DESIGN OF EDGE-TRIGGERED RHOMBIC MICROSTRIP PATCH ANTENNA FOR UWB APPLICATIONS

A Main Project Report

Submitted

In partial fulfillment of the requirements,

for the award of the Degree of

Bachelor of Technology
In
Electronics and Communication Engineering

Submitted By

R. Gopi Raju
(18481A04H6)

N. Sai Prathyusha
(18481A04F2)

Mani.Ch
(18481A04C6)

Y. Naga Pavan
(18481A04N0)

Under the Guidance of

Dr. D. Prabhakar, M.Tech., Ph.D.

Associate Professor

Department of ECE

Department of Electronics and Communication Engineering
SESHADRI RAO GUDLAVALLERU ENGINEERING COLLEGE

SESHADRI RAO KNOWLEDGE VILLAGE

GUDLAVALLERU – 521356

ANDHRA PRADESH

2021-22

Department of Electronics and Communication Engineering

SESHADRI RAO GUDLAVALLERU ENGINEERING COLLEGE

SESHADRI RAO KNOWLEDGE VILLAGE

GUDLAVALLERU – 521356

CERTIFICATE

This is to certify that the Main project report entitled "Design of Microstrip Patch Antenna for UWB Applications" is a bonafide record of work carried out by **R. Gopi Raju (18481A04H6), N. Sai Prathyusha (18481A04F2), Mani. Ch (18481A04C6), Y. Naga Pavan(18481A04N0)** under my guidance and supervision in partial fulfillment of the requirements, for the award of the degree of Bachelor of Technology in **Electronics and Communication Engineering** by **Jawaharlal Nehru Technological University, Kakinada**.

(Dr. D. Prabhakar)
Project Supervisor

(Dr. Y. RAMAKRISHNA)
Head of the Department

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R. Gopi Raju -18481A04H6
N. Sai Prathyusha -18481A04F2
Mani.Ch -18481A04C6
Y. Naga Pavan -18481A04N0

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ABSTRACT

In this project an Ultra-Wideband (UWB) microstrip antenna consisting of a Rhombic monopole patch with stepped feed line, with a 10 dB return loss bandwidth from 1.99 to 12.31 GHz is proposed. This antenna was designed on ROGERS 5880 substrate with overall size of 30 X 20 X 1.6 mm^3 and dielectric substrate with εr = 2.2 This antenna operated at UWB frequency and it designed by using Ansys HFSS (High Frequency structure simulator) Software based on the characteristic impedance for the transmission line model. The parameters like substrate dimension, feed size and ground plane which affect the performance of the antenna in terms of its frequency domain and time domain characteristics are investigated. The variations of different antenna parameters are compared between use of Copper and Graphene as the patch material.

The efficient design of rhombus-shaped microstrip patch antenna (MPA) with multiple slots and partial ground structure is proposed for desirable return loss, gain, and bandwidth for operation in Ultra-Wide Band (UWB). In recent times, MPAs are playing an important role as they are found to be immensely compatible in biomedical applications due to their compact nature, easy integration, and lightweight. ROGERS 5880 was chosen as the substrate material for its flexibility and durability. The antenna was simulated using Ansys HFSS (High-Frequency Structure simulator). The designed antenna has a bandwidth of 3.6 GHz according to the design equations. The merits of using ROGERS 5880 over Graphene were also understood by comparing different parameters. The proposed antenna is also designed to obey the SAR limit of 1.6 W/Kg acceptable limits of SAR (Specific absorption rate) for biomedical applications hence, the antenna can be used for on-body communications.

NOMENCLATURE

HFSS	-	High Frequency Structure Simulator
SAR	-	Specific Absorption Rate
UWB	-	Ultra-Wide Band
MPA	-	Microstrip Patch Antenna
VSWR	-	Voltage Standing Wave Ratio
ADAS	-	Advanced Driver Assistance Systems
IoT	-	Internet Of Things
EM	-	Electro Magnetic

CHAPTER-1

INTRODUCTION TO MICROSTRIP PATCH ANTENNAS

1 Introduction

1.1. What is Microstrip?

Deschamps was the first to suggest the notion of microstrip radiators in 1953. In 1955, a patent was issued in the names of Gutton and Baissinot in France. [2] However, it took another 20 years for usable antennas to be built. The availability of excellent substrates with low loss tangent and appealing thermal and mechanical properties, improved photolithographic processes, and Bates theoretical models spurred development in the 1970s. Howell and Munson invented the first workable antennas. [3] Microstrip antennas and arrays have been the subject of intensive research and development since then, with the goal of maximising their multiple advantages, such as light weight. Low volume, low cost, conformal construction, compatibility with integrated circuits, and other factors have resulted in a wide range of applications and the topic's separation from the broader subject of microwave antennas. [4]

In its most basic form, a microstrip antenna comprises of a radiating patch on one side of a dielectric substrate (€r 10) and a ground plane on the other. Patch conductors, which are usually made of copper or gold, can take almost any shape, but regular designs are most commonly utilised to make analysis and performance prediction easier. To improve the fringe fields that account for the radiation, the substrate's dielectric constant, €r, should be low (€r 2.5). Other performance criteria, on the other hand, may necessitate the use of substrate materials with dielectric constants larger than four. Various substrates have been created with a wide variety of dielectric constant and loss tangent values, which makes them suitable for conformal wraparound antennas.

The technique of making a microstrip patch antenna with graphene as the substrate. Ours is a technologically advanced era. One of them is wireless communication. In the twenty-first century, graphene is frequently employed in wireless communication. In comparison to conventional antennas, the microstrip patch antenna gives higher performance and anticipation. Because of its low cost, tiny size, and good performance, microstrip patch antennas are preferred above others. The surface conductivity of graphene may be reconfigured to work at the desired frequencies. The key idea here is to figure out where the best feed point for a microstrip patch antenna. A graphene-based microstrip patch antenna is described in this research. For wireless communication, it has a resonance frequency of 2.45 GHz.

Planar monopole antennas have emerged as one of the most promising alternatives for UWB applications this year, owing to their low cost, lightweight, ease of manufacture, and almost omnidirectional emission pattern. Some monopole UWB antennas only cover a portion of the UWB band's spectrum, and some monopole antenna designs are challenging to incorporate. [5] Because of its modest profile, a microstrip patch antenna is one of the most commonly used antennas in telecommunication. A patch antenna is a narrowband, wide-beam antenna made by etching the antenna element pattern in metal trace connected to an insulating dielectric substrate and forming a ground plane with a continuous metal layer bonded to the opposite side of the substrate. The cheapest technologies are photo etching and press machining. Printed antenna technology is well suited to mass production at a reasonable cost.

[7-8] The advantages of printed microstrip antennas are that they are lightweight and low volume, have a low profile planar configuration that can be easily made conformal to the host surface, and have a low fabrication cost, allowing them to be mass produced in large quantities. They also support both linear and circular signals.

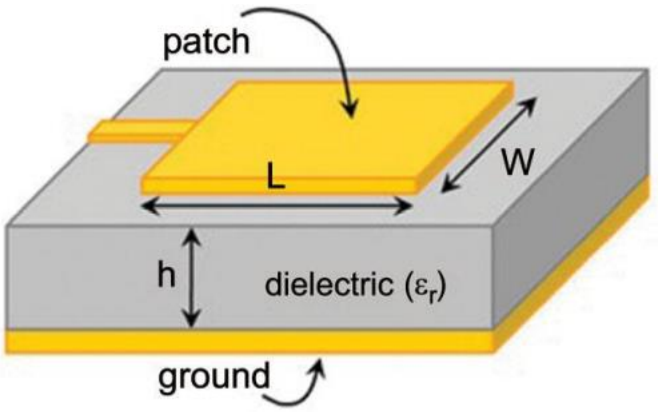


Fig1.1: Microstrip Patch Antenna.

1.2. Advantages and Limitations of Microstrip Antennas

Microstrip antennas have several advantages compared to conventional microwave antennas, and therefore many applications cover the broad frequency range from 100 MHz to 100 GHz. Some of the principal advantages of microstrip antennas compared to conventional microwave antennas are:

- Light weight, Low volume, and thin profile configurations, which can be made conformal.
- Low fabrication cost, readily amenable to mass production.
- Linear and circular polarizations are possible with simple fee.
- Dual-Frequency and dual-polarization antennas can be easily made.
- No cavity backing is required.
- Can be easily integrated with microwave integrated circuits.
- Feed lines and marching networks can be fabricated simultaneously with the antenna structure.

However, microstrip antennas also have some limitations compared to conventional microwave antennas:

- Narrow bandwidth and associated tolerance problems.
- Somewhat lower gain (-6dB). Large ohmic loss in the feed structure of arrays.
- Most microstrip antennas radiate into half-space.
- Complex feed structures required for high-performance arrays.
- Polarization purity is difficult to achieve.
- Poor end-fire radiator, except tapered slot antennas.
- Extraneous radiation from feeds and junctions.
- Lower power handling capability (~100W).

- Reduced gain and efficiency as well as unacceptably high levels of cross-polarization and mutual coupling within an array environment at high frequencies.

There are ways to minimize the effects of some of these limitations. For example, bandwidth can be increased to more than 60% by using special techniques. Lower gain and lower power handling limitations can be overcome through an array configuration. Surface wave-associated limitations such as poor efficiency, increased mutual coupling, reduced gain and radiation pattern degradations can be overcome by the use of photonic bandgap structures.

1.3. Microstrip Patch Antennas

A microstrip patch antenna (MPA) consists of a conducting patch of any planar or nonplanar geometry on one side of a dielectric substrate with a ground plane on the other side. Radiation characteristics have been calculated for a large number of patch antennas. The basic configurations used in practice are shown in fig 1.3.1. Their radiation characteristics are similar, despite the difference in geometrical shape, because they behave like a dipole. Rectangular and circular patch antennas are widely used. Typically, a patch antenna has a gain between 5 and 6 dB and exhibits a 3-dB beam width between 70º and 90º. Some of the other patch shapes are used for special applications. These are shown in fig 1.3.2.

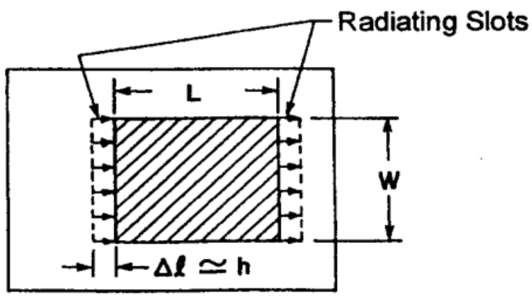
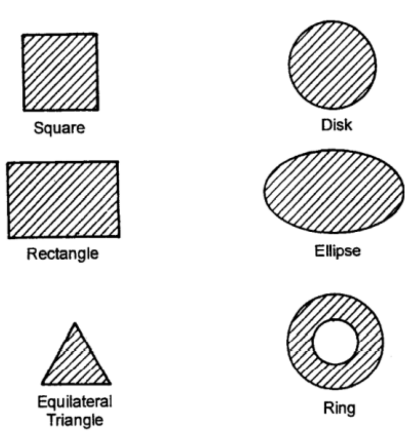


Fig1.3: Rectangular Microstrip Patch Antenna with equivalent horizontal radiating slots.



(a)

Fig1.3.1: Basic Microstrip Patch Antenna shapes commonly used in practice.

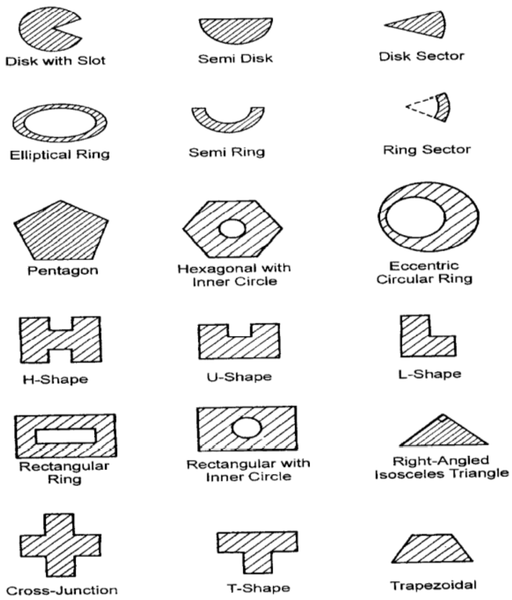


Fig1.3.2: other possible geometries for Microstrip Patch Antennas.

As a rule microstrip antennas are also referred to as patch antennas. The radiating factors and the feed traces are most commonly photograph etched on the dielectric substrate. The radiating patch is also square, rectangular, skinny strip (dipole), round, elliptical, triangular, or some other configuration.

These and others are illustrated in determine 1.7. Rectangular, rectangular, dipole (strip), and round are essentially the most original for the reason that of ease of evaluation and fabrication, and their attractive radiation traits, principally low move-polarization radiation. Microstrip dipoles are appealing given that they inherently possess a huge bandwidth and occupy much less space, which makes them attractive for arrays.

1.4. Feed for Compact Antennas

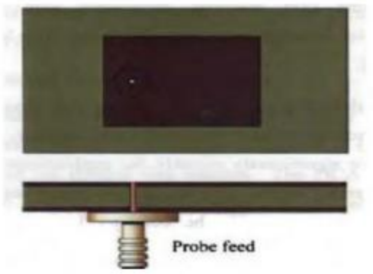
Patch antennas are in general excited via one of the most five approaches:

- Coaxial/probe feed.
- Micro strip line feed connected to the threshold of the patch.
- Micro strip line coupled to the patch by means of electromagnetic approach.
- Micro strip line coupled to the patch through aperture.
- Co-planar feed.

The choice of suitable feed is dependent upon the application.

1.4.1. Coaxial/Probe Feed

Coaxial probe is perhaps the most common method of feeding the micro strip antenna. Figure 1 depicts the basic arrangement. Eight. The coaxial cable's inner conductor is connected to the radiating patch, while the outside conductor is connected to the ground plane. This type of feeding allows for impedance matching while reducing spurious radiation. The impedance bandwidth of a coaxially supplied antenna is minimal. Thick substrates are required for accelerated bandwidth, which necessitates the use of an extended probe. However, this causes spurious radiation from the probe to acquire upward thrust. Surface wave vigour and feed



inductance are both increased.

Fig1.4: Coaxial fed Rectangular micro strip patch.

1.4.2. Microstrip Line Feed

Micro strip line feed is the simplest of the extraction techniques and has the knowledge of feed lying within the same airplane of the radiating monopole. Determine (1.9) shows the micro strip line feeding arrangement. This system of directly connecting a strip to the threshold of u patch is incredibly convenient when integrating the feeding community for enormous arrays. Nevertheless, the spurious radiation from the patch creates issues.

This can be decreased by means of settling on an excessive dielectric constant substrate. On this sort of excitation the prior knowledge of the feed point vicinity is most likely required for impedance matching.

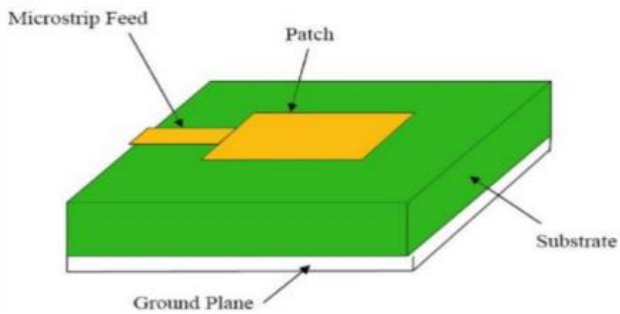


Fig1.5: Micro strip line fed rectangular patch.

1.4.3. Electromagnetic (proximity) Coupling

In this type of feeding system, the radiating patch is etched on another substrate and placed above the open-ended feed line. Thus, the radiating element is parasitically coupled to the 9 feed. Fig below depicts such a feeding mechanism. It has large bandwidth, Low spurious radiation and easy to fabricate.

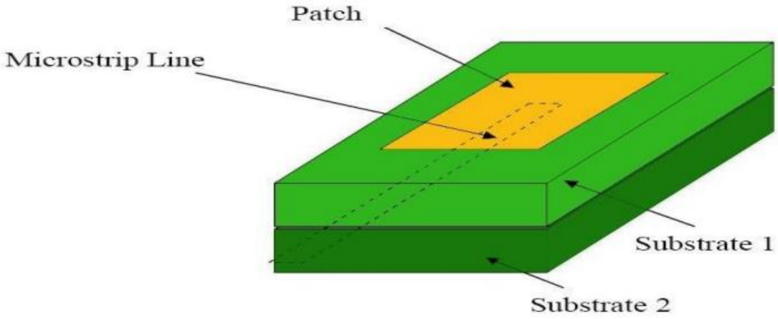


Fig1.6: Proximity Coupling.

1.4.4. Aperture Coupling

Aperture coupling feeding system has come to be very general which involves coupling of energy from a micro strip line although an aperture (slot) within the floor plane.

This process is referred to as the aperture coupling and is proven in Fig .The slot couples power from the strip line to the patch. Ordinarily high dielectric constant fabric is used for the backside substrate and thick low dielectric steady fabric for the highest substrate. The spurious radiation from the feed network is low on the grounds that the radiating aspect is isolated from the feed through the ground plane.

One more approach can be used for aperture coupling. The ground-aircraft is positioned between the patch and the feed-line, and coupling between the 2 is furnished by way of an aperture or slot in the ground airplane. A microstrip patch will also be electromagnetically-coupled utilizing a coplanar feed-line or a buried feed-Line.

The buried feed-line procedure employs a two layer substrate, one for the radiator and one for the feed-line. The substrate parameters can also be chosen individually. The higher substrate on which the antenna is printed requires a slightly thick substrate with a low relative dielectric constant to increase radiation and expand bandwidth, whereas the lessen feed-line substrate requires a thin substrate with a larger relative dielectric steady to hinder radiation.

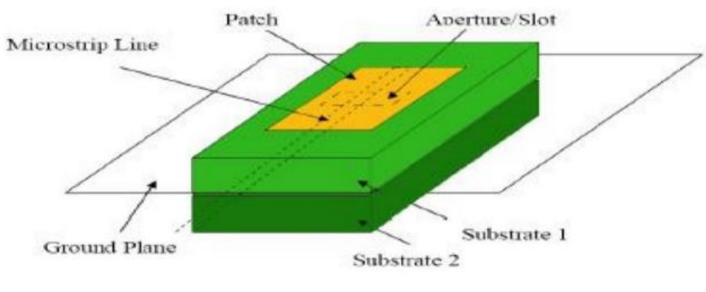


Fig1.7: Aperture Coupling.

1.4.5. Coplanar Feed

A micro strip patch can be electro-magnetically coupled using a coplanar feed line. The coplanar feed-line tends to radiate more than the buried feed line because it is printed on the same substrate as the radiator, which has high radiation efficiency. This is useful feed for coplanar printed antennas.

Fig1.8: Coplanar feed coupling.

1.5. Frequency bands allotted for various wireless communication services

Table 1.1 Frequency bands allotted for various wireless communication services.

Wireless Communication Services		Allotted Frequency Band
GPS 1575 GPS 1400	Global Positioning System	1.565 – 1.585 GHz 1.227 – 1.575 GHz
GSM 900	Global System for Mobile communication	0.890 – 0.960 GHz
DCS 1800	Digital Communication System	1.71 – 1.88 GHz
PCS 1900	Personal Communication System	1.85 – 1.99 GHz
UMTS 2000	Universal Mobile Telecommunications Systems	1.92 – 2.17 GHz
3G IMT – 2000	International Mobile Telecommunications – 2000	1.885 – 2.200 GHz
ISM 2.4 ISM 5.2 ISM 5.8	WLAN 802.11b/ Bluetooth ,Industrial, Scientific and Medical	2.4 – 2.484 GHz 5.15 – 5.35 GHz 5.725 – 5.825 GHz
RFID	Radio Frequency Identification System	0.03 – 2.4 GHz
DVB-H	Digital Video Broadcasting on hand held devices	1.67 – 1.675 GHz

UWB	Ultra-Wide Band	3.1 – 10.6 GHz
TD-SCDMA	Time Division Synchronous Code Division Multiple Access	1.85 – 2.62 GHz
LTE 2.5 GHz	Long Term Evolution	2.5 – 2.69 GHz
WiMAX	Worldwide Interoperability for Microwave Access	2.3 – 2.7 GHz 3.4 – 3.6 GHz

1.6. Background

In today's fast paced world antennas are widely used due to the increased number of wireless networks and portable communication devices. A Patch antenna is used in enhancement of various applications such as WLAN.

In this work, a microstrip patch antenna is designed and suggested for using in wide range of application covering the entirety of the UWB frequency range like wireless local area network (WLAN) technology, Satellite communication, Wi-Fi and more. The designed antenna can be operated in the 1.99-12.31 GHz frequency range using Copper patch and 1.97-12.40 GHz frequency range using Graphene patch resulting in a total bandwidth of more than 10 GHz in Ultra-Wide Band frequency range.

1.7. Analysis of Microstrip Antenna using Rogers 5880 & Graphene

1.7.1. Rogers 5880 Substrate

Rogers RT/duroid® high frequency circuit materials are filled PTFE (random glass or ceramic) composite laminates designed for high reliability applications in aerospace and defence. The RT/duroid line has a long history in the industry of producing high-reliability, high-performance materials.

RT/duroid 5880 laminates has a low dielectric constant (Dk) and low dielectric loss, making them well suited for high frequency/broadband applications. Helping to maintain the Dk uniformity are the randomly oriented microfibers reinforcing the PTFE composites.

Features:

- Dissipation factor of .0009 at 10GHz
- Low moisture absorption
- Isotropic
- Benefits
- Uniform electrical properties over wide frequency range
- Easily cut, shared and machined to shape
- Resistant to solvents and reagents used in etching or plating edges and holes
- Ideal for high moisture environments

- Well-established material
- Lowest electrical loss for reinforced PTFE material

1.7.2. Graphene Conducting Material

Many of the features of graphene are currently being researched and debated. The effect of phonons on electronic transport, the nature of electron-electron interactions, and how they modify physical properties are all research fields that are still in their early stages. We've just scratched the surface in this review.

Despite the fact that many publications have been written on monolayer graphene in recent years, only a small percentage of them deal with multilayers. The majority of theoretical and experimental studies have focused on the single layer, possibly due to its simplicity and the inherent appeal that a one atom thick material, which can be created using simple procedures in practically any laboratory, has. Nonetheless, few-layer graphene is equally fascinating and unique, with a technological potential that is possibly greater than single-layer graphene. Multilayers are, in fact, considerably behind single layers in terms of theoretical knowledge and practical inquiry. This is a future study field that is both fertile and open.

Finally, we concentrated solely on pure carbon graphene, where the Dirac description dominates the band structure.

Graphene may, however, be chemically modified to produce totally new physics. There can be a variety of effects depending on the nature of chemical dopants and how they are introduced into the graphene lattice via adsorption, substitution, or intercalation.

Adsorbed alkali metals can be utilised to alter the chemical potential, but adsorbed transition elements can cause substantial hybridization effects that alter the electronic structure. The introduction of d- and f-electron atoms into the graphene lattice may, in fact, result in a large increase in electron-electron interactions. As a result, it's easy to imagine a slew of many-body effects that can be caused by doping and must be investigated in the context of Dirac electrons: the Kondo effect, ferromagnetism, anti-ferromagnetism, and charge- and spin-density waves, to name a few. The investigation of chemically generated many-body phenomena in graphene would add a fresh chapter to the material's brief but fascinating history. Only time will tell, but there is the possibility of even more awe on the horizon.

1.8. Aim of the project

The proposed project is a Microstrip Patch Antenna which can be used for Ultra-Wide Band Applications. The main requirement is to design microstrip patch antennas using ROGERS 5880 substrate material and a ground defected plane structure. This antenna can be simply applied into various applications where a very wide band is required for operation.

1.9. Methodology

The proposed antenna is designed and simulated using the High-Frequency Structure Simulator (HFSS). The suggested antenna is a microstrip patch antenna, therefore its design in HFSS needs some geometrical and simulation parameters. The geometrical parameters of the proposed antenna are calculated using microstrip equations to be discussed. However, the major simulation parameter of an antenna is a frequency that can be defined according to the application of the proposed antenna. After the computation of geometrical parameters, the design of the suggested antenna can be modelled in the HFSS.

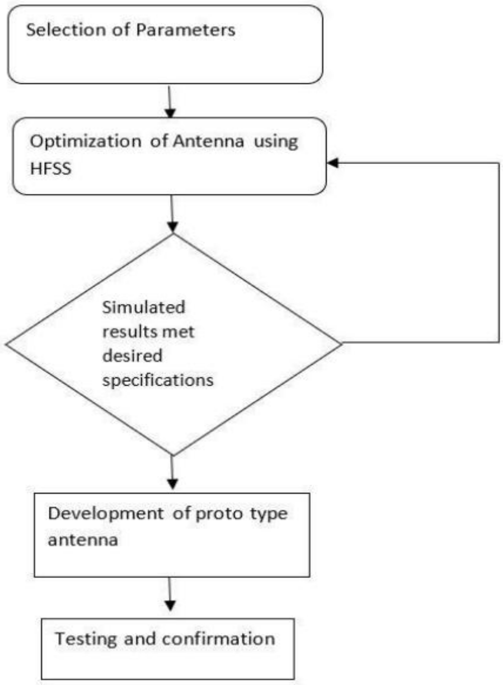


Fig1.9: Methodology flow chart.

1.10. Significance of This Work

The patch antenna is widely used in portable wireless devices because of the ease of fabricating it on printed circuit boards. Multiple patch antennas on the same substrate called microstrip antennas, can be used to make high gain array antennas, and phased arrays in which the beam can be electronically steered. By using antenna with various iterations with different ground planes, we can enhance the performance of the antenna.

1.11. Outline of the Project

Wireless Local Area Networks are being particularly used for the various real-time applications. These networks include the use of antennas for transmitting and receiving of the data for various applications. UWB is defined as a system having a bandwidth greater than 500 megahertz (MHz). UWB signals are pulse-based waveforms compressed in time, instead of sinusoidal waveforms compressed in frequency. Advancements in the field of electronics have progressed rapidly in recent times and as a result, intensive research activities are being held over antennas.

CHAPTER-2

LITERATURE OVERVIEW

2. LITERATURE REVIEW:

A printed microstrip Ultra-Wide Band (UWB) antenna for use in UWB application is designed. The developed antenna consists of a patch with appropriate dimensions on one side of a dielectric substrate and a partial ground plane on the other side of the substrate. The techniques that are used to enhance the bandwidth are the partial ground plane, feed point position, and adjusted feed gap. The substrate that is used in the proposed antenna is Rogers 5880, the optimum dimensions of the antenna are 30mm×20mm×1.6mm this antenna was designed by the HFSS program. [1] The band achieved by the proposed antenna is from 1.99-12.31 GHz frequency range using Copper patch and 1.97-12.40 GHz frequency range using Graphene patch resulting in a total bandwidth of more than 10 GHz.

In communication systems, there is a constant demand to increase the rate of data transfer. The increase in the rate of transfer information can be achieved by either increasing SNR or bandwidth.

Ultra-wide band as an emerging technology requires for the antenna characterization a thorough knowledge of the behaviour in time domain, in frequency domain and in certain cases in the spatial domain. It has been shown that for ultra-wide band, a certain antenna classes can be defined according to their radiating characteristics. Ultra-wideband is a radio technology that can use a very low energy level for short-range, high-bandwidth communications over a large portion of the radio spectrum. UWB has traditional applications in non-cooperative radar imaging. [2-3]

Ultra-wideband is a technology used to increase the bandwidth, this technology is recognized by the Federal Communication Committee (FCC), and it has a bandwidth from 3.1GHz to 10.6GHz. The UWB system has advantages such as the power consumption is low because it does not use a carrier signal, high data rate due to large bandwidth, and low interference. UWB antenna is an essential element and plays a dominant role in the ultra-wideband system, it has features such as the size of it is small, and its weight is light and low profile. These properties make it suitable to use in a portable device and it can be integrated with a circuit of radiofrequency it has a simple structure so it is easy to fabricate, and its cost is low as well as it has high precision ranging. Due to the physical features of the monopole antenna such as its small size, the cost of it is a cheap, and simple combination making it an excellent choice for use as a UWB antenna. [4] A patch antenna is the type of UWB antenna and it is a rectangular antenna consisting of three layers the medium layer is a substrate is a dielectric material the lower layer is printed on the lower side of the substrate is a conductive sheet called ground plane and an upper layer called patch.

The patch can be in different shapes such as rectangular, circular, and any other shape printed on the upper side of the substrate is a conductive material in different shapes called patch. In this project, the design and optimization of the microstrip patch ultra-wideband antenna are designed. The proposed antenna was designed using High-Frequency Structure Simulator (HFSS) software program and fabricated in the ministry of science and technology using ROGERS 5880 substrate. This project show simulation and the measured result of return loss and compare them and show a simulation result of the radiation pattern, gain, and VSWR.

This antenna was designed on Rogers 5880 substrate with overall size of 40 x 31.17 x 0.787 mm and dielectric substrate with εr = 2.2 This antenna operated at UWB frequency and it designed by using HFSS software.

The parameters like substrate dimension, feed size and ground plane which affect the performance of the antenna in terms of its frequency domain and time domain characteristics are investigated.

The first technique which is used to get wideband to achieve UWB requirement is a partial ground plane that means cut the ground plane. To choose the optimum width of the ground plane different values are tested. [7]

In this investigation of substrate material effect Roger5880 and graphene are considered. From the result it is to be observed that Roger5880 provides the min. return loss as compared to the graphene. So Roger5880 is considered as a suitable material for the proposed antenna design. With the use of Roger5880 as a substrate material the bandwidth increases. The bandwidth increases when the width of ground plane decrease.

CHAPTER-3

WORK TITLE EXPLAINATION

3.1. Introduction

In this research work, we have designed and implemented ground defected plane antenna. Several iterations were performed to obtain an Ultra-Wide Band Antenna. In this context, ground plane is varied in dimensions as per the required results. In the design with the above said ground plane techniques, the Rogers 5880 substrate is used for the simulation purpose.

Microstrip patch antenna has become a vogue, as it makes it easy to analyze and fabricate a low profile, low cost, light weight, indolent to feed and has affinity to radiation characteristics. In these days of modern age, the micro patch antenna has been widely used in reflector feeds, aerospace, radars, satellite communications and wireless communications. The versatile of bandwidth, radiation pattern, polarization and resonant frequency of patch antenna makes it an unprecedented antenna.

It has been assumed in the analysis and design of microstrip antenna that the size of ground plane is infinite. While in actual usage, only a finite size ground plane can be implemented for required antenna design. Finite ground plane gives rise to diffraction of radiation from the edge of the ground plane resulting in changes the radiation pattern, radiation conductance, VSWR and resonant frequency. Numerical and analytical techniques have been used to analyze such antennas. The effect of a finite ground plane on radiation fields has been studied by Haung using the aperture model for radiation and uniform geometrical theory diffraction (GTD). The E-Plane radiation pattern is affected more than the H-Plane pattern for a two wave length ground plane and an infinite ground plane.

The performance characteristics like Band Width, VSWR, Reflection coefficient and Gain of patch antenna by using different ground plane techniques for UWB applications are improved in this research work. The patch was designed on substrate Rogers 5880 and inset feed line is used as feeding method due to its simplicity of realization. The ultimate goal is to reduce the antenna size and the ground plane extension beyond the patch dimension to a minimum.

3.2. Antenna Design

The rhombus shaped patch antenna has been designed to operate at resonant frequency of 7 GHz with input impedance of 50Ω using ROGERS 5880 substrate with $\varepsilon_r = 2.2$, loss tangent $\delta = 0.02$ and thickness $t = 1.6$ mm. The patch antenna parameters are calculated from the following standard antenna design at reference resonant frequency.

The design procedure has the following steps.

1. Specifications

Table 3.1: Design specifications of an antenna.

Input Parameters	Specifications
Frequency of operation	7 GHz
Input impedance	50Ω
VSWR	< 2
Reflection coefficient	<=10 dB
Gain	2-3 dB

2. Substrate selection

Substrate in patch antenna is principally needed for the mechanical support of antenna metallization. For providing this support a substrate with dielectric material is needed, which affects the electrical performance of the antenna. The characteristics of substrates i.e., dielectric constant, loss tangent and their variation with temperature and frequency are to be considered for the selection of substrate. Table 3.2 Provides characteristics of different substrates

Table 3.2: Characteristics of different substrates.

Name	Relative permittivity (ε_r)	Dielectric tangent loss(δ)
ROGERS 5880 / RT Duroid	2.2	0.0009
Teflon	2.09	0.001
Flame Retardant-4 (FR-4)	4.4	0.02
Gold	1	0
Plexi glass	3.4	0.001

Similarly, other physical properties like resistance to chemicals, tensile and structural strengths, flexibility are important for fabrication process.

ROGERS 5880 was picked as the substrate material because of the lowest electrical loss and uniform electrical properties over frequency. The dimensions of the microstrip line fed patch antenna are determined using equations in the following steps by considering the ROGERS 5880 as substrate material with thickness (t) 1.6 mm, height (h)=1.6 mm, $\varepsilon_r = 2.2$.

3. Calculation of Width (W)

Width of the patch antenna is calculated by using

$$W = \frac{c}{2f_0\sqrt{(\varepsilon_r + 1/2}} \quad (3.1)$$

Where c is velocity of light = $3 * 10^8 m/s$

ε_r is the dielectric constant of the substrate

f_0 is the resonant frequency

4. Calculation of Actual Length (L)

The effective length of patch antenna L_{eff} depends on the resonant frequency (f_0).

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (3.2)$$

$$Where,\ \varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} (3.3)$$

The effective length of patch antenna is equal to the one half of a wave length within the dielectric medium.

The E-fields at the edges of the patch undergo fringing effects. As a result, effective length of the patch antenna appears to be greater than its actual length. So, actual length of the patch antenna is usually considered as $< \frac{\lambda}{2}$.

Actual length and effective length of a patch antenna can be related as

$$L = L_{eff} - 2\Delta L \quad (3.4)$$

WhereΔL is a function of effective dielectric constant ε_{reff} and the width to height ratio $\left(\frac{W}{h}\right)$.

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (3.5)$$

5. Calculation of Inset feed Depth (y_0)

The edge of the patch antenna will have high input impedance. Impedance falls rapidly if the inset position is moved from the edge of the patch towards the center. For providing impedance matching with a 50Ω connector, a curve fit formula for the inset feed depth $y_0$is expressed as

$$y_0 = 10^{-4}\{0.016922\varepsilon_r{}^7 + 0.13761\varepsilon_r{}^6 - 6.1783\varepsilon_r{}^5 + 93.187\varepsilon_r{}^4 - 682.69\varepsilon_r{}^3 + 2.561.9\varepsilon_r{}^2 - 4043\varepsilon_r + 6697\}\frac{L}{2} \quad (3.6)$$

6. Calculation of feed width (W_f)

To achieve 50 Ω characteristic impedance (Z_0), the required feed width to height ratio $\left(\frac{W_f}{h}\right)$ is computed as

$$\frac{W_f}{h} = \{\frac{8e^A}{e^{2A} - 2}\frac{W}{h} \le 2$$

$$\frac{W_f}{h} = \frac{2}{\pi}\left\{B - 1 - ln\, ln\,(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[ln\, ln\,(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\}\frac{W}{h} \ge 2 \quad (3.7)$$

Where, $A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r+1}{\varepsilon_r-1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right)$ $(3.6c)$

$B = \frac{377\pi}{2Z_0\sqrt{\varepsilon_r}}$ (3.9)

and Z_0 is the characteristics impedance.

7. Calculation of notch gap (g)

Resonant frequency of patch antenna depends on the notch gap (g). Expression which relates to notch gap and resonant frequency is given by

$$g = \frac{c}{\sqrt{2 * \varepsilon_{reff}}} \frac{4.65 * 10^{-12}}{f_0(inGHz)} \qquad (3.10)$$

With help of the above formulae all the parameters that are required to design an antenna are obtained.

3.3. Antenna Dimensions & Results

By using above equations, the important parameters of a patch like width, actual length, feedline length and slot dimensions are calculated and shown in the Table 3.3.

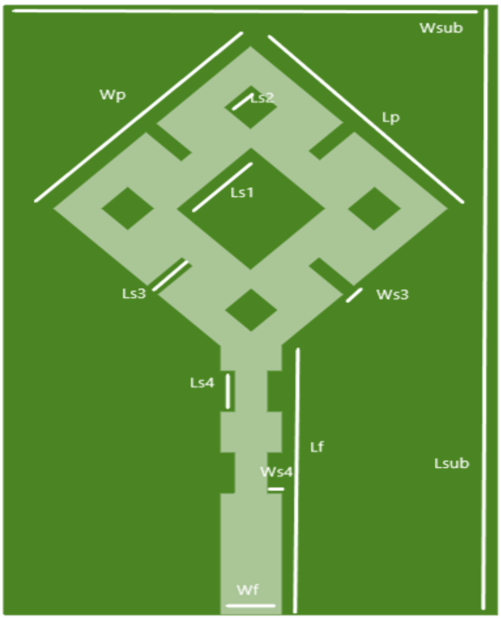


Fig 3.1: Geometry of patch antenna.

Table 3.3: Dimensions of patch Antenna.

Design Parameter	Dimensions(mm)	Design Parameter	Dimensions(mm)
Length of the substrate (L_{sub})	30	Width of the feedline Wf	2.5
Width of the substrate (W_{sub})	20	Length of feedline (Lf)	9
Width of the slit on patch (Ws_3)	0.6	Length & Width of inner slot (Ls_1)	4.24

Length of the slit on feedline & patch (Ls_3 &Ls_4)	2	Width of the slit on feedline & patch (Ws_3 &Ws_4)	0.6
Width & Length of smaller slot on patch	1.5	Width & Length of the patch (Wp & Lp)	11.31

3.4. Antenna Geometry

The geometry of the proposed antenna is shown in Figure3.1. The corresponding dimensions of patch are listed in Table 3.3.

The same dimensions are used to generate an antenna with defected ground structure. Figure 3.2 shows the bottom view of the antenna showing the ground plane. The semi-circular ring slit in the ground has a width of 0.1 mm and the corners of the ground are shorted to enhance the bandwidth of the microstrip patch antenna.

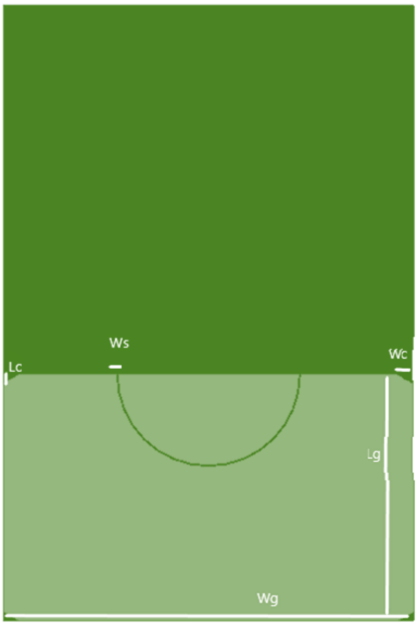


Fig 3.2: Ground plane of patch antenna.

Table 3.4: Dimensions of Defected Ground Plane Structure Antenna.

Design Parameter	**Dimensions(mm)**
Width of corner slots on ground (Wc)	0.75
Width of the ground (Wg)	20
Width of the semi-circular ring slit in ground (Ws)	0.1
Length of corner slots on ground (Lc)	0.433
Length of the ground (Lg)	12

Table 3.4: Dimensions of Defected Ground Plane Structure Antenna.

The performance of the designed Rhombic shaped microstrip patch antenna using ROGERS 5880 is analysed using both copper and graphene as patch materials and the results are compared and documented to understand the variations in different antenna parameters with change of patch material from copper to graphene. The results obtained with copper patch are as follows:

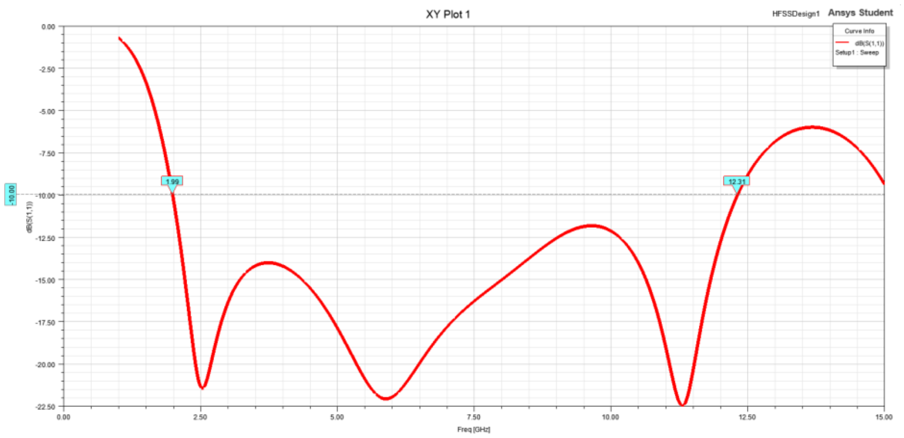


Fig 3.3: S_{11}(in dB) of designed antenna with copper patch.

According to the obtained data (see figure 3.3), the copper patch antenna's bandwidth ranges from 1.99 GHz to 12.31 GHz. The scattering parameter S_{11} (in dB) vs frequency (in GHz) graph for the planned rhombic shaped antenna is shown in the graph above.

Figure 3.4 shows the voltage standing wave ratio, VSWR (in dB), vs frequency plot of the same antenna with copper patch.

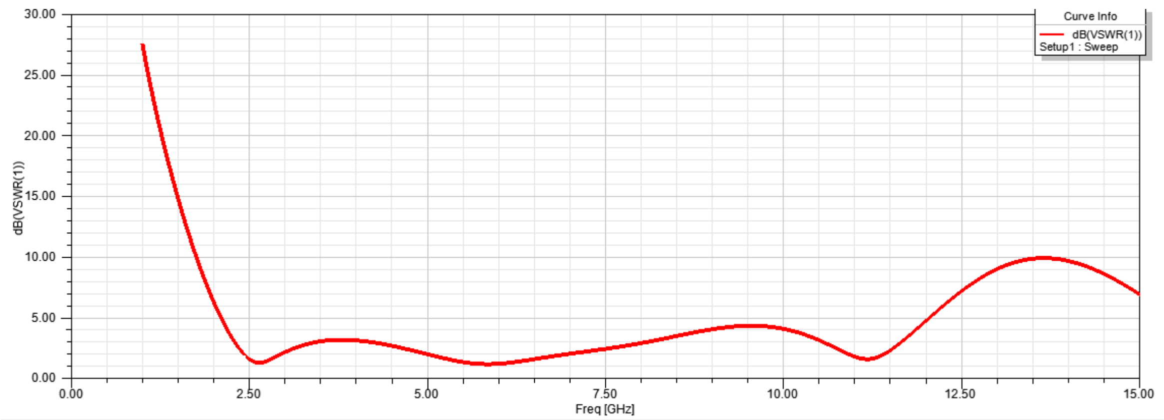


Fig 3.4: VSWR (in dB) of designed antenna with copper patch.

The 3D plot of Total Gain (in dB) for the designed rhombic shaped antenna can be observed in the figure 3.5.

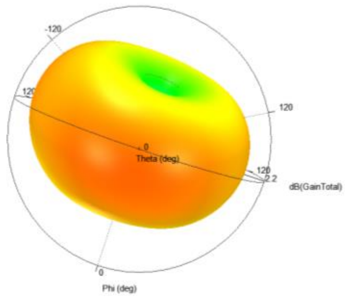


Fig 3.5: 3D plot of Total Gain (in dB) with copper patch.

The polar plot showing the Radiation pattern for the designed rhombic shaped antenna with copper patch can be observed in the figure 3.6.

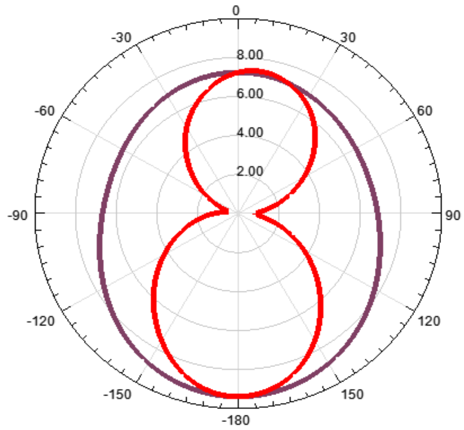


Fig 3.6: Polar plot of radiation pattern with copper patch.

The results obtained with Graphene patch are as follows:

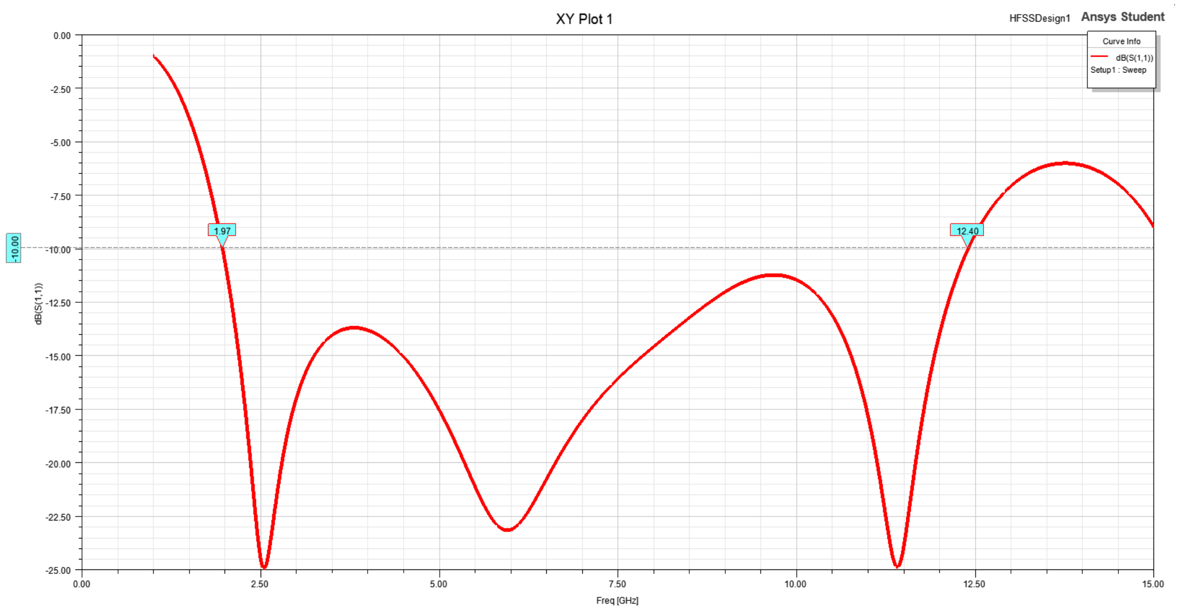


Fig 3.7: S_{11}(in dB) of designed antenna with graphene patch.

According to the obtained data (see figure 3.7), the copper patch antenna's bandwidth ranges from 1.97 GHz to 12.40 GHz. The scattering parameter S_{11} (in dB) vs frequency (in GHz) graph for the planned rhombic shaped antenna is shown in the graph above. When compared to the copper patch, we can see a bandwidth increase of roughly 110 MHz.

Figure 3.8 shows the voltage standing wave ratio, VSWR (in dB), vs frequency plot of the same antenna with copper patch.

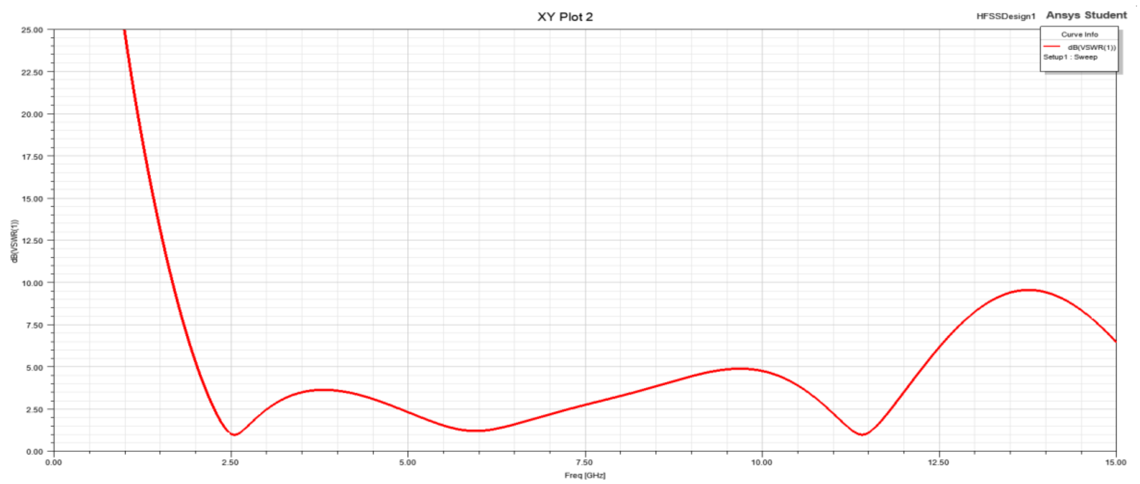


Fig 3.8: VSWR (in dB) of designed antenna with graphene patch.

The 3D plot of Total Gain (in dB) for the designed rhombic shaped antenna can be observed in the figure 3.9.

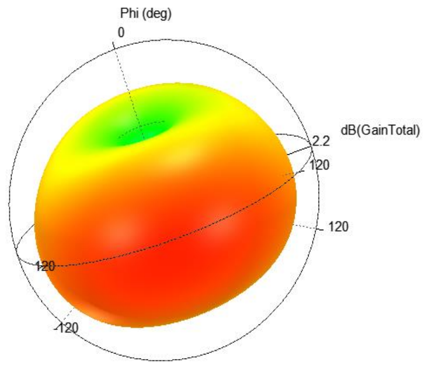


Fig 3.9: 3D plot of Total Gain (in dB) with graphene patch.

The polar plot showing the Radiation pattern for the designed rhombic shaped antenna with graphene patch can be observed in the figure 3.10.

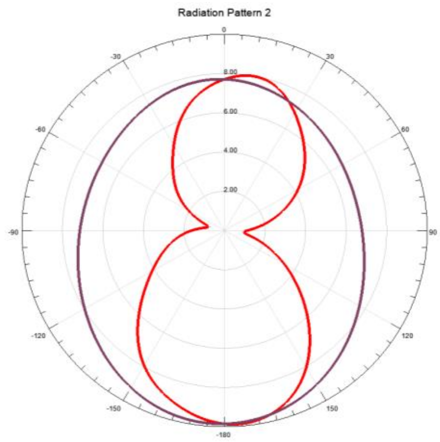


Fig 3.10: Polar plot of radiation pattern with copper patch.

CHAPTER-4

SOFTWARE USED

Ansys HFSS is a 3D electromagnetic (EM) simulation software that may be used to design and simulate high-frequency electronic devices such antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages, and printed circuit boards. Ansys HFSS software is used by engineers all around the world to develop high-frequency, high-speed circuits that can be found in communications systems, advanced driver assistance systems (ADAS), satellites, and internet-of-things (IoT) devices.

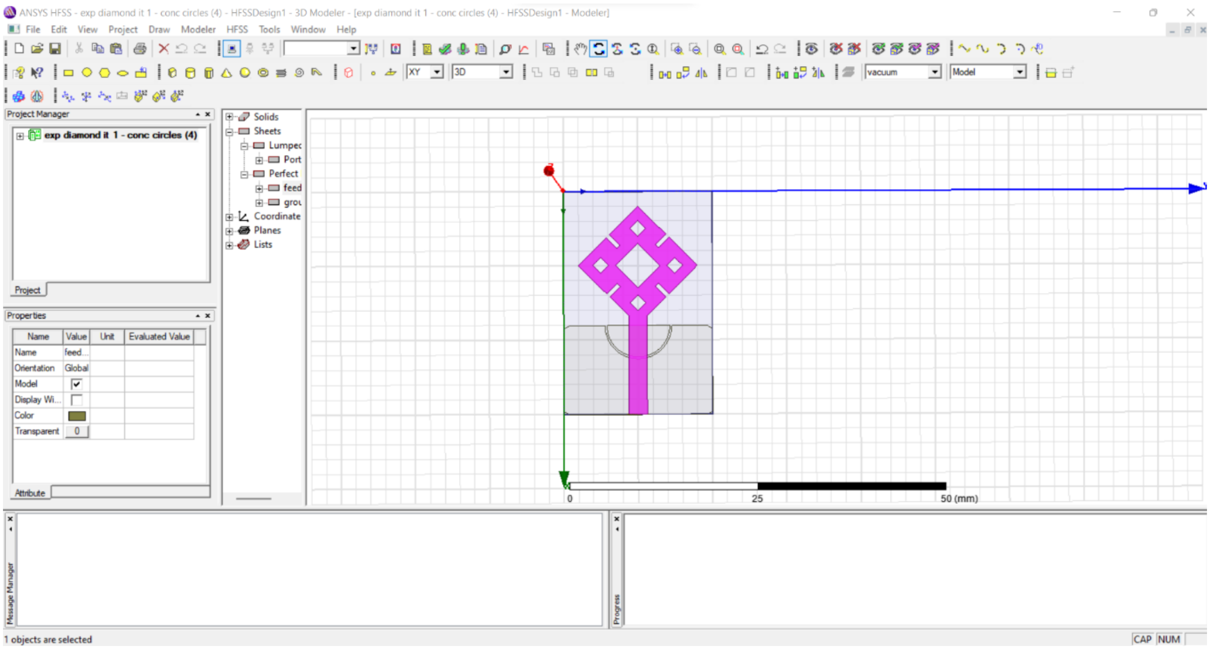
Ansys HFSS (high-frequency structure simulator) is a commercial finite element technique solver for electromagnetic (EM) structures from Ansys that includes a number of cutting-edge solver technologies. In ANSYS HFSS, each solver is an automated solution processor for which the user specifies the geometry, material parameters, and solution frequency range.

Fig 4.1: HFSS Software icon

Radar systems, communication systems, satellites, ADAS, microchips, printed circuit boards, IoT goods, and other digital and RF devices all use Ansys HFSS to design and simulate high-speed, high-frequency electronics. The solver has also been used to model the electromagnetic behaviour of items like cars and planes. System and circuit designers can use ANSYS HFSS to simulate EM difficulties such attenuation, coupling, radiation, and reflection.

Simulating a circuit's high frequency behaviour with high precision on a computer minimises the system's final testing and verification effort while also eliminating the need for expensive multiple prototypes, saving time and money in product development.

HFSS records and mimics objects in 3D, taking into account their materials composition as well as their shapes and geometries. HFSS is a commercial tool for antenna design as well as the design of sophisticated radio frequency electronic circuit elements such as filters,



transmission lines, and packaging. Professor Zoltan Cendes and his students at Carnegie Mellon University created it first. Prof. Cendes and his brother Nicholas Cendes created Ansoft, which sold HFSS standalone and integrated into Ansoft products under a 1989 marketing agreement with Hewlett-Packard. Optimization Systems Associates Inc. (OSA), a firm created by John Bandler in 1983, was acquired by Hewlett-Packard in 1997. The acquisition was motivated by HP's desire for HFSS optimization capabilities.

Fig 4.2(a): Layout of HFSS software

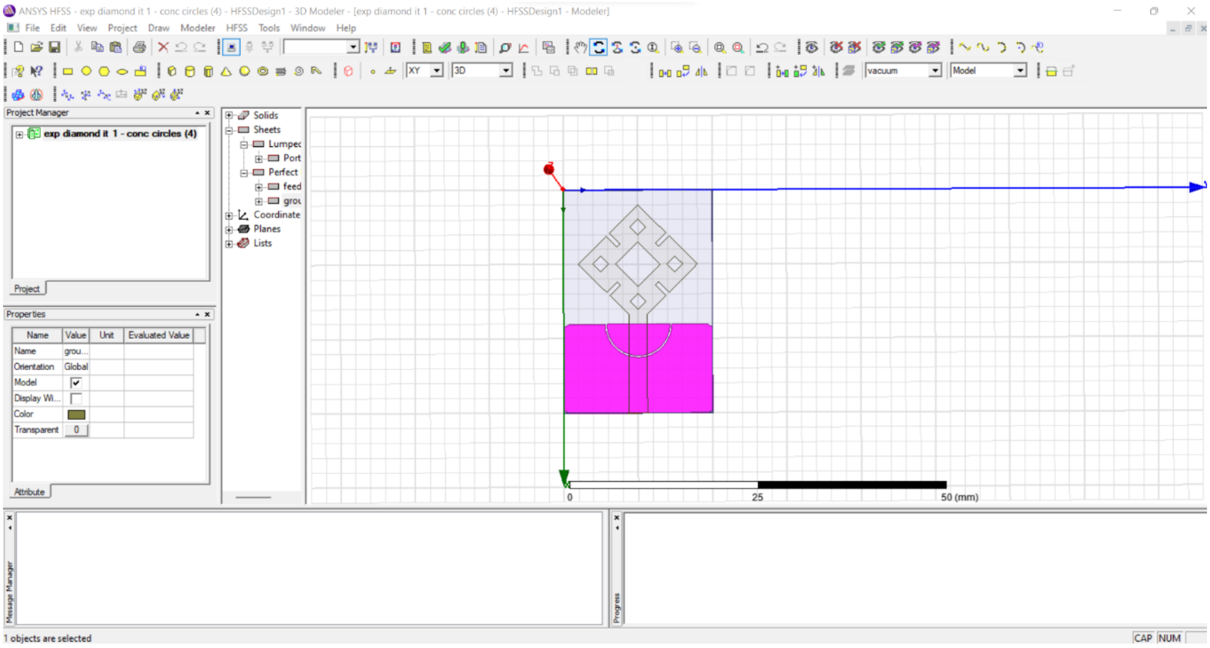


Fig 4.2(b): Layout of HFSS software

CHAPTER-5

RESULTS

The individual results obtained after simulation of both copper and graphene patches in HFSS software are used to compare different antenna parameters like VSWR (Voltage standing wave ratio), Scattering parameter (S_{11}), Total Directivity and Total Gain using MATLAB.

The plots obtained can be used to arrive at conclusions on the effect of the patch material on different antenna parameters in Ultra-wide band frequency range. All the comparisons are done in the frequency range of 1 GHz to 15 GHz for uniformity in the plots drawn using MATLAB.

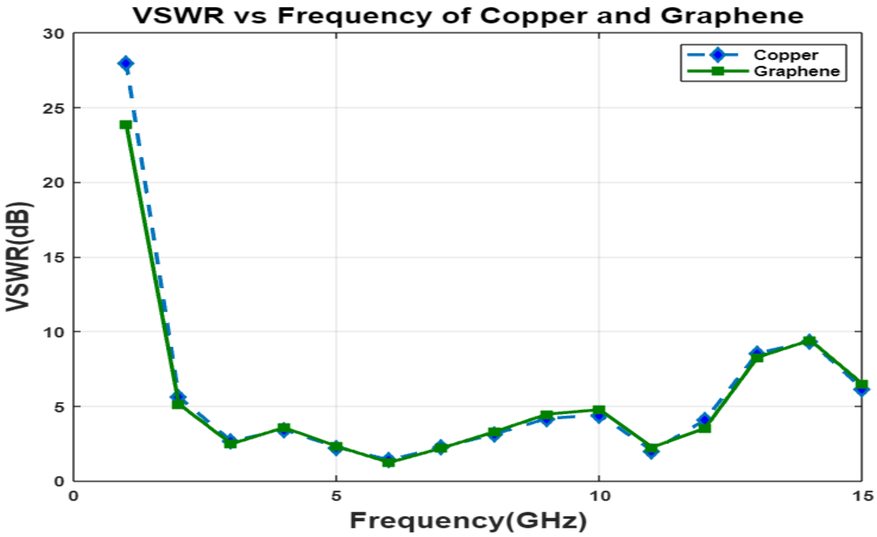


Fig 5.1: Comparison plot of VSWR (in dB) for Copper and Graphene antenna.

In the above comparison plot it can be observed that maximum VSWR of 28.00 dB and 23.89 dB are obtained at 1 GHz for copper and graphene respectively.

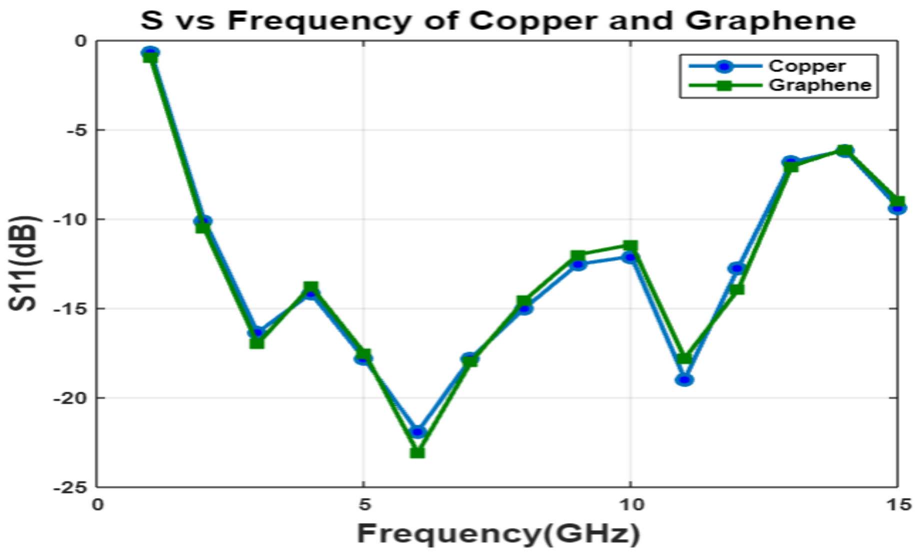


Fig 5.2: Comparison plot of S_{11} (in dB) for Copper and Graphene antenna.

In the comparison plot drawn for S_{11}(in dB) against frequency for both copper and graphene, it can be observed that maximum S_{11} scattering parameter of -0.69 dB and -0.98 dB are obtained at 1 GHz for copper and graphene respectively.

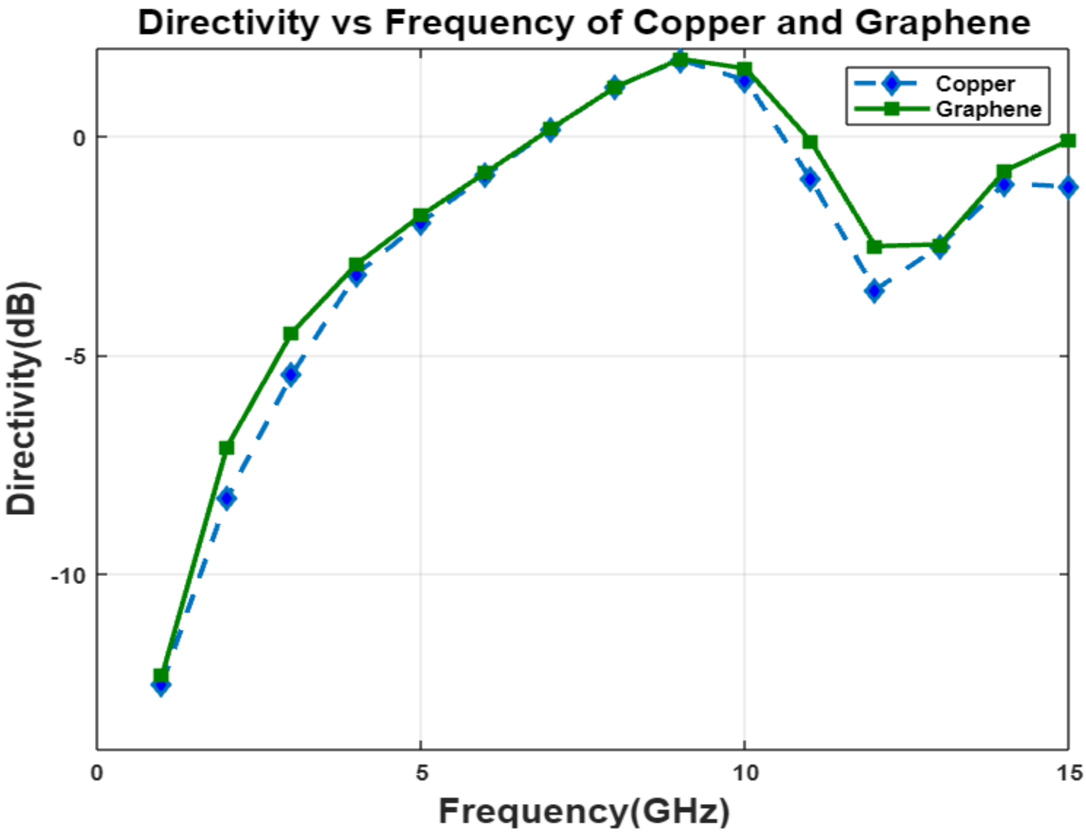


Fig 5.3: Comparison plot of Directivity (in dB) for Copper and Graphene antenna.

In the above comparison plot for Directivity (in dB) against frequency, it can be observed that maximum Directivity of 1.75 dB and 1.77 dB are obtained at 9 GHz for copper and graphene respectively.

CHAPTER-6

FUTURE SCOPE & CONCLUSION

Future Scope

Microstrip antennas have a tremendous application potential. Even as of now, these antennas are designed and used in Industrial, Scientific Research, Medical, Wireless Local Area Network, etc.

Simulators are invaluable tools for microstrip patch antenna. Suitability of these tools depends upon the sophistication of the models used in them. Microstrip antennas are actively considered for that light weight is important. The present model can be extended for increased bandwidth microstrip patch antenna. For this development some additional models will have to be developed.

Conclusion

In this Project Design of Microstrip Patch antenna for the UWB and wearable electronics applications which are operating at UW band has been proposed and its result has been compared with various dimensions. The simulation results shows the gain, VSWR and radiation pattern of the Microstrip Patch Antenna. This indicates how important it is to design a ground plane with appropriate dimensions, as well as a patch to decrease VSWR, reflection coefficient and to increase gain and directivity.

Generations of the UWB antennas for wearable application development have been presented. Recent advancements have been characterized by the failure of successive generations of antenna designers to benefit from the lessons of earlier pioneers. It is necessary to be familiar with the history of the antenna art for any serious antenna designer who aims to implement novel designs rather than recreate the antennas of previous generations.

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PROJECT OUTCOMES MAPPED WITH PROGRAMME SPECIFIC OUTCOMES (PSOs) AND PROGRAMME OUTCOMES (POs)

Classification of the Project	Applications	Product	Research	Review
			✓	

PROJECT OUTCOMES

1. Design microstrip patch antennas using defected ground plane.
2. By using different ground plane structures based patch antennas gain is improved. It can be implementing in UWB Band applications.

PROGRAMME SPECIFIC OUTCOMES (PSOs)

The ECE Graduates will be able to

PSO1: Understand important and fundamental antenna engineering parameters and terminology. PSO2: Understand, explain and illustrate structures, working and other operation in microstrip antennas.

PS03: Will be able to implement these learning to design own microstrip patch antennas.

PROGRAMME OUTCOMES (POs)

1. Engineering knowledge: Apply then knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. Problem analysis: Identify, formulae, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. Conduct investigation of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice
7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentations, make effective presentations, and give and receive clear instructions.
11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. Life-long learning: Recognize the need for, and have the preparation and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Mapping Table

Project Outcomes	**Programme Outcomes (POs)**											**Programme Specific Outcomes (PSOs)**	
1	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO 11	PO 12	PSO1	PSO2
	3	3	2	2	1	2	1	3	3	2	2	3	3	2

1-Slightly (Low) mapped
2-Moderately (Medium)mapped
3-Substantially (High)mapped