A Comprehensive Review in Radar System Technology

Major Project

Submitted for the partial fulfillment of the degree of

Bachelor of Technology

In

Electronics Engineering

Submitted By

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0901EC201035

UNDER THE SUPERVISION AND GUIDANCE OF

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माधव प्रौद्योगिकी एवं विज्ञान संस्थान, ग्वालियर (म.प्र.), भारत

MADHAV INSTITUTE OF TECHNOLOGY & SCIENCE, GWALIOR (M.P.), INDIA

Deemed to be University

(Declared under Distinct Category by Ministry of Education, Government of India)

NAAC ACCREDITED WITH A++ GRADE

JUNE 2024

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I hereby declare that the work entitled **"A Comprehensive Review of Advancement in Radar System Technology"** is my work, conducted under the supervision of **Dr. Deepak Batham, Professor** during the session Jan-May2024. The report submitted by me is a record of bonafide work carried out by me.

I further declare that the work reported in this report has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

Ayush Shrivastava

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Date: 27/05/24
Place: Gwalior

This is to certify that the above statement made by the candidates is correct to the best of my knowledge and belief.

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PLAGIARISM CHECK CERTIFICATE

This is to certify that I/we, a student of B.Tech. In **Department of Electronics have** checked my complete report entitled **"A Comprehensive Review of Advancement in Radar System Technology"** for similarity/plagiarism using the "Turnitin"software available in the institute.

This is to certify that the similarity in my report is found to be 7% which is within the specified limit (30%).

The full plagiarism report along with the summary is enclosed.

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ABSTRACT

Radar technology, short for Radio Detection and Ranging, is a critical system that uses radio waves to detect and track objects, measuring their distance and speed. This report provides an incisive review of radar technology, including its principles, kinds, uses, and future possibilities.

Beginning with the fundamental operation of radar, the article explains how electromagnetic energy radiated by an antenna interacts with reflecting objects to detect target echoes. Various types of radar systems are then investigated and classified based on resolution, modulation, and other factors, demonstrating their diverse functionality.

The research goes into recent breakthroughs, such as the use of reconfigurable holographic surfaces (RHSs) for multi-target detection, which provides cost-effectiveness and adaptable capabilities.

Furthermore, it investigates radar applications beyond traditional domains, such as non-destructive evaluation, medical diagnostics, and automotive safety, demonstrating radar's versatility and effect across sectors.

The report also analyses the evolution of millimetre-wave (mmWave) radar sensors, their applications in the automotive, industrial, medical, and security industries, and their current spike in popularity due to advances in chip technology.

Antennas, critical components of radar systems, are reviewed, including phased array antennas, parabolic antennas, and horn antennas, each designed for a distinct purpose and application.

Finally, the research emphasizes radar technology's revolutionary potential, from improving safety and connection to fostering innovation across multiple sectors. It underscores the limitless possibilities for further exploration and integration, ushering in a future in which radar continues to reshape technology landscapes.

ACKNOWLEDGEMENT

We express our sincere gratitude and earnest indebtedness to Madhav Institute of Technology & Science, Gwalior (M.P) for providing us the golden opportunity to complete our internship. We acknowledge with great pleasure and grateful indebtedness towards our project mentor **Dr. Deepak Batham** Assistant Professor for providing us with very useful and beneficial guidance throughout the Internship. I am also thankful to **Prof. Rachit Jain** for his cooperation with me in facilitating the Technical Aspects and guidance during my work.

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We would also like to acknowledge our Director **Dr. R. K. Pandit** for helping us with the resources needed to accomplish this task. The environment at M.I.T.S. has been a valuable experience for us. With many difficulties, this Internship has blessed us with great knowledge in our field of interest. We also thank all those who have helped us in every path in the completion of this Internship and made this Internship a success.

Name & Signature of Students

Ayush Shrivastava
0901EC201035

Date: - 27/05/2024

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MULTIDISCIPLINARY LEARNING & RESEARCH CLUB

CERTIFICATE OF PARTICIPATION

ISCMCTR-2024

This is to certify that **Ayush Shrivastava** of **Madhav Institute of Technology & Science, Gwalior, India** presented the paper in the 2nd International Student Conference on Multidisciplinary and Current Technical Research (ISCMCTR - 2024), held at Madhav Institute of Technology & Science, Gwalior (M.P.), India, during 20 - 21 April, 2024.

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Dr. Manjaree Pandit

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ACRONYMS

RADAR Radio Detection and Ranging

1. **WAOA:** Waveform And Amplitude Optimization Approach
2. **RHS:** Reconfigurable Holographic Surfaces
3. **FMCW:** Frequency-Modulated Continuous Wave
4. **FFT:** Fast Fourier Transform
5. **RR:** Respiratory Rate
6. **HR:** Heart Rate
7. **TI:** Texas Instruments
8. **SAR:** Synthetic Aperture Radar
9. **IF:** Intermediate Frequency

NOMENCLATURE

Radar, or radio detection and ranging, is a technology that tracks and detects objects using radio waves to calculate their distance and speed.

Echoes are radio waves that bounce back from things that radar has identified.

Target Signal: An echo that is distinctly emanating from the desired location.

Electromagnetic Sensor: Radar is a tool used to find and identify things that reflect light.

Radar antenna: In radar systems, a device that emits and receives electromagnetic energy.

Dissecting Examining the fundamentals and workings of radar systems is known as radar technology.

Radar's versatility: There are many uses for radar technology, from medical imaging to weather forecasting.

Radar technology benefits include: advantages including weather independence, low care requirements, and adaptability to both indoor and outdoor settings.

Multi-target detection refers to the methods and tools that allow radar systems to identify several targets at once.

Non-Destructive Evaluation: Radar-based techniques that evaluate structural integrity and find flaws without inflicting harm.

Contactless Stethoscope: Contactless systems, which offer safety and precision benefits, are radar-based cardiac monitoring devices that do not require physical contact.

Advanced radar technology for non-invasive patient monitoring that provides precise vital sign data is known as short-range **millimeter-wave radar**.

Growth of mmWave Radar: New applications are made possible by advances in radar technology, especially in millimeter-wave radar sensors.

Automobile Radar Applications: Radar sensors are used in a variety of automobile technologies, such as autonomous driving and driver support systems.

Industrial Radar Applications: Surface quality evaluation and fluid level detection are two examples of industrial radar applications.

Radar systems are employed in medical diagnostics and patient monitoring, among other uses.

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INTRODUCTION

Radar, an acronym for Radio Detection and Ranging, is a tribute to human ingenuity and technical prowess. Few inventions in modern technology have been as basic and impactful as radar technology. It has transformed numerous sectors and paved the way for unparalleled advances in safety, communication, and exploration. Radar systems are essential instruments for detecting and tracking objects, as well as determining their spatial coordinates, velocity, and composition. They are based on electromagnetic wave propagation and reflection principles. From its humble beginnings in military applications to its widespread presence in everyday life, radar technology represents the never-ending search of advancement and innovation.

Radar technology originated in the early twentieth century against the backdrop of fast technological advancement and international strife. Early radar systems were developed in response to the urgent need for better defence and surveillance mechanisms, and they set the stage for later advancements in the discipline. The practical use of radar for detecting distant objects was made possible by the groundbreaking work of scientists like Christian Hülsmeyer and Sir Robert Watson-Watt, who ushered in a new era of extraordinary capabilities in remote sensing and navigation.

Radar functions primarily by sending out radio waves from a transmitter and then listening for echoes that are reflected off nearby objects. Radar uses a method called echo-ranging to determine whether an object is present, where it is, and how it is moving within its operational range. Radar systems are able to precisely track and monitor objects in a variety of settings by evaluating the time delay and Doppler shift of the returning echoes. This analysis provides important insights into the spatial distribution and velocity of detected targets.

Radar technology's adaptability and versatility have pushed its integration into a wide range of industries and applications outside of its conventional use in military surveillance. Radar systems are widely used in many fields today, including industrial automation, vehicle safety, medical imaging, weather forecasting, air traffic control, and maritime navigation. Radar's intrinsic ability to see through bad weather, darkness, and other obstacles makes it invaluable in situations where other sensing modalities could be ineffective.

The goal of this essay is to present a thorough analysis of radar technology, covering its background, guiding ideas, development over time, and current uses. By carefully analysing the classification, operational mechanisms, and developing functionalities of radar, this study seeks to clarify the complex role that radar plays in forming contemporary technological environments.

This study will explore the complexities of radar technology in more detail in the following sections, starting with an introduction to its basic ideas and workings. Using this as a starting point, the study will examine the various types of radar systems and highlight their distinct characteristics, functions, and uses. In addition, the article will examine current developments in radar technology, such as the deployment of millimetre-wave (mmWave) radar sensors in a variety of industries and the incorporation of reconfigurable holographic surfaces (RHSs) enabling multi-target detection.

As essential parts of radar systems, antennas will be given specific attention. Phased array, parabolic, and horn antennas will all be thoroughly examined, with design concepts and applications explained.

Over the years, radar technology has undergone significant study and development, leading to the production of a large body of literature covering a wide range of topics from basic principles to cutting-edge applications. The purpose of this review of the literature is to give a broad overview of the major contributions and developments in radar technology, covering its historical development, current trends, and potential future possibilities.

HISTORICAL PERSPECTIVES

Over the years, radar technology has undergone significant study and development, leading to the production of a large body of literature covering a wide range of topics from basic principles to cutting-edge applications. The purpose of this review of the literature is to give a broad overview of the major contributions and developments in radar technology, covering its historical development, current trends, and potential future possibilities.

PRINCIPLE AND OPERATION

Radar system operating principles have been thoroughly examined and clarified in the literature. Radar technology is based on fundamental ideas such target detection algorithms, signal processing, antenna design, and waveform modulation. Classic textbooks that offer thorough insights into radar theory and application, such as Merrill Skolnik's "Introduction to Radar Systems" and Peebles Jr.'s "Radar Principles," are important sources of information in this field.

TYPOLOGIES AND CLASSIFICATION

There has been a lot of research and discussion on the classification of radar systems based on several factors like resolution, modulation, and operating frequency. Skolnik made a significant contribution when he described the many kinds of radar systems according to their unique functions and uses. Furthermore, in order to increase the typologies and functionalities of radar systems, current research has concentrated on developing radar technologies such millimetre-wave radar, phased array radar, and synthetic aperture radar (SAR).

LITERATURE SURVEY

Weather forecasting and traffic monitoring:

Radar is essential for managing traffic and predicting the weather, which enhances safety and navigation.

Non-Destructive Evaluation:

Holographic radar provides accurate and efficient non-destructive testing of structural materials by identifying flaws.

Medical Applications:

Non-contact cardiac monitoring is made possible by radar-based approaches, which also provide vital sign monitoring and insights into heart health.

Automotive Radar:

Using driver assistance systems, adaptive cruise control, and autonomous driving technologies, millimetre-wave radar sensors improve vehicle safety.

Applications in Industry and Security:

Radar technology enhances efficiency and safety protocols in indoor positioning systems, industrial processes, and security surveillance.

Figure 1: Weather forecasting Radar

Figure 2: Electronic Stethoscope

Weather forecasting and monitoring Radar

Meteorologists employ weather forecasting and radar monitoring technologies as essential instruments to track weather trends, identify hazardous weather occurrences, and notify the public in a timely manner. The basic idea behind these radar systems is to send radio waves into the atmosphere and then monitor the echoes that are returned by clouds, precipitation, and other atmospheric elements. Weather radar systems use a transmitter to release electromagnetic radiation pulses, usually in the microwave range.

As they move through the atmosphere, these pulses come into contact with snowflakes, hailstones, and other precipitation-related particles.

Within the radar's coverage region, some of the radiation is reflected back towards the radar receiver as echoes, giving information about the position, intensity, and velocity of precipitation.

Meteorologists can deduce significant meteorological parameters like rainfall rate, storm strength, wind speed, and direction by examining the features of these echoes, such as their intensity, shape, and Doppler shift.

Non-Destructive Radar Technology

A variety of methods are included in non-destructive radar technology, which is used to examine and assess materials and structures without inflicting harm. These methods work by penetrating and interacting with the target material using radar waves, giving important details about its composition, integrity, and internal structure.

Radar procedures that are non-destructive entail the introduction of electromagnetic waves into the substance being examined.

The internal characteristics of the material, such as discontinuities, voids, fractures, and interfaces between various materials, are impacted by these waves.

A portion of the wave energy that is broadcast is reflected back to the radar receiver, where it is examined to determine the characteristics of the material and identify any flaws.

Non-destructive radar methods can measure material thickness, evaluate structural integrity, and detect and characterize flaws by examining the amplitude, phase, and time delay of the reflected signals.

Medical Applications

Radar technology, which has historically been connected to the aerospace and military industries, has found creative uses in the medical field. Radar-based non-invasive and contactless solutions are transforming patient monitoring, medical diagnostics, and healthcare delivery. These uses of radar waves collect physiological data and offer insightful information on a range of elements related to human health and wellbeing.

Medical radar systems direct electromagnetic waves at the human body, usually in the microwave or millimetre wave frequency range.

The body's tissues are penetrated by these waves, which then interact with internal organs, blood vessels, and physiological processes.

A portion of the wave energy that is broadcast is reflected back to the radar receiver, where it is processed to determine physiological aspects of the body, including mobility, heart rate, and respiration rate.

Applications of Medical Radar Types:

Cardiac Monitoring: Without the need for invasive electrodes or sensors, radar-based systems are used to monitor cardiac activity, including heart rate, heart sounds, and arrhythmias. These devices pick up on the smallest movements in the chest brought on by the heartbeat and convert them into physiological information for medical diagnosis and therapy.

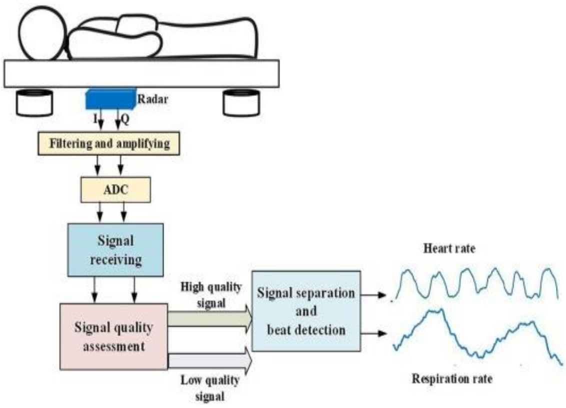


Figure 3: Cardiac Monitoring Radar

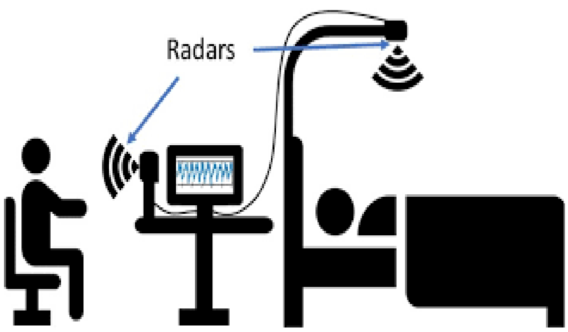


Figure 4: Heart and Respiration Rate Detection Radar

Respiratory Monitoring: By identifying movements in the chest wall during breathing, radar technology allows for the non-contact assessment of respiratory parameters, including tidal volume and respiration rate. Since traditional approaches may be intrusive or impracticable in critical care settings, this contactless approach is especially helpful for patient monitoring.

Blood Pressure Monitoring: By examining the pulsations of the arteries in the body's tissues, radar systems are able to monitor blood pressure in a non-invasive manner. With the continuous and real-time monitoring of blood pressure changes provided by this contactless approach, important insights into cardiovascular health and disease management can be gained.

Continuous Vital Sign Monitoring: In both clinical and home settings, radar-based sensors are used to continuously monitor vital signs such as heart rate, breathing rate, body movement, and sleep patterns. Patients can benefit from these systems' ease, comfort, and mobility, which helps with early abnormality detection and prompt action.

Utilizations in Medical Practice:

Critical Care Monitoring: To follow patients' vital signs, identify physiological changes, and notify medical professionals of possible emergencies, intensive care units (ICUs) and emergency rooms are equipped with radar-based monitoring systems.
Radar technology makes it possible to remotely monitor patients' health status via telemedicine applications. This allows medical professionals to analyze vital signs, keep an eye on chronic illnesses, and conduct virtual consultations without having to see patients in person.

Home Healthcare: Radar-based sensors are used in home healthcare settings to remotely monitor patients' health and well-being. This helps to foster independence and autonomy while also giving patients and their caregivers piece of mind.

In summary, radar technology allows for the non-invasive, contactless, and continuous measurement of physiological indicators, which has the potential to revolutionize medical diagnostics, patient monitoring, and healthcare delivery. Radar-based healthcare solutions have the potential to alter the way we monitor and manage health and illness, improve clinical results, and improve patient care through continued research and technical developments.

RADAR ANTENNAS

Radar antennas are essential parts of radar systems because they act as a bridge between the electromagnetic waves needed for range and detection and the electronic circuitry. These antennas are essential for sending radar signals into the surrounding area, picking up signals that targets reflect back to us, and adjusting the radar beam to work as efficiently as possible. As antenna technology has developed over time, extremely effective and adaptable radar systems with a wide range of applications across several industries have been created.

Fundamentals of Radar Antennas:

Radar antennas work by transmitting electrical signals as electromagnetic waves and receiving those waves back.

Electromagnetic waves are produced by transmitting antennas and travel through space, interacting with surrounding objects. These waves hit a target, reflect off its surface, and then return to the radar antenna to be picked up and processed.

The polarization, directionality, and coverage area of a radar beam are all determined by the design and configuration of the radar antenna.

Radar antenna types:

Parabolic Antennas: Due to their high gain and small beamwidth, parabolic antennas—also referred to as dish antennas—are frequently employed in radar systems. They are made up of a feed horn or dipole antenna placed at the focal point and a curved reflector (parabola). Applications like weather radar and satellite communication that demand long-range detection and high-resolution imaging frequently use parabolic antennas.

Phased Array Antennas: Phased array antennas electronically steer the radar beam without physically moving the antenna by using a range of separate antenna elements, each with its own phase shifter. Phased array antennas quickly shape the beam direction, scan angle, and beamwidth by varying the phase of each element. Because of their adaptability, agility, and real-time electronic beam scanning capabilities, these antennas are preferred for use in military surveillance, radar imaging, and air traffic control.

Horn Antennas: Named for their horn-shaped form, horn antennas enable effective electromagnetic wave coupling between the antenna and the surrounding medium. Horn antennas are commonly used in radar systems for their wide bandwidth, low sidelobe levels, and high-power handling capabilities. They find applications in radar measurements, microwave testing, and antenna calibration.

Prospective Courses

Smart Antenna Systems: By combining machine learning and artificial intelligence (AI) with radar antennas, intelligent radar beam management, adaptive signal processing, and autonomous beamforming are made possible. Smart antenna systems reduce interference, enhance target identification and tracking precision, and maximize radar performance in dynamic settings.

Multi-Functional Antennas: The development of multi-functional radar antennas that can carry out several functions at once, including sensing, navigation, and communication, increases the usability and adaptability of radar systems in a variety of applications. Cost-effective options for integrated radar systems with improved performance and capabilities are provided by multi-functional antennas.

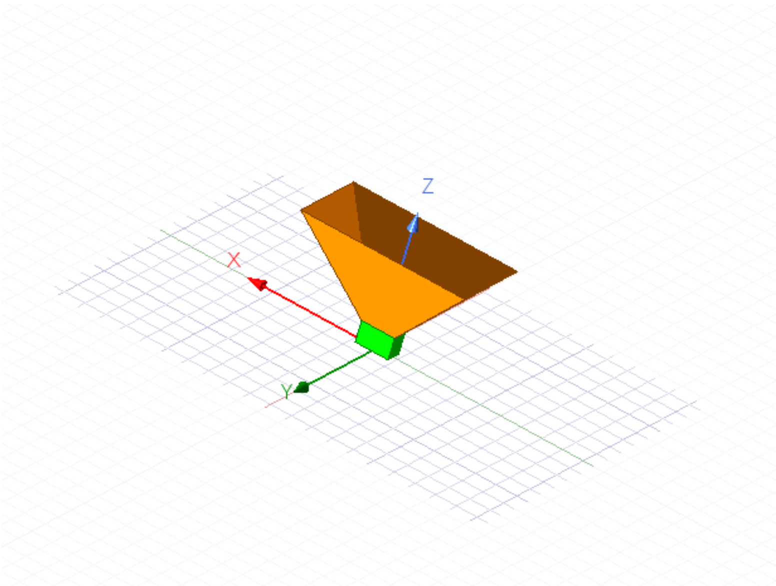
Figure 5: Parabolic Antenna

Figure 6: Horn Antenna

HORN ANTENNA DESIGN

An antenna that resembles a horn is called a horn antenna because it is made of a flaring metal waveguide. It is utilized for microwave and radio wave transmission and reception. Due to its broad bandwidth and high gain, the horn antenna is well-suited for a number of uses, including radio astronomy, microwave communication, and radar systems.

The guided electromagnetic waves inside the waveguide are transformed into free-space electromagnetic waves by the horn antenna. In order to minimize reflections and losses, the guided waves can gradually transition to free-space waves thanks to the horn's flared shape. This design element also aids in regulating the directivity and radiation pattern of the antenna. Horn antennas come in different shapes and sizes, including pyramidal, conical, and sectoral horns, each with specific characteristics suitable for different applications. They are commonly used in microwave engineering due to their efficiency, simplicity, and versatility.



Pyramidal horn antenna has extensively been used as a feed element for radio astronomy, satellite communications and in the antenna test bench as a reference antenna for last several decades due to its simplicity in construction, ease of excitation, large gain and relatively better radiation characteristics at microwave frequencies. Much research work has been devoted to develop improved feed systems utilizing corrugated horns in pyramidal and conical shapes to reduce spillover efficiency and increase radiation efficiency.

DIMENSIONS

Dimensions of the Waveguides are as follows:

Properties: horn antenna final - HFSSDesign3 - Modeler

Command

Name	Value	Unit	Evaluated V...	Description
Command	CreateBox			
Coordinate ...	Global			
Position	-0.795 ,-0.3975 ,0	in	-0.795in , -0.3...	
XSize	1.59	in	1.59in	
YSize	0.795	in	0.795in	
ZSize	1	in	1in	

Table No. 1

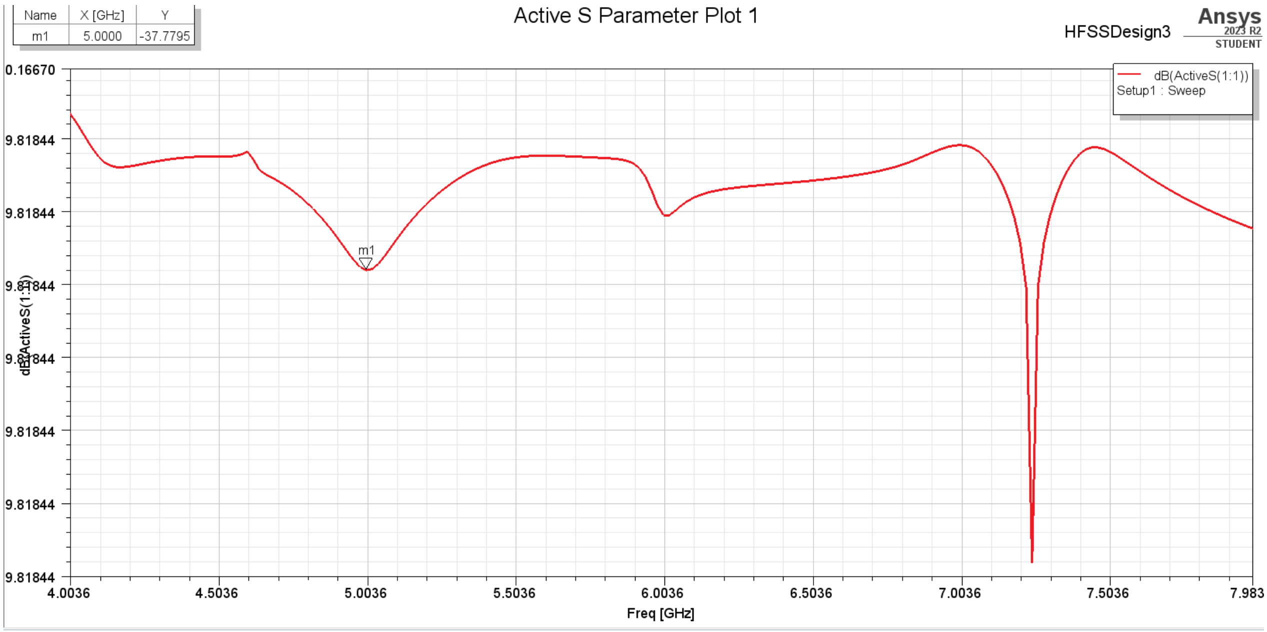
Dimensions of the face are as follows

NAME	VALUE	UNIT
POSITION	-3.975, -1.9875, 5	in
AXIS	Z	
X AXIS	7.95	in
Y AXIX	3.975	in

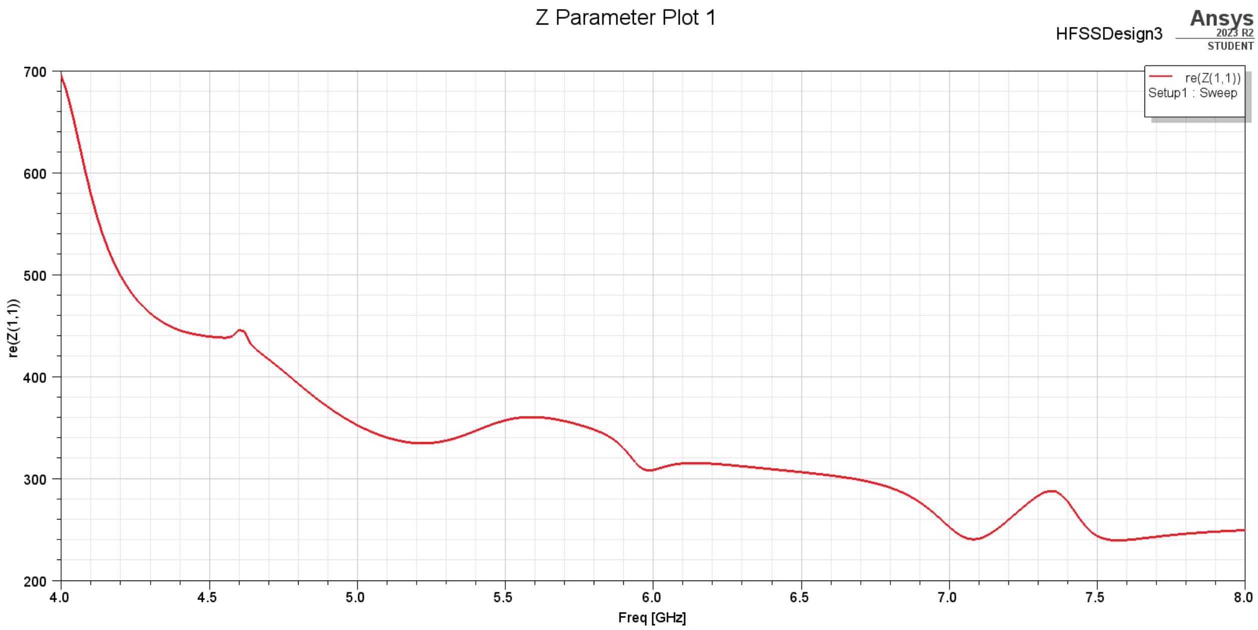
Table No. 2

GRAPH AND RESULTS

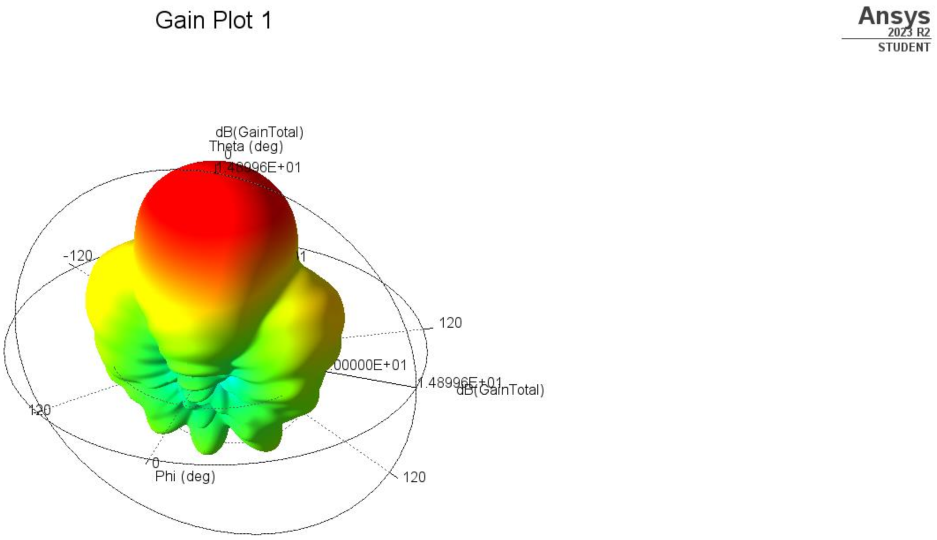
Active S Parameter Plot



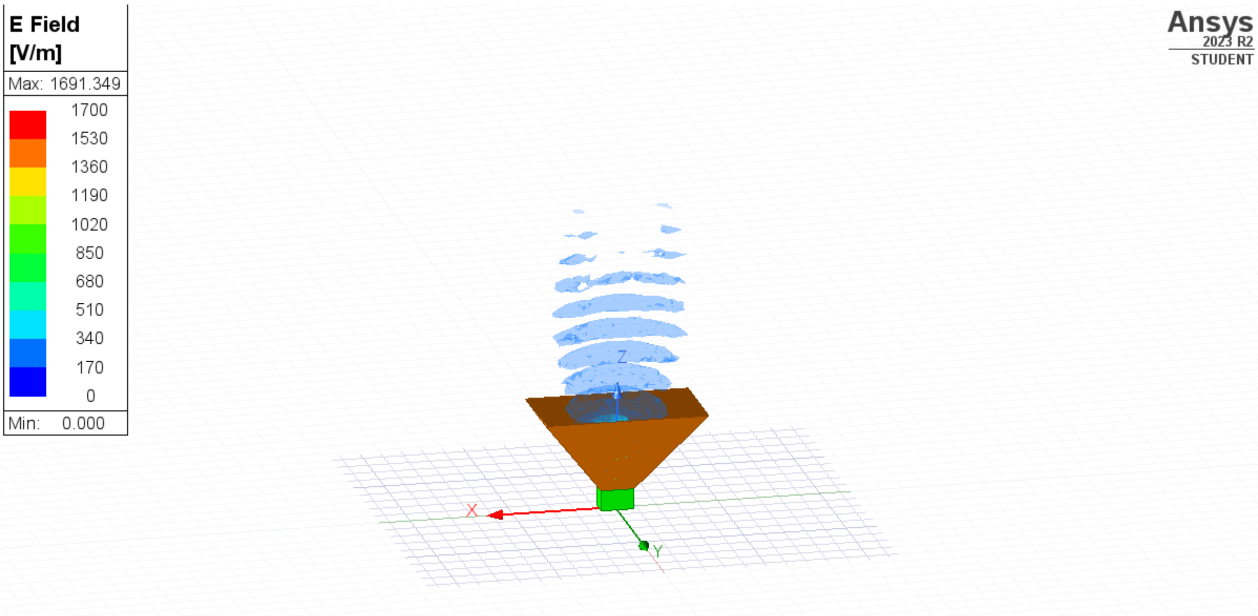
Z parameter Plot



GAIN PLOT



RADIATION PATTERN



ANTENNA PARAMETERS

QUANTITY	FREQ	VALUE
Max U	5GHz	2.4585W/sr
Peak Directivity		29.752
Peak Gain		30.9
Peak Realized gain		30.895
Peak System Gain		30.895
Radiated Power		1.0384W
Accepted Power		999.83mW
Incident Power		1W
System Power		1W
Radiation Efficiency		1.0386
Total Efficiency		1.0384
System Efficiency		1.0384
Front to Back		673.48
Decay Factor		0

Table No. 3

MONOPOLE ANTENNA DESIGN

A monopole antenna is a kind of radio antenna that is installed above a conductive surface, like the Earth or a ground plane, and consists of a single conducting element, usually a vertical rod or wire. Because of its ease of usage and broad frequency range performance, this is one of the most often used antenna designs.

The following are some essential traits and attributes of monopole antennas:

Single Element: The construction and installation of a monopole antenna are made simpler by the presence of just one active element.

Ground Plane: A conductive surface referred to as a ground plane is necessary for the operation of monopole antennas. The second "half" of the antenna is the ground plane, which supplies the counterpoise required for effective radiation.

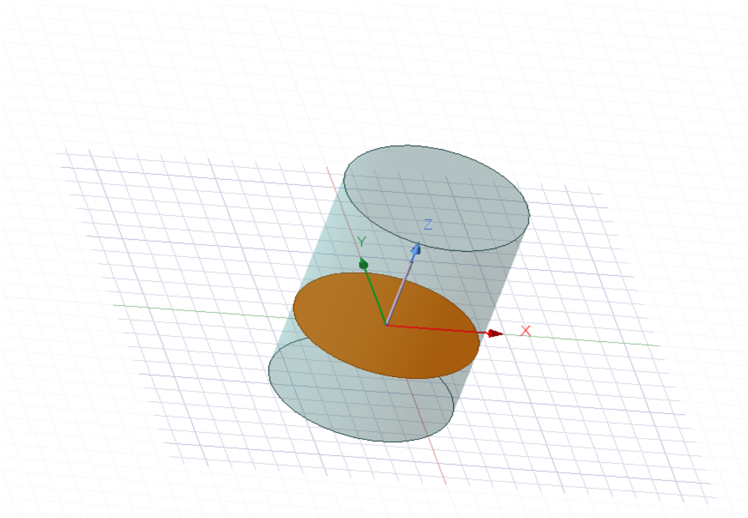
Omnidirectional Radiation: When a monopole antenna is operating in its simplest configuration, it usually emits electromagnetic waves uniformly in all horizontal directions that are perpendicular to the antenna axis. Because of this, it can be used in situations where omnidirectional coverage is required, like in mobile communication networks.

Variation in Shapes and Sizes: PCB traces, wires, and straight rods are just a few examples of the different shapes and sizes that monopole antennas can take. The frequency of operation, the amount of space available, and the intended radiation pattern all influence the design decision.

Flexibility in Frequency: By varying the radiating element's length, monopole antennas can be made to function across a broad frequency range, from microwave frequencies to low-frequency radio waves.

Impedance Matching: To maximize efficiency and reduce signal reflections, the antenna's feedline and impedance must be properly matched. To do this, methods like matching networks and baluns are frequently used.

Due to their ease of use, effectiveness, and omnidirectional radiation pattern, monopole antennas are widely employed in radar systems. This is because they are beneficial in a wide range of radar applications. In radar systems, monopole antennas are used as follows:



Pulse Radar Systems: Short bursts of high-frequency electromagnetic waves are emitted and targets' echoes are detected in pulse radar systems, which typically use monopole antennas. The monopole antenna's omnidirectional radiation pattern makes it appropriate for radar applications such as search and surveillance since it enables efficient transmission and reception of radar pulses in all horizontal directions.

Secondary Surveillance Radar (SSR): In order to query aircraft transponders for air traffic control purposes, secondary surveillance radar systems frequently employ monopole antennas. These omnidirectional antennas, which are usually installed on the ground or on tall buildings, offer dependable contact with aircraft transponders in all directions.

Weather Radar: Systems that employ weather radar to observe the weather also use monopole antennas. In order to offer a clear line of sight for detecting precipitation and other atmospheric events, these antennas are frequently installed atop large towers or buildings. Because of the monopole antenna's omnidirectional transmission pattern, which effectively covers the surrounding area, meteorologists are able to monitor weather conditions over a large geographic area.

Collision Avoidance Radar: Systems fitted in cars, airplanes, and marine vessels use monopole antennas to prevent collisions. These radar systems emit and receive radar signals using monopole antennas in order to identify adjacent obstructions and possible collision hazards. The monopole antenna's omnidirectional emission pattern makes sure the radar system can identify obstructions surrounding the car or vessel from every angle.

Ground Penetrating Radar (GPR): For subsurface sensing and imaging applications, ground-penetrating radar systems also use monopole antennas. Monopole antennas are commonly used in GPR systems to send and receive electromagnetic waves that enter the ground and bounce off subsurface structures like geological strata, buried items, and utilities.

DIMENSIONS

Dimensions of Infinite Ground are as follows

NAME	VALUE	UNIT
Command	Create Circle	
Coordinate System	GLOBAL	
Centre Position	0,0,0	mm
axis	Z	
Radius	Radi.co	mm
Number of Segments	0	

Table No. 4

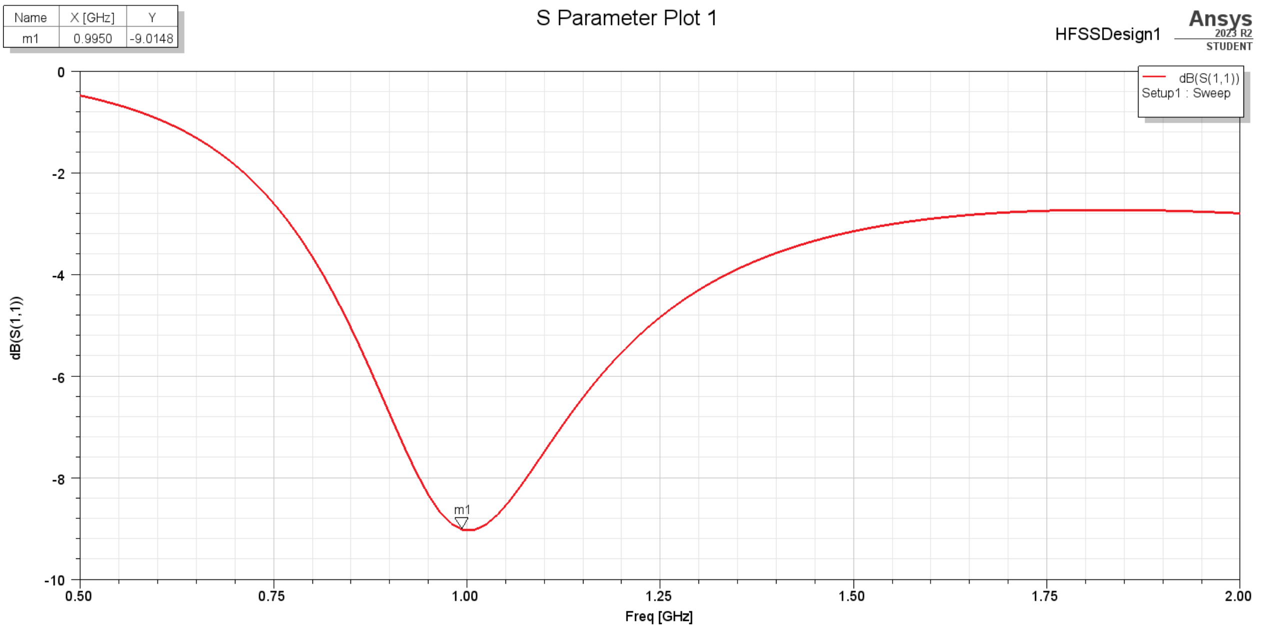
Dimensions of Cylinder

NAME	VALUE	UNIT
Command	Create Cylinder	
Coordinate System	GLOBAL	
Centre Position	0,0, -lambda/4	
axis	Z	
Radius	Radi.co	mm
Number Of Segments	0	
Height	a.co	

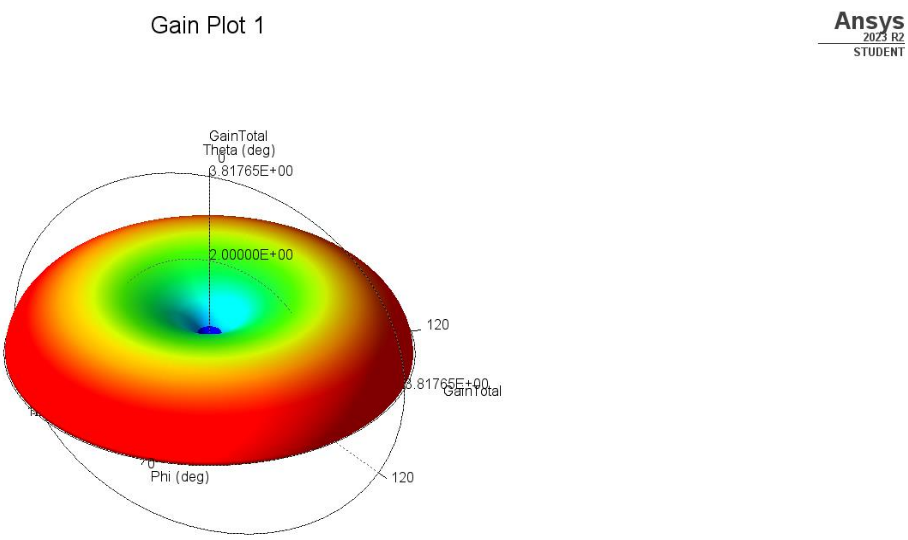
Table No. 5

GRAPH AND RESULTS

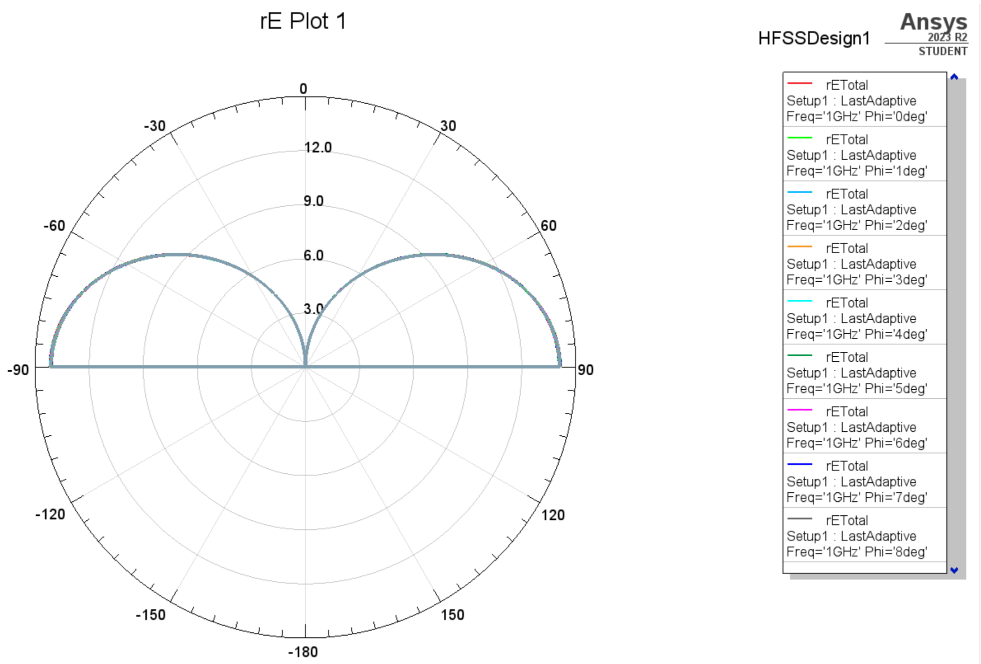
S Parameter plot



Gain Plot



Radiation Efficiency Plot



ANTENNA PARAMETERS

QUANTITY	FREQ	VALUE
Max U	1GHz	265.8W/sr
Peak Directivity		3.8385
Peak Gain		3.8177
Peak Realized gain		3.3402
Peak System Gain		3.3402
Radiated Power		870.19mW
Accepted Power		874.95mW
Incident Power		1W
System Power		1W
Radiation Efficiency		0.99457
Total Efficiency		0.87019
System Efficiency		0.87019
Front to Back		1.0055
Decay Factor		0

Table No. 6

CONCLUSION

Radar technology is a constant force for innovation in the rapidly changing field of technology, altering industries and advancing humankind toward a future characterized by increased efficiency, safety, and connectedness. Radar technology has evolved remarkably from its modest beginnings in military defence to its ubiquitous presence in daily life, completely changing how we see and engage with the world around us.

We have been taken on an engrossing voyage through the basic ideas, intricate workings, and revolutionary uses of radar technology during this thorough overview. We have looked at how radar, which uses electromagnetic waves to track and detect things, has become a vital tool in a variety of fields, including autonomous navigation, weather forecasting, and air traffic management.

Radar technology is remarkably versatile and adaptable, surpassing conventional bounds to find inventive applications in a wide range of areas. Radar sensors are essential to the development of advanced driver assistance systems, autonomous driving, and road safety in the automotive industry. Utilizing millimeter-wave frequencies, these sensors provide unmatched accuracy in identifying and monitoring things in motion, transforming the automotive sector and laying the foundation for intelligent mobility in the future.

It is clear that radar technology has enormous potential for innovation and improvement when we consider how much of an impact it has had on civilization. The future of radar holds great promise for opening up new vistas for research and exploration, from the creation of specialized antennas for use in radar applications to the integration of radar systems with cutting-edge technologies like artificial intelligence and machine learning.

In conclusion, radar technology is a monument to our unwavering quest of knowledge and advancement and embodies the spirit of human inventiveness and technological progression. Radar technology will surely continue to be at the forefront of innovation as we push the frontiers of what is possible, influencing the modern world and enabling humanity to achieve unprecedented heights.

Internship/Project Daily Diary
Session: Jan–June 2024

udents: Ayush Shrivastava

t Number: 0901EC201035

d Year: Electronics, 2024

/Project Title: A Comprehensive Review of Advancement in Radar system
r

Name with Full Address: Madhav Institute of Technology and Science, Gwalior

tail: No **Stipend Amount: NA**

Mentor Detail

dustry Mentor: Dr. Deepak Batham

ress of Industry mentor: dbatham@mitsgwalior.in

st mention the daily progress detail with dates in the given format.

Date	Daily Progress Detail/Report
01/01/24	In the initial month of my Project into the fulfillment of academic degree, I started a journey of intellectual discovery, traversing a multitude of topics in search of the one that would captivate both my imagination and the exigencies of our contemporary world. With each keystroke and every page turned, I delved deeper into the vast expanse of knowledge that the internet offered. Going through several topics I found Radar to be most demanding in today's world. Also, this is trending topics as it is much used in applications like defense and maritime. Radar according to me will proof to be one of the best topics as now in current scenario it is being not only used in defense system but also in many day-to-day life applications like in medical fields, in security applications and also in industrial applications.

01/02/24	Now I finalized to write a paper on Radar technology after this I went to my mentor in order to discuss my topic with him and also to take a confirmation that whether I can work on this topic or not. Hopefully my mentor supported a lot in my project also he helped to assign an author for my research work in order to solve any query in my domain. Also, this month I started reading different published paper to get information how radar technology is currently evolving with today's world needs. After reading several papers I got to know that to work in this project I also need to learn a software named HFSS in order to design radar antenna.
01/03/24	From the very first day of this month, I went to several videos on YouTube to learn software HFSS. And on the other hand, I started writing Review paper on the topic A comprehensive Review on Advancement in Radar system technology. I learned the software enough to design a radar antenna on it also this was my first time to write a paper I discussed basic rules to write a paper with my mentor and author. By March 20 my rough paper was approx. ready I presented it to my mentor and got to know that still I have to work on it I need to give some more citations on it also I need to figure citations after doing this I was instructed to change my paper format to the respective journal format, till the end of this month my paper was ready and also, I submitted it for plagiarism verification first I got approx. 30% content from internet and some AI content.
01/04/24	After rectifying plagiarism content, I was able to bring plagiarism content below 20%. I submitted my paper to the respective journal and on the other hand I kept working on designing radar antenna on HFSS software. By mid of this month, I received a mail from journal that my paper is now officially accepted for publication. I choose horn antenna to design on software later I also designed monopole antenna for some comparison by referring some research paper and with help of YouTube videos I made antenna and also its radiation pattern. On 21st of this month I presented my paper to Session and later I presented

	it for midterm assessment. To the end of this month my both antennas were also ready only some minor modifications were required to do in it.
01/05/24	I started this month by rectifying some parameters in my antennas and now further I will work more on it in order to get various antenna parameters also I updated this Daily diary accordingly.

28/5/24

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tudent

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