrate permittivity $\epsilon_r = 3, 2.2, 1.25$ are realized. Different substrates having different permittivity affect the antenna performance in various ways. Here, Microstrip patch antenna is designed for narrow band WBAN (Wearable Body Area Network) at the frequency level of 2.45GHz. In this case, Dacron fabric, woven fiberglass fabric and Fleece fabric are used as antenna substrates and woven copper threads are used as the conductive part of the antenna patch. This paper demonstrates the effects of antenna bending at five different angles. Here, resonance frequency fluctuations due to impedance matching as well as effects of radiation pattern deformation due to bending at different angles are focused. The disadvantage of the published paper is impedance mismatching.

Yahya R et al(2014) have designed “Effect of Rainwater and Seawater on the Permittivity of Denim Jean Substrate and Performance of UWB Eye- Shaped Antenna”. The effect of rainwater and seawater on the permittivity of denim jean substrate and performance of an ultra wide band (UWB) eye- shaped textile antenna is investigated in this paper. For the simulated and measured reflection coefficients in dry condition, it was found that the antenna operates at 2.4-10.9 and 1.6-12 GHz, respectively, with the simulated gain between 3.2 and 5.8 dBi from 2 to 12 GHz with efficiencies greater than 50%. The antenna can operate at the entire range in dry conditions when $S_{11} \leq -10$ dB. From the investigation, it can be shown that the permittivities of denim jean substrate

under wet and immersed conditions are proportional to the permittivities of the absorbed medium (rainwater or seawater) at 2-12 GHz. The disadvantage of this paper is it has limited performance under wet conditions and it cannot be used when it is immersed in rainwater and seawater.

Kachan D Katore (2017), proposed on the topic “2.4/5.2 Dual band rectangular microstrip antenna with orthogonal polarization for wlan application and Bluetooth”. This paper exhibits horizontal linear polarization at Bluetooth band and vertical linear polarization at WLAN band. The proposed antenna has its radiation pattern in broadside direction. The proposed dual band rectangular microstrip antenna is fully planar, low cost and small in size. It can be easily fabricated using simple PCB etching technique. A Dual band microstrip matched printed antenna for wlan application.

Bharath Kelothu(2019), he proposed on the topic “A compact High-Gain Microstrip Patch Antennas for Dual Band WLAN Applications”. It can be concluded that , the performance of the microstrip antenna depends heavily on the dimension of the slot. As the width and length of the slot increase, the return loss(S_{11}) and VSWR increase but the gain decreases. The maximum gains of the two bands are 8.4 and 7.1dBi, making the proposed antenna appropriate for high-gain applications. The simulated results verify that the designed antenna is as good solution for dual band wlan applications.

Bunge Lee. Et al(2002) have designed Miniature microstrip antenna with a partially filled high-permittivity substrate. A new technique to reduce the overall dimension of a microstrip antenna using a partially filled high-permittivity substrate is proposed. The miniaturized microstrip antenna for a repeater system in a mobile communication cellular band (824-894 MHz) is designed with the proposed technique and manufactured with light weight and small size. The disadvantage of the published paper is high return loss.

Dey s et al(2011), proposed on the topic “Design and performance analysis of narrow band textile antenna for three different substrate permittivity materials and bending consequence”. In this paper the design of textile antennas for materials with three different substrate permittivity $\epsilon_r = 3, 2.2, 1.25$ are realized. Different substrates having different permittivity affect the antenna performance in various ways. Here, Microstrip patch antenna is designed for narrow band WBAN (Wearable Body Area Network) at the frequency level of

2.45GHz. In this case, Dacron fabric, woven fiberglass fabric and Fleece fabric are used as antenna substrates and woven copper threads are used as the conductive part of the antenna patch. This paper demonstrates the effects of antenna bending at five different angles. Here, resonance frequency fluctuations due to impedance matching as well as effects of radiation pattern deformation due to bending at different angles are focused. The disadvantage of the published paper is impedance mismatching.

U. Chakraborty et al(2015), The problem addressed by them is “A compact dual-band microstrip patch antenna is designed and analyzed to support the IEEE 802.11a wireless LAN band (5.125–5.395 and 5.725–5.985 GHz)”.The design technique used for the double-slotted dual- band antenna using two separate single slotted RMSAs is successful for the application in IEEE 802.11a WLAN band (5.15–5.35 and 5.725–5.825 GHz).

D. C. Thompson et al(2004), proposed on the topic “Characterization of liquid crystal polymer (LCP) material and transmission lines on LCP substrates from 30 to 110 GHz”. Liquid crystal polymer (LCP) is a material that has gained attention as a potential high-performance microwave substrate and packaging material. This investigation uses several methods to determine the electrical properties of LCP for millimeter-wave frequencies. Microstrip ring resonators and cavity resonators are measured in order to characterize the dielectric constant and loss tangent of LCP above 30 GHz. The measured dielectric constant is shown to be steady near 3.16, and the loss tangent stays below 0.0049. In addition, various transmission lines are fabricated on different LCP substrate thicknesses and the loss characteristics are given in decibels per centimeter from 2 to 110 GHz. Peak transmission-line losses at 110 GHz vary between 0.88-2.55 dB/cm, depending on the line type and geometry. The disadvantage of this paper is it is hard in real time applications.

G. DeJean et al(2005), proposed on the topic “Liquid Crystal polymer (LCP): a new organic material for the development of multilayer dual-frequency/dual-polarization flexible antenna arrays”. The development of dual-frequency (14 and 35 GHz), dual-polarization microstrip antenna arrays is presented for the first time on liquid crystal polymer (LCP) multilayer technology. Some of the properties of LCP, such as multilayer (three-

dimensional) vertical integration capability, good electrical and mechanical properties, and near-hermetic nature, make this substrate a practical choice for the design of low-cost antenna arrays that can be integrated with remote sensing applications operating in the Ku and millimeter-wave frequency bands. This work illustrates the potential of LCP as a low-cost, "all-package" solution for developing compact, flexible, antenna arrays that can be used in future communication and remote sensing systems. The disadvantage of this paper is low gain.

2.1 SUMMARY

The given text contains summaries of different research papers on microstrip antennas. The first paper proposes a technique to reduce the overall size of a microstrip antenna using a partially filled high-permittivity substrate. The disadvantage of this paper is high return loss. The second paper presents the design of high-gain 24-GHz CPW-fed microstrip patch antennas on high-permittivity substrates, but the disadvantage of this paper is that it is not cost-effective. The third paper introduces a combination of proximity-coupled circular microstrip antenna and a square quasi-planar surface-mounted short horn to increase the gain of a compact circularly polarized patch. The disadvantage of this paper is high directivity. The fourth paper designs textile antennas for materials with three different substrate permittivity and demonstrates the effects of antenna bending at different angles, but the disadvantage of this paper is impedance mismatching. The fifth paper investigates the effect of rainwater and seawater on the permittivity of denim jean substrate and the performance of a UWB eye-shaped textile antenna, but the disadvantage of this paper is limited performance under wet conditions. The sixth paper proposes a dual-band rectangular microstrip antenna with orthogonal polarization for WLAN and Bluetooth applications. Finally, the seventh paper presents a compact high-gain microstrip patch antenna for dual-band WLAN applications, where the antenna's performance heavily depends on the dimension of the slot.

CHAPTER-3

EXISTING METHODOLOGY

3.1 INTRODUCTION

The fabricated antenna shows dual operating bands of 3.24– 8.29 GHz (5.05 GHz) and 9.12– 11.25 GHz (2.13 GHz). Moreover, the antenna is compact, and its reflection coefficient measured where a good agreement is observed with the stimulated results. A dual frequency band frequency at 2.4 & 5.8GHz range that is suitable for WLAN. The gain is 2dB at the frequency. The antenna is a dual band structure one which can operate in the frequency ranges from 2.4 GHz(802.11g/N) and 5.1 GHz (802.11a/N). A dual frequency band frequency at 2.4 & 5.8 GHz range that is suitable for WLAN. The gain is 2dB at the frequency of 2.4GHz and about 3.1dB peak gain at the frequency band of 5.8GHz. The peak antenna efficiency is 70% at lower bands and at the higher bands an efficiency of 60% is achieved. All three wifi frequencies require an independent antenna so the size of the system is very high. Due to the independent antenna the modem device needs more power to work. The directivity of the modem was very low.

3.2 MINIATURIZATION OF AN ANTENNA:

Miniaturization of an antenna is topic of interest for a long time. Most of the study concluded that reducing the size of antenna gain and bandwidth also reduce by some fraction. It has been well known that there is a theoretical lower limit on Q factor that can be achieved for antenna. Theoretical lower bound of Q- factor can be given by, where 'k' is wave number and given expression is valid for lossless antenna. It shows that by decreasing the size of antenna Q factor increases so antenna performances reduce. So, Q can be reduced at the expense of the antenna efficiency and gain of antenna. Basically, there are two methods to miniaturize microstrip patch antenna. The first method is to change the properties of substrate such that effective wavelength in the substrate is reduced. The second method is to increase the electrical path for current flowing. Use of high permittivity Material: It is the easiest way to reduce the size of patch antenna is to use high dielectric constant (ϵ_r) material. Antenna dimensions such as length and width are inversely proportional to the square root of relative permittivity of

the substrate material. By using higher dielectric constant materials surface wave propagation will increase within the substrate and results in lower radiation efficiency because of increased losses and bandwidth will decrease. Size reduction in the ground plane results poor polarization as well as changes the performance characteristics of patch antenna. Various studies have investigated different materials as well as configurations to effectively use the above approach to miniaturize an MPA. Microstrip patch antennas with thicker substrate and dielectric constant of 10 to 13 were analyzed. Radiation performances were found different from that of conventional antennas. Input impedances were less than its theoretical values for thin substrates. Ceramic substrate is also used by some groups to reduce the size of antennas. There are various types of ceramic substrate available. A square ring microstrip patch antenna was developed on the ceramic substrate of dielectric constant of 58. Circular polarization was achieved by simple microstrip feed line through coupling on the same plane. Size reduction was achieved by 50 % with respect to conventional antenna for FR4 substrate. Impedance bandwidth of 1.1% achieved at 1573 MHz frequency. Magneto- dielectric substrate was also used for miniaturization of microstrip patch antenna. By using this method 65% size reduction was achieved at 2.45 GHz with respect to conventional antenna.

3.2.1 Use of sierpinski carpet fractal method: The space-filling property of the fractal causes effectively increase the electrical length which is used to reduce the size of the antenna. Sierpinski carpet fractal method with different iterations was used to reduce the size of the patch of the microstrip patch antenna. By using this method 32 % size reduction was achieved at 2nd iteration. In this design initially patch was divided into nine congruent rectangles and central rectangle was removed. In the further iterations remaining eight rectangles were again divided into another nine congruent rectangles and from these rectangles again central rectangle was removed. This similar procedure was followed for other iterations. This design was not printed for the whole part of design. The part containing feed line was not disturbed by the Sierpinski carpet fractal to get better impedance matching.

3.2.2 Use of shorting pins between patch and ground plane: By using the shorting pins between the patch and ground plane size reduction of antenna can be achieved because it makes antenna electrically small. With respect to transmission line model, for a half wavelength rectangular patch antenna E- field distribution is maximum at the radiating edges

and zero at the middle. So, we can remove the one half of that distribution and can get the same Q performance at the same resonant frequency that is called quarter wavelength antenna. By introducing shorting pins between patch and ground plane higher size reduction achieved but directivity was reduced and hence antenna gain was also reduced

3.2.3 Use of metamaterials: Metamaterials (MTMs) are artificially engineered materials designed to provide material properties not readily available commercially. MTMs can be designed to realize materials with near zero values of permittivity; negative permittivity or permeability; or simultaneous negative permittivity and permeability. A material with only negative permittivity is called epsilon negative (ENG), whereas one with only negative permeability is referred to as a μ -negative (MNG) material. A material with both negative permittivity and permeability is called double-negative (DNG). During the past decade, several structures have been realized which when arranged periodically, exhibited MTM properties over a certain frequency range. These structures have been of interest to many and have been widely studied and improved. They have also been used in many RF, microwave and photonics devices to achieve interesting properties. The concept of MTM as well as MTM structures have also been used to design various types of antennas with enhanced performance, such as high gain as well as improved efficiency. Additionally, they have been used for the miniaturization of antennas. Two terms are used in the literature for antennas utilizing MTM. Ones that make use of ENG, MNG or DNG substrate are called 'MTM-based antennas. Others, that only utilize the MTM unit cell such as the SRR, CSRR, omega structures etc., are referred to as 'MTM-inspired antennas. The former exists mostly as hypothetical antennas which are studied theoretically using the ENG, MNG or DNG media. A true realization of MTM-based antenna is not possible. The latter are not truly MTM antennas since they do not make use of ENG, MNG or DNG properties of an MTM. However, since they make use of MTM unit cells, and since they are analyzed using the theories of MTM unit cells, they are referred to as MTM-inspired antennas. The effect of an MTM substrate on the size of the MPA can be analyzed from the expression of its resonant frequency which can be derived using the cavity model. There is an inverse square root relationship between the resonant frequency of the MPA and the permittivity and permeability of its substrate. Consequently, an MPA placed on a homogeneous ENG or MNG substrate will not resonate; furthermore, no special feature can be realized using a homogeneous DNG substrate. In MPAs on MTM substrates have been theoretically investigated. The equation for the resonant frequency is simply as if an unknown as

an annular ring patch on an MTM substrate has been derived in. The substrate of the patch was a combination of DNG medium ('called the backward wave medium), and the normal medium with ϵ and μ values that are both positive ('also called double positive medium (DPS) in the literature'). The DNG formed the inner circle, which was surrounded by the DPS medium. From the derived expression of the dominant resonant mode, it was found that patch miniaturization was possible by carefully selecting the ratios of area filled by the DNG and DPS media and their properties.

3.3 KEY TYPES OF DUAL BAND WIFI ANTENNAS

3.3.1 Dual-band dipole antennas are the most common type of dual-band antenna and are used to provide omni directional coverage. Dual-band antennas are usually made up of two or more dipole elements, which have a simple structure consisting of paired conductive arms and a centered feed line between them. The dipole arm lengths maybe symmetric or unequal. Asymmetric dipole antennas separate the frequencies for dual-band operation by having distinct resonant nodes.

3.3.2 Articulating dual-band antennas are often attached to routers or access points. They are ideal for indoor settings as they can be angled to get the required coverage. The articulation is a mechanical feature that uses a knuckle that can move the antenna into an angled position. This is a potential point of vulnerability to environmental exposure as the cables from the antenna run through the knuckle to the attached connector. The additional moving parts can make the antenna weaker also. Some of these articulating antennas are also capable of rotating due to an outer shell that can rotate independently of the radio frequency connector. Care may need to be taken in connecting this type of antenna to devices.

3.3.3 i-Bar dual band antennas are flexible, adhesive, and extremely low-profile antennas that deliver excellent performance despite their simplicity. These omni-directional ultra-wide band antennas can be conveniently mounted on plastic or glass (not metal), making them ideal for vehicle interiors.

3.3.4 Dual-band puck antennas are low profile cylindrical antennas named because of their similarity to a hockey puck. Within this type of omni-directional antenna are elements that have a sensitivity to the 2.4 and 5 GHz frequencies. They offer versatile mounting options and can

be ceiling-mounted, through-hole mounted, or screw-mounted on an L- bracket for secure wall mounting.

3.3.5 Dual- band collinear antennas are powerful Omni antennas that are made up of an array of vertically stacked dipole elements housed within a cylindrical fiberglass radome. The arrangement of the antenna elements makes each element perform like an extension of the element beneath it leading to a summing effect of their radiating power. They are weatherproof and designed to be mounted at height outdoors to provide coverage over a large area.

3.3.6 Panel dual-band Wi-Fi antennas deliver targeted connectivity because they are directional antennas. Their flat profile and directivity are advantageous in applications which require a reliable point to point connectivity, especially if the 5GHz function is used for high data throughput.

3.4 RADIO FREQUENCY CONNECTORS FOR DUAL BAND ANTENNAS

Dual-band antennas carry a range of commonly encountered radio frequency connectors which maintain a competent mechanical and electrical connection to cabling and wireless equipment. Your selection of antenna may be, in part, determined by the connector it carries. All dual- band antenna connectors are 50 Ohm connectors with suitably matched electrical specifications to ensure optimal performance of the network.

- RP-SMA connectors are commonly used for consumer Wi-Fi network equipment, including antennas. They are a variant of the SMA connector. The RP-SMA connector mates by screw-coupling and is rated for over 500 mating cycles.
- SMA connectors may also be found on wireless networking equipment and antennas. It has a near- identical external physical appearance to the RP-SMA connector, but the inner mating interface of the reversed polarity variant is switched. This makes RP-SMA and SMA connectors incompatible. N-type connectors or N connectors are a medium-sized rugged class of threaded connector that is useful in outdoor antenna installations, especially where the antenna is mounted via an N female bulkhead. UFL connectors are micro-miniature radio connectors that facilitate the connection of a dual-band antenna to a complementary male jack that is mounted on a PCB. They connect by pressing the female plug down onto the jack with a tactile clicking sensation. This connector can only tolerate a limited number of mating cycles.

3.5 SUMMARY

The easiest way to reduce the size of a patch antenna is to use high dielectric constant (ϵ_r) material. However, this can result in lower radiation efficiency and decreased bandwidth. Other methods have been studied, such as using thicker substrates or ceramic substrates with high dielectric constants. Magneto-dielectric substrates have also been used to achieve size reduction. Another method is using the Sierpinski carpet fractal method, which effectively increases the electrical length of the antenna, resulting in a size reduction of up to 32%. This method involves dividing the patch into congruent rectangles and removing the central rectangle in each iteration. The feed line is not disturbed to ensure better impedance matching. The miniaturization of microstrip patch antennas can be achieved through various techniques such as using high dielectric constant materials, ceramic substrates, magneto-dielectric substrates, and the Sierpinski carpet fractal method. However, some of these techniques can result in lower radiation efficiency, decreased bandwidth, or more complex antenna structures. Furthermore, it is important to consider the size of the ground plane and manage the tradeoff between size, gain, and bandwidth based on the application. It is also noted that none of the works reported breach the fundamental limits of ESA. Future works should focus on providing insight into general design procedures and applying techniques to design antennas in other frequency bands.

CHAPTER-4

PROPOSED METHODOLOGY

4.1 INTRODUCTION

In WLAN application so many substrates have been designed and many fabrications have already been done. Our proposed system is going for miniaturization as they haven't concentrated on miniaturization, so we are going to concentrate on the miniaturization part. The proposed single antenna works with three classes of wifi with less operating power. The linear proposed 3X3 array antenna provides better efficiency and directivity compared to the existing methods. The proposed antenna design and analysis using transmission line models with stub matching properties. The proposed antenna array elements are designed by a quarter wave transmission line property with a stub matching resistive feed model, so it provides 92% efficiency with high area coverage.

4.2 BLOCK DIAGRAM

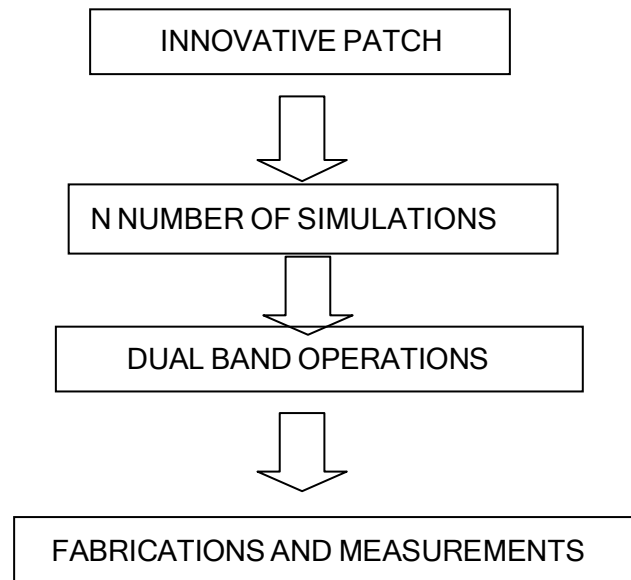


Fig 4.1: Fabrication process

As this is a mini block diagram of what we are proposing, these are the steps which we are going to implement, as the first step is innovative patch and the second step is N number of simulations and the third step is Dual Band operations and then followed by Fabrications and Measurements. For example we will go for different substrates (like Airlon, Roger, FR4 substrates) and then we co-relate with the WLAN applications.

From this block diagram we can able to determine the steps involved in the process of the fabrication of the antenna and what methodologies it follows As you can see the above block diagram consists of 4 Major steps . The first one starts with the innovative patch and then this step is followed by N number of simulations and then this step is followedby further process Dual band and operations and then the last process is fabrications and measurements.

4.3 MICROSTRIP PATCH ANTENNA DESIGN FORMULAS

Wavelength

All you have to do is divide the speed of light by the product of frequency and 1,000,000. And as a result, you have the wavelength of the dipole antenna.

$$\lambda = \frac{c}{f} \text{ mm/sec} \quad (4.1)$$

Width

$$W = \frac{\lambda}{2} \sqrt{\frac{2}{\epsilon_r + 1}} \text{ mm} \quad (4.2)$$

Where, W = Width of the patch, C = Speed of light, ϵ_r = value of the dielectric substrate and λ = Wavelength

Fringing effect

Calculation of the Effective Dielectric Constant(ϵ_{eff}). This is based on the height, dielectric constant of the dielectric and the calculated width of the patch antenna.

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(1 + 12 \frac{h}{w}\right)^{-1} \quad (4.3)$$

Calculation of the length extension ΔL Formula is mentioned below:

$$\Delta L = 0.412h \left\{ \frac{(\epsilon_{eff} + 0.3) \left(\frac{w}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{w}{h} + 0.8 \right)} \right\} \quad (4.4)$$

Calculation of the Effective length (L_{eff}) formula is mentioned below:

$$L_{eff} = \frac{\lambda}{2\sqrt{\epsilon_{eff}}} \quad (4.5)$$

Length

Calculation of actual length of the patch(L) formula is given below:

$$L = L_{eff} - 2\Delta L \quad (4.6)$$

Ground and Substrate Dimensions

The length of a ground plane (L_g) and the width of a ground plane (W_g) are calculated using the following equations :

$$L_g = L + 6h \text{ mm} \quad (4.7)$$

$$W_g = W + 6h \text{ mm} \quad (4.8)$$

SRR and CSRR Metamaterial

Split ring resonators (SRRs) consist of a pair of concentric metallic rings, etched on a dielectric substrate, with slits etched on opposite sides. SRRs can produce an effect of being electrically smaller when responding to an oscillating electromagnetic field. These resonators have been used for the synthesis of left-handed and negative refractive index media, where the necessary value of the negative effective permeability is due to the presence of the SRRs.

$$L_1 = 4 \times l_1 - S - 4 \times W \quad (4.9)$$

$$L_2 = 4 \times l_2 - S - 4 \times W \quad (4.10)$$

$$f_1 = \frac{c}{2L_1 \sqrt{\epsilon_{reff}}} \quad (4.11)$$

$$f_2 = \frac{c}{2L_2 \sqrt{\epsilon_{reff}}} \quad (4.12)$$

$$L = 0.00508l(2.303 \log_{10} \frac{4l}{d} - \gamma) \quad (4.13)$$

$$C_1 = (\pi - \theta)r_0 C_{pul} \quad (4.14)$$

$$C_2 = (\pi + \theta)r_0 C_{pul} \quad (4.15)$$

$$f'_0 = \frac{1}{\sqrt{2r_0 L^{\frac{(\pi+k)^2 - \theta^2}{2(\pi+k)}} C_{pul}}} \quad (4.16)$$

Substrate Position:

$$(x, y, z) = (0, 0, 0)$$

$$x = Lg$$

$$y = Wg$$

$$z = h$$

Ground Position:

$$(x, y, z) = (0, 0, 0)$$

$$x = Lg$$

$$y = Wg$$

Patch Position:

$$(x, y, z) = (Lg - L/2, Wg - W/2, h)$$

$$x = L$$

$$y = W$$

Feed Position:

$$(x, y, z) = ((Lg/2 - Wf/2), 0, h)$$

$$x = Wf$$

$$y = Lf$$

Port Position:

$$(x, y, z) = ((Lg/2 - Wf/2), 0, 0)$$

$$x = Wf$$

$$z = h$$

4.4 DIMENSION TABLE OF THE MSP ANTENNA

Tabel 4.1: Dimensions and positions of the Microstrip Patch array antenna

Model	Type	Material	Position	X	Y	Z	Assign Excitation	Assign Boundary
Substrate	Solids Box1	FR4_epo xy	0,0,0	19.6	27.2	1.6	None	None
Ground	Ground	None	0,0,0	19.6	5	-	None	Perfect E
Ground 1	Ground 1	None	0,27.2,0	19.6	-5	-	None	Perfect E
Patch 1	a1	None	2.65,10,1.6	3	3	-	None	Perfect E
Patch 2	a2	None	8.3,10,1.6	3	3	-	None	Perfect E
Patch 3	a3	None	13.95,10,1.6	3	3	-	None	Perfect E
Patch4	a4	None	2.65,16,1.6	3	3	-	None	Perfect E
Patch 5	a5	None	8.3,16,1.6	3	3	-	None	Perfect E
Patch 6	a6	None	13.95,16,1.6	3	3	-	None	Perfect E

Patch 7	a7	None	2.65,22,1.6	3	3	-	None	Perfect E
Patch 8	a8	None	8.3,22,1.6	3	3	-	None	Perfect E
Patch 9	a9	None	13.95,22,1.6	3	3	-	None	Perfect E
Feedline	Rectangle	None	8.7,0,1.6	2.2	4.4	-	None	Perfect E
Feedline 1	Rectangle	None	9.25,2.2,1.6	1.1	4.38	-	None	Perfect E
Feed1	Rectangle1	None	3.9,6.58,1.6	0.5	4.42	-	None	Perfect E
Feed2	Rectangle2	None	9.55,6.58,1.6	0.5	4.42	-	None	Perfect E
Feed3	Rectangle3	None	3.9,6.58,1.6	0.5	4.42	-	None	Perfect E
Feed4	Rectangle4	None	3.9,6.58,1.6	11.8	0.5	-	None	Perfect E
Feed 5	Rectangle5	None	3.9,14.5,1.6	3	0.5	-	None	Perfect E
Feed 6	Rectangle6	None	3.9,14.5,1.6	0.5	3	-	None	Perfect E

Feed 7	Rectangle8	None	15.2,14.5, 1.6	0.5	3	-	None	Perfect E
Feed 8	Rectangle9	None	6.72,20.5, 1.6	6.15	0.5	-	None	Perfect E
Feed 9	Rectangle 10	None	3.9,19,1.6	0.5	4	-	None	Perfect E
Feed 10	Rectangle 11	None	9.55,20.5, 1.6	0.5	2.5	-	None	Perfect E
Feed 11	Rectangle 12	None	15.2,19,1.6	0.5	4	-	None	Perfect E
Feed 12	Rectangle	None	6.725,6.58,	0.5	13.9	-	None	Perfect E
Feed 13	Rectangle 14	None	12.327,6.58, 1.6	0.5	13.9	-	None	Perfect E
Feed 14	Rectangle 27	None	12.5,14.5, 1.6	3	0.5	-	None	Perfect E
Lumped Port	Port	None	8.7,0,0	2.2	-	1.6	Lumped port	None

The above table 4.1 shows the positioning, Dimension and name of the materials implemented on the antenna. It also shows the excitation and boundary condition of the design

4.5 ANSYS HFSS SOFTWARE

Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards. Engineers worldwide use Ansys HFSS software to design high-frequency, high-speed electronics found in communications systems, advanced driver assistance systems (ADAS), satellites, and internet-of-things (IoT) products.

Ansys HFSS combines the highly accurate finite element method (FEM), the large-scale method of moments (MoM) technique, the ultra-large-scale asymptotic methods of physical optics (PO) and shooting and bouncing rays (SBR).

Engineers use Ansys HFSS primarily to design and simulate high-speed, high-frequency electronics in radar systems, communication systems, satellites, ADAS, microchips, printed circuit boards, IoT products, and other digital devices and RF devices. The solver has also been used to simulate the electromagnetic behaviour of objects such as automobiles and aircraft. ANSYS HFSS allows system and circuit designers to simulate EM issues such as losses due to attenuation, coupling, radiation and reflection. The benefits of simulating a circuit's high frequency behavior with high accuracy on a computer reduces the final testing and verification effort of the system as well as mitigating the necessity of building costly multiple prototypes, saving both time and money in product development.

HFSS captures and simulates objects in 3D, accounting for materials composition and shapes/geometries of each object. HFSS is one of several commercial tools used for an antenna design, and the design of complex radio frequency electronic circuit elements including filters, transmission lines, and packaging. The full-featured 3-D solid modeler and layout interface enables you to work in a layout design flow, or to import and edit 3-D CAD geometry.

4.5.1 HFSS 3-D Modeler: The 3-D interface enables you to model complex 3-D geometry or import CAD geometry for simulation of high-frequency components, such as antennas, RF/microwave components and biomedical devices. You can extract scattering matrix parameters (S, Y, Z parameters), visualize 3-D electromagnetic fields (near- and far- field), and

generate ANSYS Full-Wave SPICE models that link to circuit simulations.

4.5.2 HFSS 3-D Layout: HFSS 3-D Layout is an optimized interface for layered geometry of PCBs, IC packages or on-chip embedded passives. Geometry is assembled and rendered in a 2-D design environment; however, all effects are rigorously simulated, including 3-D features such as trace thickness and etching, bond wires, solder bumps and solder balls. Layout primitives such as stack-up dimensions, anti-pad radius, trace widths or thicknesses can be easily parameterized in the design environment. HFSS 3-D Layout includes advanced phi meshing technology that is optimized for meshing silicon substrates, redistribution layers, electronic packages, and PCBs.

ANSYS HFSS can simulate phased-array antennas with all electromagnetic effects, including element-to-element coupling, embedded element patterns, scan input impedance and near- or far-field radiation. Infinitely large and finite-sized arrays can be simulated efficiently by exploiting the periodic nature of the geometry. For infinite arrays, one or more antenna elements are placed within a unit cell with periodic boundary conditions on the surrounding walls to mirror fields creating an infinite number of elements in two directions. Per- elementscan impedance and embedded element radiation patterns can be computed, including all mutual coupling effects. The method is especially useful for predicting array blind zones that can occur under certain scan conditions. The finite-sized array simulation technology leverages HPC domain decomposition to obtain a fast solution for large finite-sized arrays. This technology makes it possible to perform complete array analysis to predict all mutual coupling, scan impedance, element patterns, array patterns and array edge effects.

4.6 SUMMARY

Anslys HFSS is a simulation software tool used by engineers to design and simulate high-speed, high-frequency electronics in various applications such as radar systems, communication systems, microchips, printed circuit boards, IoT products, and other digital and RF devices. The software combines various techniques such as the finite element method (FEM), the method of moments (MoM), physical optics (PO), and shooting and bouncing rays (SBR) to provide high- accuracy simulation results. Ansys HFSS captures and simulates objects in 3D, accounting for materials composition and shapes/geometries of each object and allows for the design of complex radio frequency electronic circuit elements, including filters,

transmission lines, and packaging. It includes a 3-D solid modeler and layout interface for working in a layout design flow or importing and editing 3-D CAD geometry. The software enables the simulation of phased-array antennas with all electromagnetic effects, including element-to-element coupling, embedded element patterns, scan input impedance, and near- or far-field radiation, and allows for the simulation of the electromagnetic behavior of objects such as automobiles and aircraft. The software reduces the final testing and verification effort of the system and mitigates the necessity of building costly multiple prototypes, saving both time and money in product development.

CHAPTER – 5

RESULTS AND DISCUSSION

5.1 INTRODUCTION

In this chapter we will be concentrating on the results as the diagram which is given below consists of 3x3 array antenna which consists of nine patches and two feed line and also the given antenna design is a Transmission model and we are going to concentrate on the result part such as gain, directivity, VSWR, Electric and magnetic field flow in the patch, return loss, reflection coefficient, and we will be concentrating on the fabricating part of the antenna and testing results of the antenna

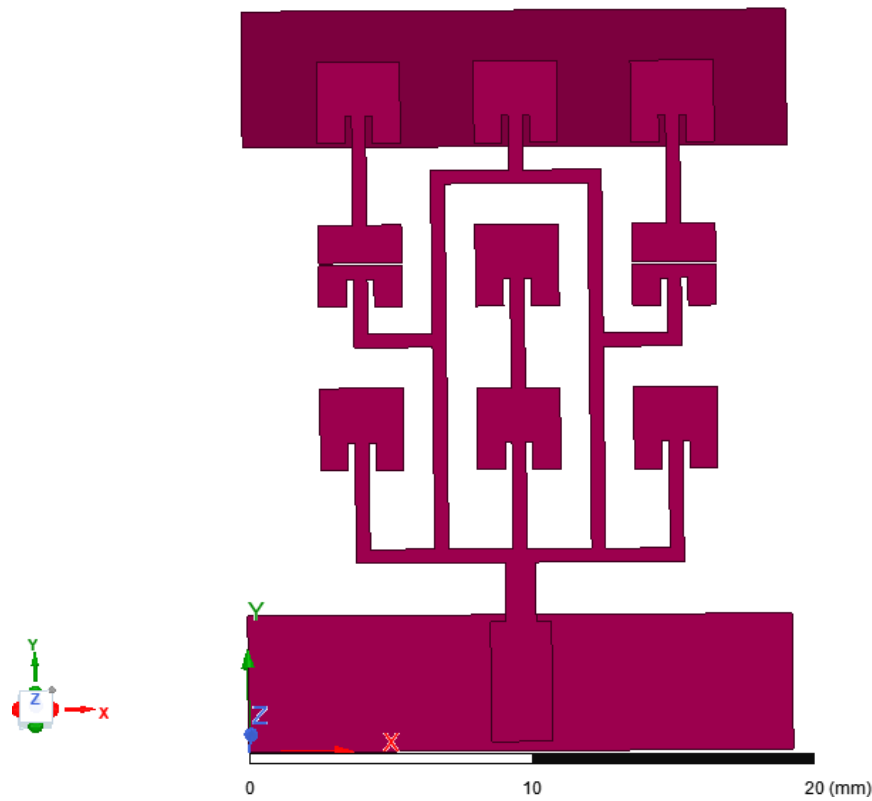


Fig 5.1: Simulated structure of an antenna

5.1.1 GAIN

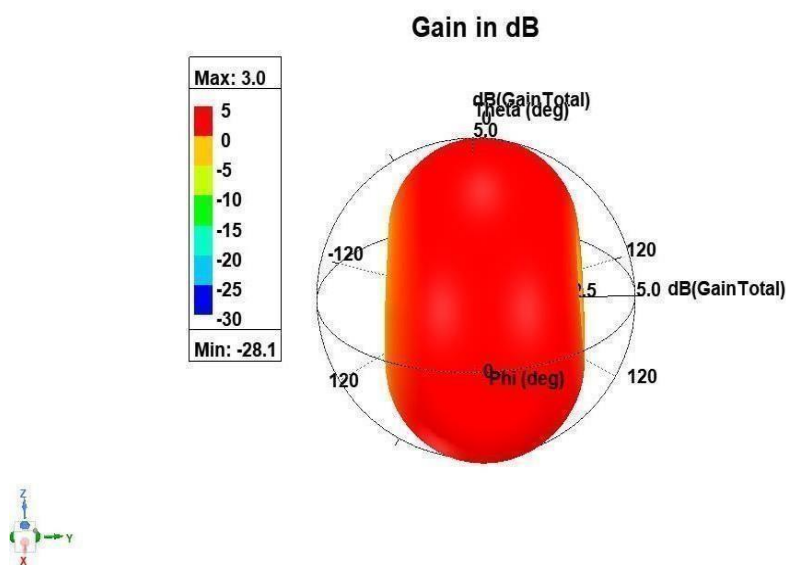


Fig 5.2: Gain of the antenna

Antenna gain is the measure how strong the signal of an antenna can transmit or receive in particular direction. So the remaining work in this project is to get better gain and directivity. Using ground – based electro magnetic band gap structure, or EBG Structure, we will increase the antenna's gain. The EBG Structure is essentially a periodic structural arrangement of metallic conductors, a high and low dielectric substrate, and both. Here, we're employing PGB for mushrooms (Photonic — crystal and band gaps). Due to its unique electromagnetic properties, the EBG structure has recently received a lot of interest.

The above Fig 5.2 shows the gain of the antenna. As we know, Antenna Gain is the measure of how strong the signal of an antenna can transmit or receive direction. Here the gain is 3 maximum which is strong enough to transfer power and information.

The EBG Structure consists basically of periodic structure arrangements of a high and low dielectric substrate and metallic conductors. Here we are using mushroom PGB (Photonic-crystals and Band Gaps). The EBG structure has attracted much attention recently due to their unique electromagnetic features. Applications of microstrip antennas on high dielectric constant substrates are of growing interest due to their compact size and conformability with monolithic microwave integrated circuit. By this we can get the proper gain plot what we needed.

5.1.2 DIRECTIVITY

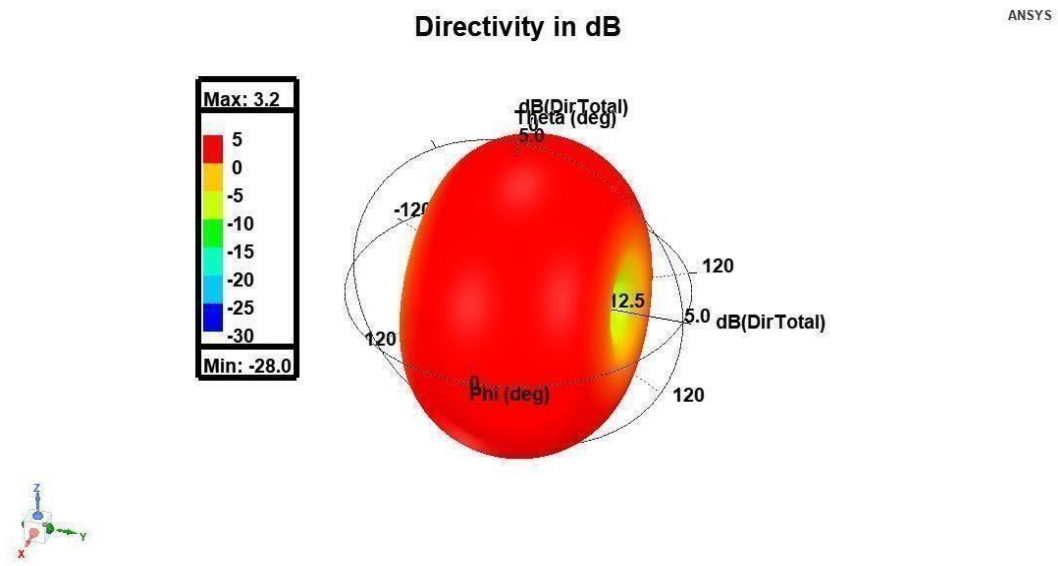


Fig 5.3: Directivity of an antenna

The directivity of an antenna is a measure of its radiation pattern in a certain direction. The top of the patches will be cut into triangular shapes with sharp edges in order to achieve or produce the directivity plot in positive, which will naturally increase the antenna's radiation pattern. This is what we will put into practice over the next several days to get the right gain and directivity, which will allow the aerial design to function without any loss and achieve the highest power transfer. The above Fig 5.3 shows the directivity of the antenna. Directivity is a measure of how well the array directs energy toward a particular direction. Directivity is a fundamental antenna parameter. It is a measure of how 'directional' an antenna's radiation pattern is. An antenna that radiates equally in all directions would have effectively zero directionality, and the directivity of this type of antenna would be 1 (or 0 dB).

Gain is the product of directivity and efficiency. Where efficiency accounts for the losses on the antenna such as manufacturing faults, surface coating losses, dielectric, resistance, VSWR, or any other factor. The directivity of patch antennas is approximately 3.2 maximum. Here for this antenna's design the directivity is given as 3.2 maximum. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π . If the direction is not strictly specified, the direction of maximum radiation intensity is implied.

5.1.3 RETURN LOSS(S-PARAMETER PLOT)

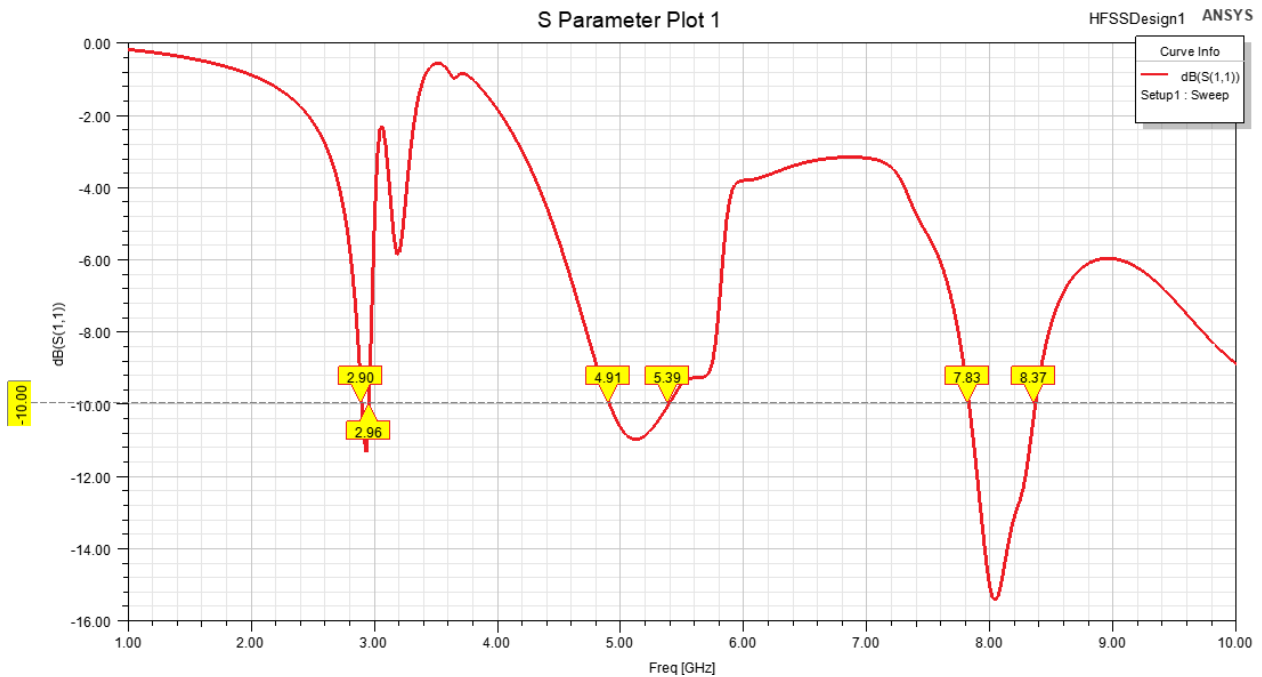


Fig 5.4: Return loss(S-parameter plot)

The above plot Fig 5.4 describes the S-Parameter of the antenna. Scattering parameters or S-parameters describe the electrical behavior of linear electrical networks when undergoing various steady state stimuli by electrical signals. S-parameters are used to describe how energy can propagate through an electric network, when it becomes especially important to describe a network in terms of amplitude and phase versus frequencies, rather than voltages and currents.

Various optimizations are done to get the return loss at the required frequency (2.4-8.1 GHz), which is also used in the antenna design. This is achieved by varying patch size and the feedline size, and in the ground layer by applying half ground, a quarter ground, and SRR in the ground (Split Ring Resonator). Impedance matching is done between the patches to get the maximum power transfer. The above graph shows the required frequency output at nearly -11dB exactly at 2.4 GHz.

Before receiving the required output on the plot, front- to-back ratio is observed, which is the primary thing to get this output. The front-to-Back ratio is nothing, but the gain is 180 degrees more in the forward and 90 degrees less in the back from the required frequency. With this, the required frequency is obtained.

5.1.4 ELECTRIC AND MAGNETIC FIELD FLOW IN THE PATCH

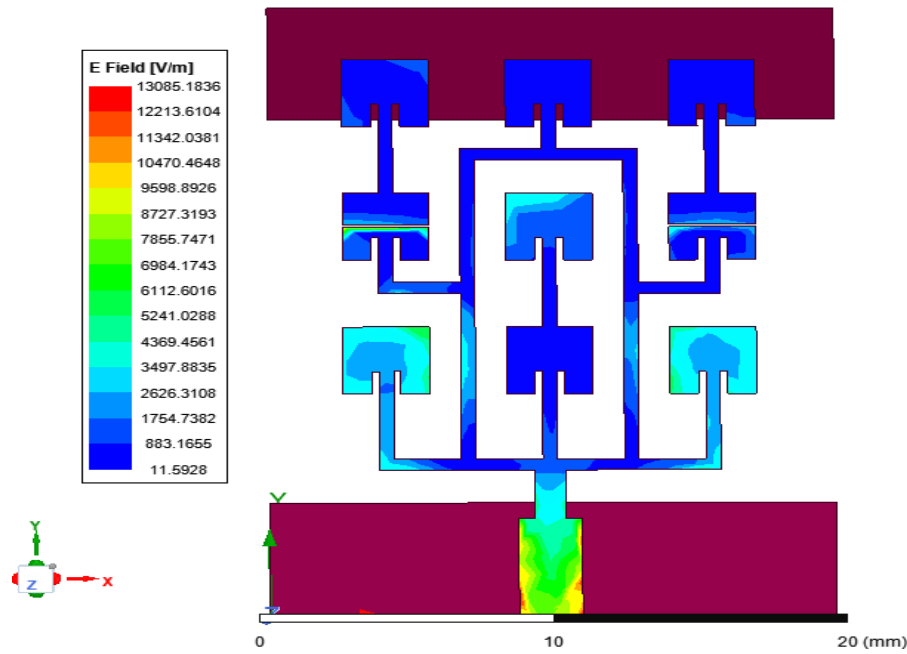


Fig 5.5: Electric field of an antenna

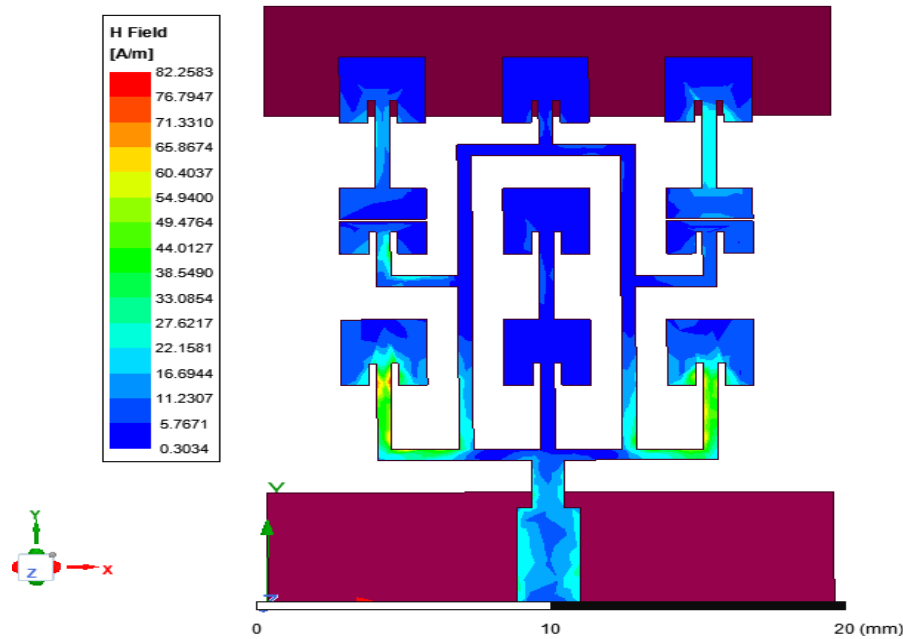


Fig 5.6: magnetic field of an antenna

The above figures Fig 5.5 and Fig 5.6 display the electric and magnetic field flow on the patch of the antenna. So, from the above figures it is clearly shown that the flow of both the electric and magnetic field in the patch is very good.

5.1.5 REFLECTION COEFFICIENT

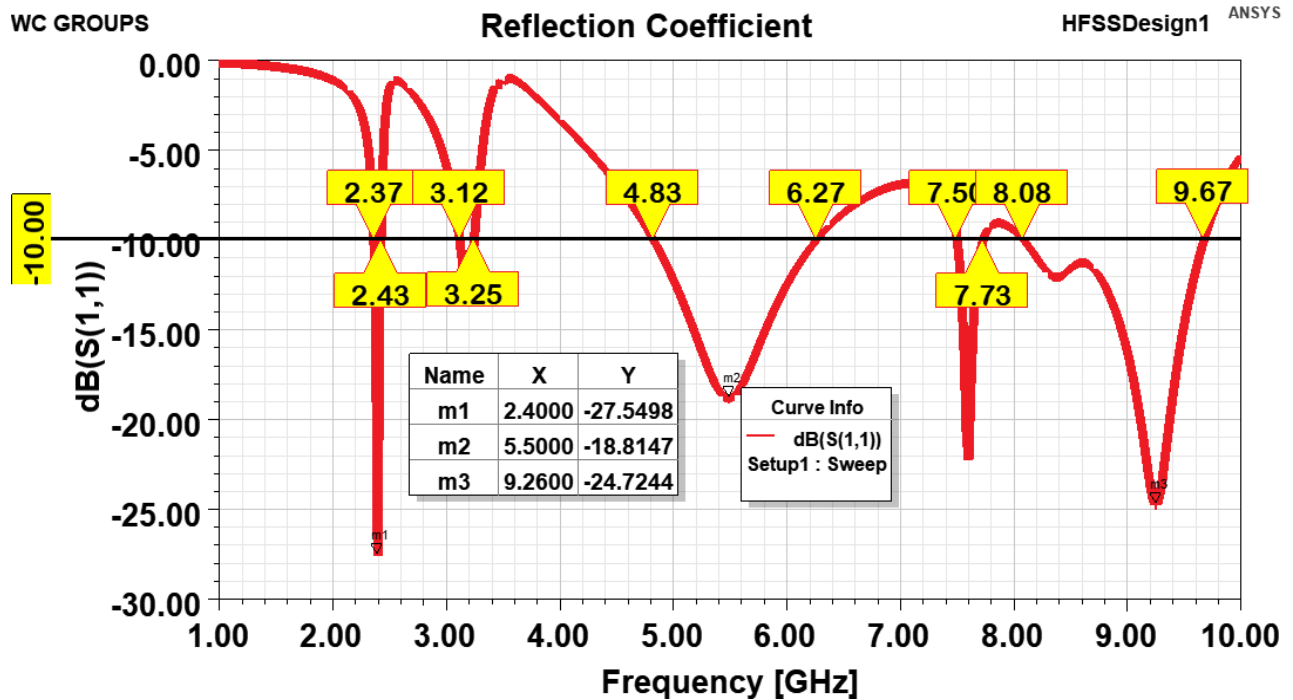


Fig 5.7: Reflection coefficient

This graph shows the three different frequencies with a db of -10 which consists of yellow marked points which represent that the antenna will be active at this points the gap between the points just take case one i.e, frequency at 2.4 GHz the mark starts from 2.37 to 2.43 which implies that the antenna works perfectly between these points . The same scenario goes for the other two frequencies. Now take case for 5 GHz as you can see that the point starts from 4.83 to 6.27 which indicated that the antenna is active between these mentioned points, and the last one starts from 7.5 to 8.08 Also from the above diagram we can also conclude that the designed antenna is a perfectly working antenna as you can see in the above diagram that the starting frequency 2.4GHz has a dB of -27 and the second frequency 5 GHz has a dB of -17 and coming to the last frequency it has a dB of -22.5dB, which implies that the designed antenna works in a perfect condition.

5.1.6 VSWR

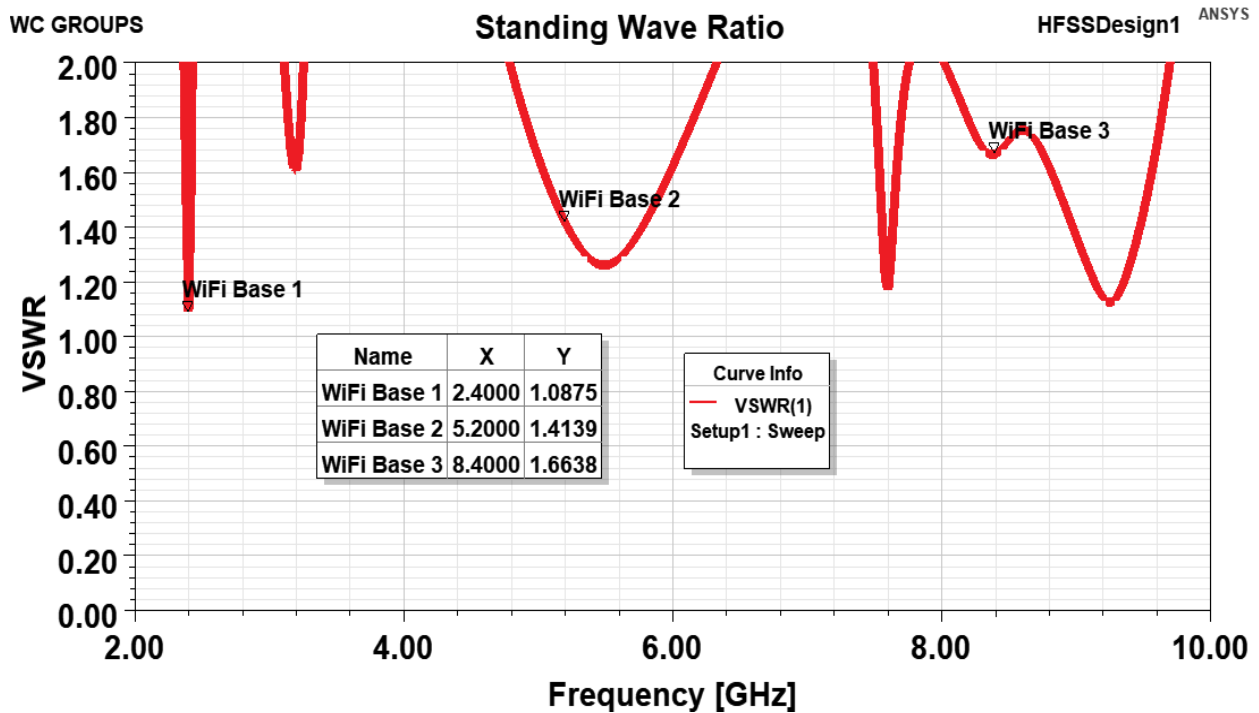


Fig 5.8: VSWR

The above figure 5.8 shows the ratio of the scattering aperture to the effective aperture is defined as scattering ratio. The scattering ratio may assume values between zero and infinity. For conditions of maximum power transfer and zero antenna losses, the scattering ratio is unity.

When a transmission line (cable) is terminated by an impedance that does not match the characteristic impedance of the transmission line, not all of the power is absorbed by the termination. Part of the power is reflected back down the transmission line. The forward (or incident) signal mixes with the reverse (or reflected) signal to cause a voltage standing wave pattern on the transmission line. When a transmission line (cable) is terminated by an impedance that does not match the characteristic impedance of the transmission line, not all of the power is absorbed by the termination. Part of the power is reflected back down the transmission line. The forward (or incident) signal mixes with the reverse (or reflected) signal to cause a voltage standing wave pattern on the transmission line. The ratio of the maximum to minimum voltage is known as VSWR, or Voltage Standing Wave Ratio.

5.1.7 RADIATION EFFICIENCY

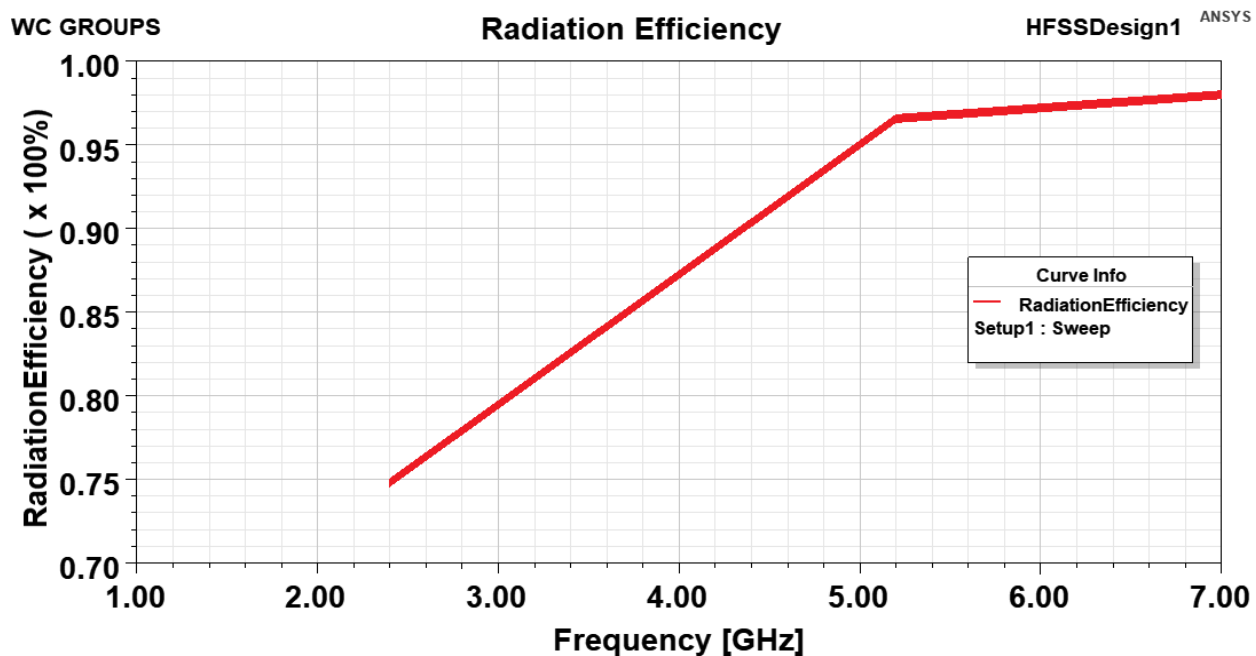


Fig 5.9: Radiation Efficiency Plot of the Microstrip antenna

The above graph Fig 5.9 shows the Radiation Efficiency of the antenna. The radiation efficiency of an antenna is defined as the ratio of the power radiated by an antenna to the power fed to the excitation port of the antenna.

The power loss due to port impedance mismatch is not considered here. For wire antennas which have a defined radiation resistance the radiation efficiency is the ratio of the radiation resistance to the total resistance of the antenna including ground loss (see below) and conductor resistance. In practical cases the resistive loss in any tuning and/or matching network is often included, although network loss is strictly not a property of the antenna.

For other types of antennas, the radiation efficiency is less easy to calculate and is usually determined by measurements.

5.1.8 RADIATION INTENSITY

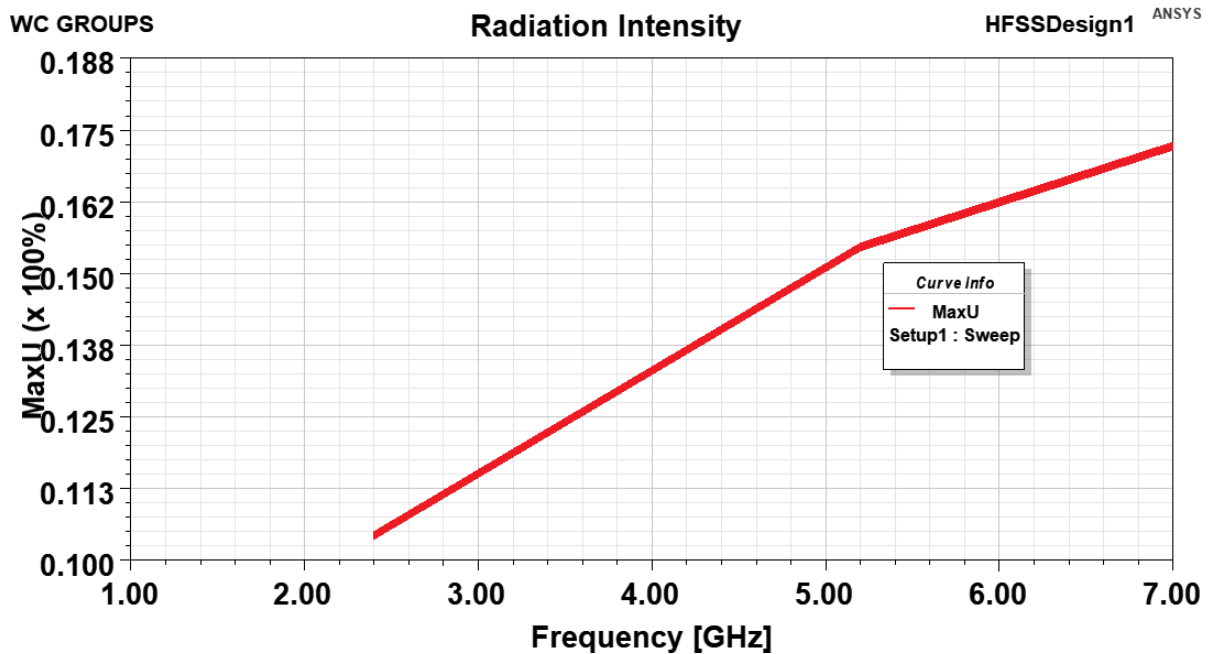


Fig 5.10: Radiation Intensity Plot of the Microstrip antenna

The above plot Fig 5.10 shows the Radiation Intensity of the microstrip patch array antenna. Radiation intensity, or the antenna power pattern, in each direction is defined as the power radiated from an antenna per unit solid angle. The radiation intensity is a far field parameter which can be obtained by simply multiplying the radiation power density by the square distance.

An Antenna radiates power, but the direction in which it radiates matters much. The antenna, whose performance is being observed, is termed as subject antenna. Its radiation intensity is focused in a particular direction, while it is transmitting or receiving. Hence, the antenna is said to have its directivity in that particular direction.

The ratio of radiation intensity in each direction from an antenna to the radiation intensity averaged over all directions, is termed as directivity. If that particular direction is not specified, then the direction in which maximum intensity is observed, can be taken as the directivity of that antenna.

5.1.9 FRONT TO BACK RATIO

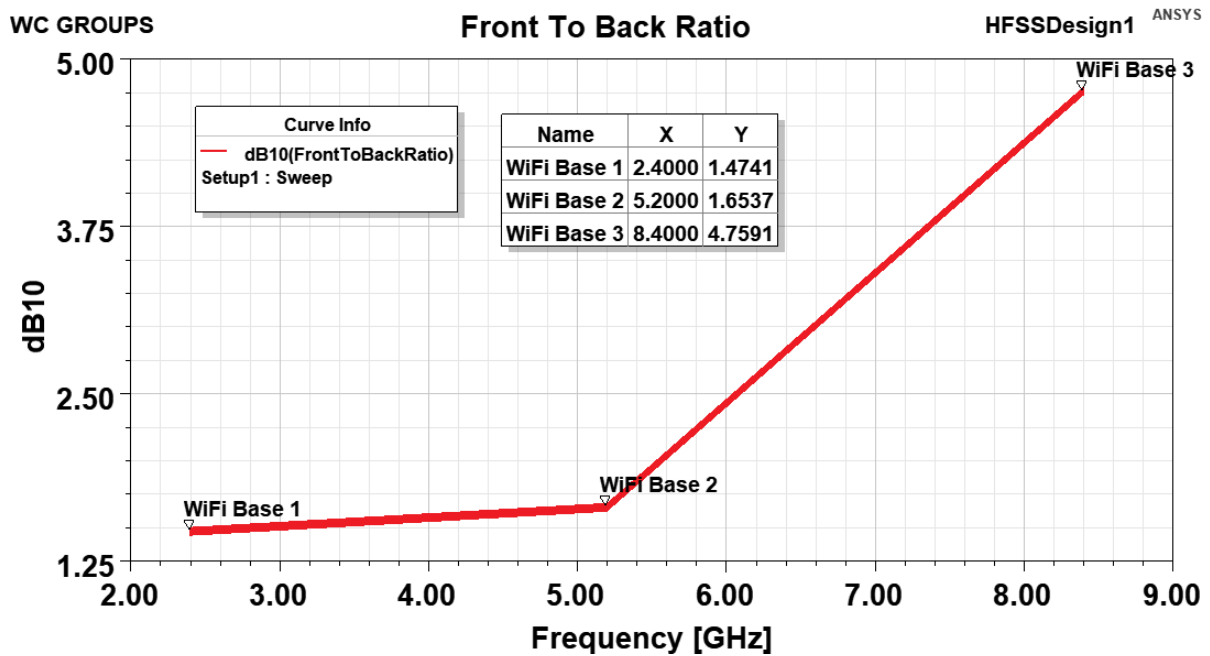


Fig 5.11: Front to Back Ratio Plot of the Microstrip antenna

The above plot Fig 5.11 displays the Front to Back Ratio Plot of the antenna. The Front to Back Ratio (F/B Ratio) of an antenna is the ratio of power radiated in the front/main radiation lobe and the power radiated in the opposite direction (180 degrees from the main beam).

This ratio tells us the extent of backward radiation and is normally expressed in dB. This parameter is important in circumstances where interference or coverage in the reverse direction needs to be minimized. In other electrical engineering the front to back ratio is a ratio of parameters used to characterize rectifiers or other devices, in which electric current, signal strength, resistance, or other parameters, in one direction is compared with that in the opposite direction.

Minimum value in dB. It is subject to a statistical validation for a single-sided parameter. This parameter is to be defined for the nominal sub bands in a broadband antenna. Unless otherwise noted it will be assumed the specification is for the full electrical down tilt range, and for all the ports associated with each frequency sub band of the antenna.

5.1.10 RADIATION PATTERN

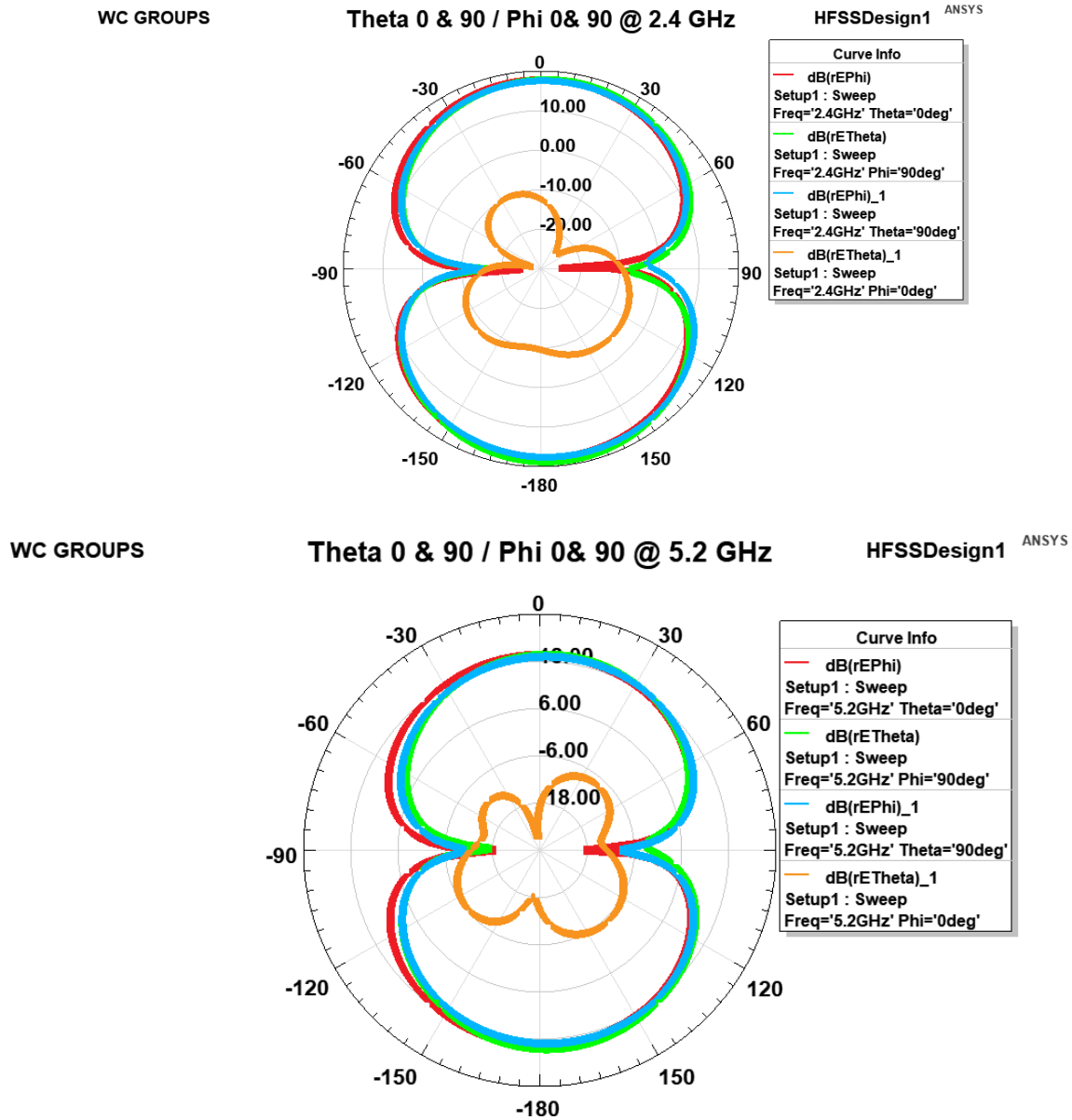


Fig 5.12 and Fig 5.13 Radiation Pattern of the Microstrip Antenna

The above Fig 5.12 and Fig 5.13 show the Radiation pattern of the microstrip patch array antenna. Fig 5.12 shows the pattern when theta is zero and phi is 90-degree value for 2.4Ghz and similarly the Fig 5.13 shows for theta 90 degree and phi zero degree at 5.2Ghz. The radiation form of the antenna is an electromagnetic wave, by calculating and measuring the strength of this electromagnetic wave at a distant point. This far point is where the wave is considered a plane wave and is perpendicular to the direction of the antenna.

5.1.11 SMITH CHART

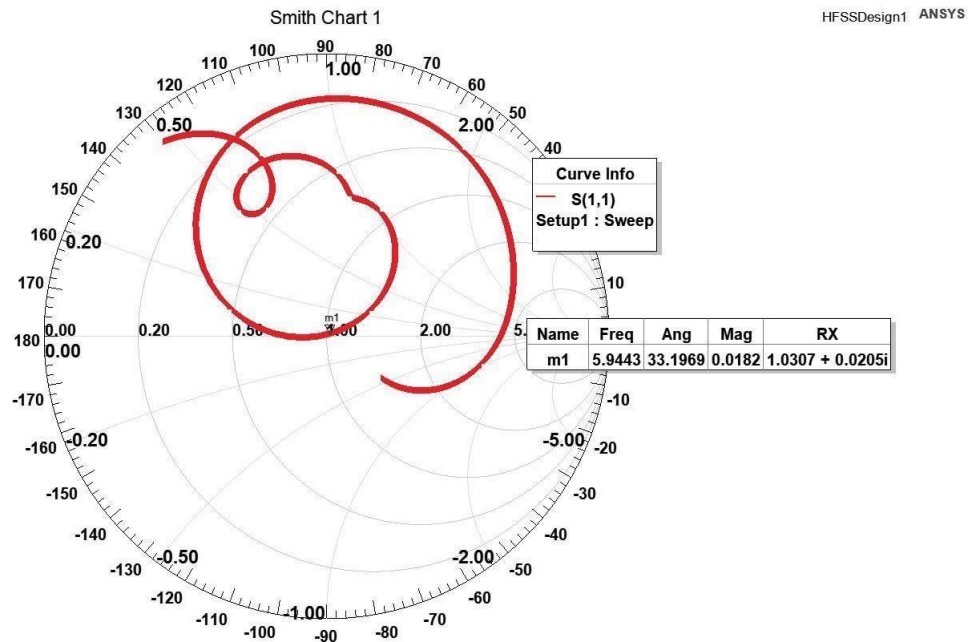


Fig 5.14 Smith chart of the Microstrip patch Antenna

The above Chart Fig 5.14 is the Smith chart of the designed antenna. A Smith chart is a circular plot with a lot of interlaced circles on it. When used correctly, matching impedances, with apparent complicated structures, can be made without any computation. The only effort required is the reading and following of values along the circles.

The Smith chart is a polar plot of the complex reflection coefficient (also called gamma and symbolized by Γ). Or, it is defined mathematically as the 1-port scattering parameter s or s_{11} . The Smith Chart, as it has been presented up to this point, is a plot of reflection coefficient for magnitudes either equal to or less than 1, thereby encompassing all real, positive values of resistance.

A Smith chart is developed by examining the load where the impedance must be matched. Instead of considering its impedance directly, you express its reflection coefficient Γ_L , which is used to characterize a load (such as admittance, gain, and trans conductance). The Γ_L is more useful when dealing with RF frequencies.

5.2 FABRICATION WORK

The antenna design which is fabricated using the inkjet printing technology covers the ISM 2.45 GHz and fed by a CPW feed. Moreover, the performance of the antenna is evaluated under bending effects in terms of impedance matching and shift in resonant frequency.

5.2.1 Fabrication steps of Antenna

Design and fabrication processes of the prototype antenna. As shown in Figure 1, there are five main stages in the proposed approach, namely,

- Simulation,
- Antenna printing,
- Antenna curing,
- Conductivity measurement,
- Antenna parameters measurements.

5.2.2 Materials used in Antenna Fabrication

Manufacturing cost and the weight of the material should be as minimum as possible.

- Copper,
- Brass (copper-zinc alloy),
- Bronze (copper-tin alloy)
- Aluminium is among widely used conducting materials to build antennas.

5.2.3 Fabrication process in Microstrip patch Antenna

The designed microstrip patch antenna is fabricated by photo-lithographic method. Photo-lithographic method is a chemical etching process which removes the unwanted metal regions of the metallic layer. Photo-lithographic method produces highly accurate etched pattern for the microstrip patch.

5.2.4 Fabrication Results



Fig 5.15: fabricated antenna-front side



Fig 5.16: fabricated antenna-back side

The above Fig 5.15 and 5.16 shows the picture of the fabricated microstrip patch array antenna. As we can see clearly that the antenna is designed or fabricated perfectly as the design that was shown in the ANSYS HFSS software.

The antenna was fabricated and it was in good working condition and satisfies its applications. Now this antenna is ready to be integrated with the processors and to be added in the automobiles to work for the application of WLAN communications.

A microstrip antenna consists of a metal patch of length usually equal to one-half wavelength. The length is maintained so that the antenna behaves as a resonator. The metal patch is mounted to the ground plane and the dielectric material is filled in between. Due to the presence of a conducting patch, a microstrip antenna is also known as a microstrip patch antenna. Generally, copper material is used to make the patch.

5.3 TESTING RESULTS OF FABRICATED ANTENNA

5.3.1 S – Parameter

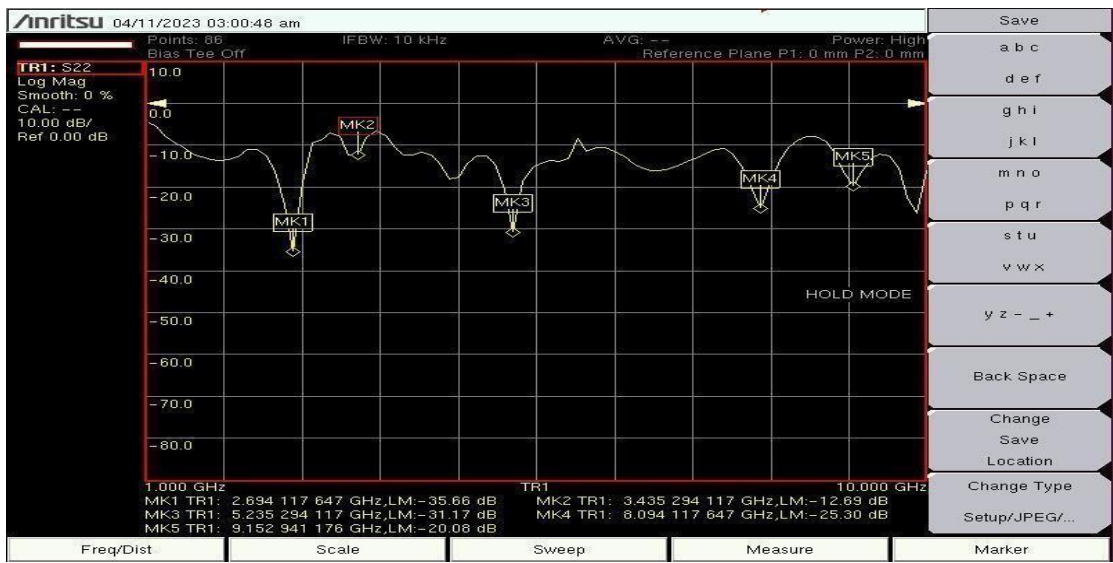


Fig 5.17: S – Parameter plot

As shown in the fig 5.17 known as S11, which is a S11 graph made-up antenna testing by using fabricated antenna design for Dual-band.

5.3.2 VSWR plot

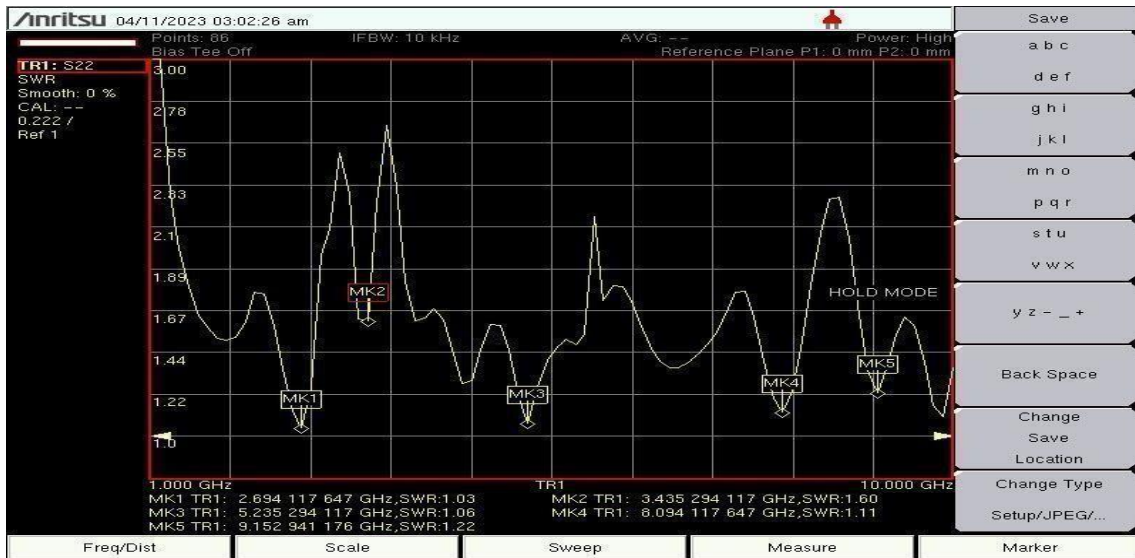


fig 5.18: vswr plot

As shown in the fig 5.18 known as Voltage Standing Wave Ratio(VSWR), which is a VSWR graph made-up antenna testing by using fabricated antenna design for multiband.

5.3.3 Smith chart

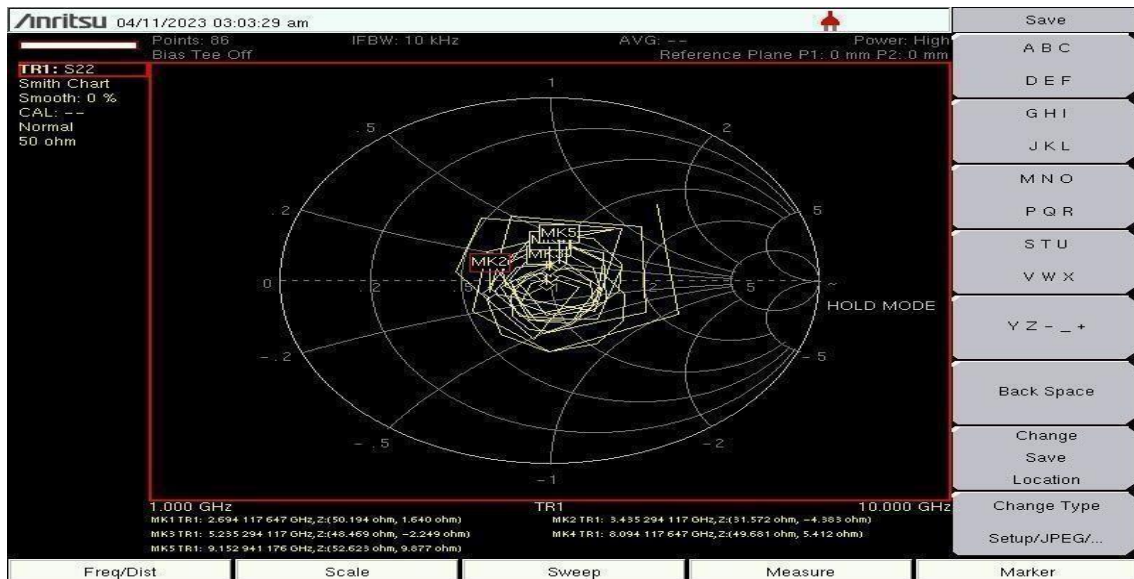


fig 5.19: smith chart

The above Fig 5.19 shows the Smith chart plot of the fabricated microstrip patch array antenna. The results received from the testing of the designed microstrip patch array antenna in real time. Hence there is not a much difference in their output plots. The results are closer to the one that got in the simulation. So it is considered that this antenna is working well and it will satisfies its application and conditions.

5.4 MAXIMUM AND MINIMUM VALUE OF SIMULATED ANTENNA DESIGN

Table: 5.1 Maximum and Minimum values of simulated antenna designs

Parameters	Maximum value	Minimum value
Gain	3.0 dB	-28.1 dB
Directivity	3.2 dB	-28. dB
Standing wave ratio	8.2GHz frequency bandwidth	2.2GHz frequency bandwidth
Reflection coefficient	9.2 Frequency	2.4 Frequency

5.5 SUMMARY

Antenna gain measures the strength of the signal transmitted or received by an antenna in a particular direction. The project aims to increase the antenna's gain and directivity using a ground-based electromagnetic band gap (EBG) structure, specifically PGB for mushrooms. The EBG structure is a periodic arrangement of metallic conductors, high and low dielectric substrates, and both. Cutting the top of the patches into triangular shapes with sharp edges will improve the antenna's directivity. Return loss is the measure of the reflected power when a signal is transmitted through a transmission line, and it plays a crucial role in antenna design. The S-parameter plot shows the frequency bands in which the signal can transmit, and yellow

marks represent the path of the signal. Improving gain and directivity while minimizing return loss will allow the antenna to function without loss and achieve maximum power transfer.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 INTRODUCTION

The overall working of antennas was understood. The major parameters (such as Return Loss curves, Radiation Patterns, Directivity and Beam width) that affect design and applications were studied and their implications understood. The rectangular patch with circular slot antenna is operated at the desired frequency. The patch antenna was simulated (using HFSS) and the desired level of optimization was obtained. It was concluded that the software results we obtained matched the theoretically predicted results.

6.2 CONCLUSION

As a part of literature survey a simple Rectangular Patch Antenna is designed with FR4 glass epoxy substrate having thickness 3mm and relative permittivity is 4.4. The Microstrip Antenna has a compact size of 30mm ×24mm ×3mm having dual band characteristics covering various bands for wireless communications. The Proposed antenna has return loss of -11 and -10.5 dB at resonating frequency of 2.4 and 5 GHz respectively and gain of 3 and 3.2 dB at resonating frequency of 2.4 and 5 GHz respectively. This antenna is designed and simulated in HFSS Software and calculated different antenna parameters. This proposed antenna is feed by coplanar wave guide line feed technique and it gives satisfactory results of return loss, gain, directivity and radiation pattern. Hence, it can be used in many applications like wireless communication, satellite communication, space communication, military systems and air traffic control.

6.3 FUTURE SCOPE

6.3.1 Optimization of antenna performance: The project could be further developed by optimizing the performance of the substrate waveguide antenna, such as by increasing the bandwidth, gain, and radiation efficiency of the antenna. This could involve using advanced simulation and optimization tools to fine-tune the antenna design.

- 6.3.2 ***Integration with other wireless technologies:*** The substrate waveguide antenna could be integrated with other wireless technologies, such as Bluetooth, Wi-Fi, or 5G, to provide a more comprehensive wireless communication system. This would require developing the necessary hardware and software interfaces to enable seamless integration.
- 6.3.3 ***Miniaturization of the antenna:*** The substrate waveguide antenna could be further miniaturized to enable its use in smaller devices, such as wearables or Internet of Things (IoT) devices. This would require developing new fabrication techniques and optimizing the antenna design for smaller form factors.
- 6.3.4 ***Power efficiency:*** Power efficiency is an important consideration for wireless applications, particularly for battery-powered devices. Future research could focus on improving the power efficiency of the substrate waveguide antenna, such as by reducing the antenna's power consumption or optimizing the antenna's impedance matching.
- 6.3.5 ***Real-world testing:*** The performance of the substrate waveguide antenna could be tested in real-world environments to determine how it performs in various conditions, such as indoors, outdoors, or in the presence of obstacles. This would require developing testing methodologies and conducting field trials.

6.4 SUMMARY

Overall, there are many potential areas for future research and development of the substrate waveguide antenna for wireless applications. Further optimization of the antenna's performance, integration with other wireless technologies, miniaturization, power efficiency, and real-world testing are all areas that could be explored to improve the antenna's functionality and usability.

REFERENCES

- [1] Aditya s et.al., "High gain 24GHZ CPW-fed microstrip patch antennas on high permittivity substrates", IEEE Antennas and wireless propagation letters, vol 3, 2004 pp 30-33.
- [2] Byungje Lee et.al., "Miniature microstrip antenna with a partially filled high permittivity substrate", IEEE Transactions on Antennas and Propagation, vol 50, 2002, pp 1160- 1162.
- [3] Chen yc et.al., "Inverted E shaped monopole on high permittivity substrate for application in industrial, scientific, medical, high performance radio local area network, unlicensed national information infrastructure, and worldwide interoperability for microwave access", IET microwaves, Antennas & Propagation, vol8,2014, pp 272- 277.
- [4] DeJean G, Bairava Subramanian G, Thompon D, Ponchak G. E., Tentzeris M.M. and Papapolymerou J, "Liquid Crystal Polymer (LCP): A new organic material for the development of multilayer dual - frequency / dual polarization flexible antenna arrays," IEEE Antenna and Wireless Propag. Lett., vol. 4, 2005, pp. 22-26.
- [5] Hayat Errifi, Abdennaceur Baghdad, Abdelmajid Badri and Aicha Sahel(2014), "Improving Microstrip Patch Antenna Directivity using EBG Superstrate" American Journal of Engineering Research,Vol.3, 2014, pp.125-130.
- [6] Nasimuddin et al. "Compact circularly polarized enhanced gain microstrip antenna on high permittivity substrate", Microwave conference proceedings vol 4, 2005, pp. 4-7.
- [7] Rahul Rajoria, "Microstrip Patch Antenna Loaded with Squares Shapes Metamaterial Structure for Bandwidth Improvement and Return loss", International Journal of Electrical and ElectronicsEngineering (IJEET),Vol.4,2014, pp.1-5.
- [8] Sayantan Mazumder, Saswata Sundar Laga," Design and Simulationof pi shape Metamaterial in Microstrip Patch Antenna", International Journal of Scientific & Engineering Research, Vol.8, March 2017, pp.99-104.
- [9] Saidulu. V, Kumara Swamy. K, Srinivasa Rao. K and Somasekhar Rao. P. V. D," Performance

analysis of Circular Microstrip Patch Antenna with Dielectric Superstrates"IOSR Journal of Engineering, Vol.3,2013, pp. 39-51

- [10] Thompson. D. C, Tantot. O, Jallageas. H, Ponchak G. E, Tentzeris. M.M and Papapolymerou. J, "Characterization of liquid crystal polymer (LCP) material and transmission lines on LCP substrates from 30- 110GHz", IEEE Trans. Microwave Theory Tech., vol. 52, no. 4, 2004, pp.1343-1352.
- [11] Yahya R et.al., "Effect of Rainwater and sea water on the permittivity of Denim jean substrate and performance of UWB Eye-shaped Antenna", IEEE Antennas and wireless propagation letters, vol 13, 2014, pp 806- 809.
- [12] Yue Li et.al., "High permittivity substrate multi resonant Antenna Inside Metallic cover of Laptop Computer", IEEE Antennas and Wireless propagation letters, vol10, 2011, pp 1092-1095.
analysis of Circular Microstrip Patch Antenna with Dielectric Superstrates "IOSR Journal of Engineering, Vol.3,2013, pp. 39-51

analysis of Circular Microstrip Patch Antenna with Dielectric Superstrates
"IOSR Journal of Engineering, Vol.3,2013, pp. 39-51

- [13] Thompson. D. C, Tantot. O, Jallageas. H, Ponchak G. E, Tentzeris. M.M and Papapolymerou. J, "Characterization of liquid crystal polymer (LCP) material and transmission lines on LCP substrates from 30-110GHz", IEEE Trans. Microwave Theory Tech., vol. 52, no. 4, 2004, pp.1343-1352.
- [14] Yahya R et.al., "Effect of Rainwater and sea water on the permittivity of Denim jean substrate and performance of UWB Eye-shaped Antenna", IEEE Antennas and wireless propagation letters, vol 13, 2014, pp 806-809.
- [15] Yue Li et.al., "High permittivity substrate multi resonant Antenna Inside Metallic cover of Laptop Computer", IEEE Antennas and Wireless propagation letters, vol10, 2011, pp 1092-1095.
analysis of Circular Microstrip Patch Antenna with Dielectric Superstrates "IOSR Journal of Engineering, Vol.3,2013, pp. 39-51
- [16] Thompson. D. C, Tantot. O, Jallageas. H, Ponchak G. E, Tentzeris. M.M and Papapolymerou. J, "Characterization of liquid crystal polymer (LCP) material and transmission lines on LCP substrates from 30-110GHz", IEEE Trans. Microwave Theory Tech., vol. 52, no. 4, 2004, pp.1343-1352.
- [17]Yahya R et.al., "Effect of Rainwater and sea water on the permittivity of Denim jean substrate and performance of UWB Eye-shaped Antenna", IEEE Antennas and wireless propagation letters, vol 13, 2014, pp 806- 809.

