TRIPLE-BAND MIMO ANTENNA FOR 5G MOBILE APPLICATION

A MINOR PROJECT - II REPORT

Submitted by

NAVEEENA.K	**927621BEC136**
PADMAVATHI.S	**927621BEC141**
PAVIPRAVEENA.G	**927621BEC142**
PAVITHRA.G	**927621BEC143**

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BONAFIDE CERTIFICATE

Certified that this project **18ECP104L – Minor Project II** report **"TRIPLE-BAND MIMO ANTENNA FOR 5G MOBILE APPLICATION"** is the bonafide work of **"NAVEENA.K (927621BEC136), PADMAVATHI.S (927621BEC141), PAVIPRAVEENA.G (927621BEC142), PAVITHRA.G (927621BEC143) "** who carried out project work under my supervision in the academic year **2022-2023 - EVEN.**

SIGNATURE	**SIGNATURE**
Dr.S.PALANIVEL RAJAN,M.E., M.B.A., Ph.D., D.Litt (USA).,	**Dr.M.DHAMODARAN, M.E., Ph.D.,**
HEAD OF THE DEPARTMENT,	**SUPERVISOR,**
Professor,	Professor,
Department of Electronics and	Department of Electronics and
Communication Engineering,	Communication Engineering,
M.Kumarasamy College of Engineering,	M.Kumarasamy College of Engineering,
Thalavapalayam, Karur-639113.	Thalavapalayam, Karur-639113.

This Minor project-II report has been submitted for the **18ECP104L–Minor Project-II** Review held at M. Kumarasamy College of Engineering, Karur on ________________.

PROJECT COORDINATOR

INSTITUTION VISION AND MISSION

Vision

To emerge as a leader among the top institutions in the field of technical education.

Mission

M1: Produce smart technocrats with empirical knowledge who can surmount the global challenges.

M2: Create a diverse, fully -engaged, learner -centric campus environment to provide quality education to the students.

M3: Maintain mutually beneficial partnerships with our alumni, industry and professional associations

DEPARTMENT VISION, MISSION, PEO, PO AND PSO

Vision

To empower the Electronics and Communication Engineering students with emerging technologies, professionalism, innovative research and social responsibility.

Mission

M1: Attain the academic excellence through innovative teaching learning process, research areas & laboratories and Consultancy projects.

M2: Inculcate the students in problem solving and lifelong learning ability.

M3: Provide entrepreneurial skills and leadership qualities.

M4: Render the technical knowledge and skills of faculty members.

Program Educational Objectives

PEO1: Core Competence: Graduates will have a successful career in academia or industry associated with Electronics and Communication Engineering

PEO2: Professionalism: Graduates will provide feasible solutions for the challenging problems through comprehensive research and innovation in the allied areas of Electronics and Communication Engineering.

PEO3: Lifelong Learning: Graduates will contribute to the social needs through lifelong learning, practicing professional ethics and leadership quality

Program Outcomes

PO 1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 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.

PO 4: Conduct investigations 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.

PO 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.

PO 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.

PO 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.

PO 8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 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 documentation, make effective presentations, and give and receive clear instructions.

PO 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.

PO 12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO1: Applying knowledge in various areas, like Electronics, Communications, Signal processing, VLSI, Embedded systems etc., in the design and implementation of Engineering application.

PSO2: Able to solve complex problems in Electronics and Communication Engineering with analytical and managerial skills either independently or in team using latest hardware and software tools to fulfil the industrial expectations.

Abstract	Matching with POs, PSOs
MIMO, HFSS, Antenna radiation pattern	PO1, PO2, PO3,PO4,PO5,PO6,PO7,PO8,PO9, PSO1,PSO2

ACKNOWLEDGEMENT

Our sincere thanks to **Thiru.M.Kumarasamy, Chairman** and **Dr.K.Ramakrishnan, Secretary** of **M.Kumarasamy College of Engineering** for providing extraordinary infrastructure, which helped us to complete this project in time.

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We would like to thank **Dr.S.Palanivel Rajan, M.E., M.B.A., Ph.D., D.Litt (USA)., Professor and Head**, **Department of Electronics and Communication Engineering** for his unwavering moral support and constant encouragement towards the completion of this project work.

We offer our wholehearted thanks to our **Project Supervisor, Dr.M.DHAMODARAN**,**M.E.,Ph.D., Professor**, Department of Electronics and Communication Engineering for his precious guidance, tremendous supervision, kind cooperation, valuable suggestions and support rendered in making our project to be successful.

We would like to thank our **Minor Project Co-ordinator**, **Dr.E.Dinesh, M.E., Ph.D., Associate Professor**, Department of Electronics and Communication Engineering for his kind cooperation and culminating in the successful completion of this project work. We are glad to thank all the Faculty Members of the Department of Electronics and Communication Engineering for extending a warm helping hand and valuable suggestions throughout the project. Words are boundless to thank our Parents and Friends for their motivation to complete this project successfully.

ABSTRACT

In order to address the demand of higher data rates and greater channel capacity, multiple input multiple output (MIMO) antenna technology will be applied to fifth-generation (5G) communication applications. In MIMO solutions, a large number of antennas will be placed in the limited space of the mobile terminal. Increasing spectrum efficiency can effectively improve communication capabilities. However, due to the limited spectrum resources, it is necessary to increase the operating frequency of the antenna. The traditional F-type structure was employed to demonstrate the MIMO miniaturization, yet it can only achieve dual frequency bands. To further improve the spectrum utilization, different types of triple-band antennas have been designed. To achieve multiple frequency bands, one common method is to use coupled feed arm and parasitic arm at the same time. Opening and etching slots are also widely used to obtain additional frequency bands. Three-segment zigzag patch and a common feeder connected to micro strip line are designed to achieve triple band. However, these designs entail relatively large volume, limiting the practical application of antennas in 5G terminals.

Keywords: MIMO, Antenna radiation pattern, HFSS.

TABLE OF CONTENTS

LIST OF FIGURE

LIST OF ABBREVIATIONS

ACRONYM		ABBREVIATION
MIMO	-	Multiple Input and Multiple Output
HFSS	-	High Frequency Structure Simulator
UAV	-	Unmanned Aerial Vehicle

CHAPTER 1

INTRODUCTION

Antenna:

Antennas are key components of any wireless system. An Antenna is a device that receives or transmits electromagnetic waves. An Antenna is one type of transducer that converts electric energy into electromagnetic energy in the form of electromagnetic waves. Recently, Unmanned Aerial Vehicles (UAV) have attracted lots of attentions for scientific, industrial and military applications. Generally, the antenna should be compact in sizes to satisfy the highly limited space in UAV and low profile to minimize the air resistance for aerodynamics requirements. A monopole like omnidirectional radiation pattern in the horizontal plane is preferable, since it can enhance the communication link between the UAV and the ground base stations.

MIMO Antenna:

In this paper, we proposed a novel F-type triple-band antenna MIMO system based on coupled feeding. The traditional inverted F antenna is fed from the middle, leaving one side short-circuited, and the other side open. Another limitation imposed by the inverted F antenna structure is that the F antenna is single due to the intermediate grounding, thus limiting the antenna structure accessible of either single or dual frequencies. To address the above mentioned issues, we implemented our F antenna in the form of tortuous feeder and coupling feed. Such implementation of the F antenna not only increases the operating frequency band, but also greatly reduce the occupied space, making it an appealing option for future 5G terminal applications. The prototype MIMO antenna can cover the 2370- 2450MHz frequency band of the international ISM (Industry Science Medicine) and two 5G operating frequency bands of 3510-3610MHz and 4830-5080m Hz proposed by the Ministry of Industry and Information Technology (MIIT) of China. The isolation at 2.4GHz (low frequency band) and 3.5GHz (middle frequency band) are better than -20dB, and the isolation at 4.9GHz (high frequency band) is better than -15dB, respectively. In the rest part of the paper, we present the design process followed by simulation and measurement verifications.

Performance Parameters

Radiation Pattern:

The radiation pattern is a three dimensional graphical representation of the radiation of the antenna as the function of direction. It is actually the plot of the power radiated from an antenna per units solid angle. Isotropic antennas do not exist in reality but are generally used as a reference to compare the performance of other antennas. The radiation pattern provides all the required information on antenna beam-width, side lobes and resolution of the antenna [1].

Gain:

It is the ratio of the maximum radiation intensity at the peak of the beam to the radiation intensity in the same direction produced by an isotropic radiator having same input power is known as the gain of the antenna.

Directivity:

The ratio of normalized power density at the peak of the main beam of the three-dimensional antenna pattern to the average density is known as directivity.

Band Width:

Bandwidth is the range of usable frequencies with in which the performance of the antenna with respective designed character, meets the specific standards. Bandwidth ranges across a central frequency and within this range all the other antenna parameters like radiation pattern, input impedance, beam-width, polarization, gain, directivity or with in the tolerable limits from there corresponding values at the central frequency.

Return Loss:

Return loss or reflection loss is the signal power's reflection from the insertion of a device in a transmission line. It is expressed as ratio in decibels (dB) relative to the transmitted signal power. The return loss should restricted to less then – 10 dB, show that the antenna can radiate effectively.

VSWR:

Voltage Standing Wave Ratio (VSWR) is the wave in the transmission line where distribution of electric parameters like current, voltage or field strength is formed by superposition of two waves of same frequency that propagate in the opposite direction. This voltage standing wave along the line producers a series of nodes and anti-nodes at fixed positions. VSWR is a measure of how efficiently radio frequency power is transmitted from a power source, through a transmission line into a load the smaller the VSWR is, the better the antenna is matched to the transmission line and the more power is deliver to the antenna. The minimum VSWR is 1.0, no power is reflected from the antenna. A VSWR value under 2 is considered suitable for most antenna applications. VSWR is very important parameter in radio frequency transmission systems where a high VSWR can reduce the power deliver to an antenna are system significantly [1].

Objective:

The main objective of this project is to understand the working and the design of the antenna. Specific Objective:

- To design the antenna according to designed specifications.
- To be acquainted with some of the characteristics of parasitic antennaelement modelling and operations.
- To know the antenna radiation pattern.
- Test antenna and verify it performs as expected.

The project system performance objectives are:

a) Develop large, low cost antenna structure.

b) Validate mechanical packaging efficiency.

CHAPTER 2

LITERATURE REVIEW

In order to start the project, the first is to study the research paper that has been performed previous by other researches. The paper that has related to this title are chosen and studied. With the help of this literature review, it gives more clear understanding to perform the With the creation of standards for and the development of fifth-generation (5G) mobile communication, more and more research has been conducted into related technologies with the hope of achieving a higher transmission rate, lower cost and higher gain. Multiple-input–multiple-output (MIMO) technology is a key to realizing a higher transmission rate. By using MIMO technology, multiple independent channels can be achieved on the original spectrum by the diversity method, and multipath fading can be reduced so as to improve the data transmission rate. A MIMO antenna is a significant facility to improve the channel capacity of a MIMO system. MIMO systems of 2 × 2 are successfully employed for 4G mobile networks, and a large number of antenna elements are expected to be applied for 5G communications[2].

However, these MIMO antenna designs either suffer from a narrow frequency bandwidth or occupy a huge space on a smartphone mainboard. Furthermore, some of the reported designs use uniplanar radiators, which are difficult to fabricate and integrate with the 5G smartphone circuit. In the designs of many MIMO antennas, it is common to avoid placing elements in parallel and to choose instead to place them vertically, which can avoid strong mutual couplings caused by the same polarization mode. In this paper, however, the antenna elements are both perpendicular and parallel to each other to exhibit the diversity function. In addition, the T-shaped strip of the antenna configuration can act as a decoupling structure. Due to compact size and also placement of the antenna, the proposed MIMO design occupies a very small part of the smartphone printed circuit board (PCB). Therefore, the antenna achieves not only low mutual couplings but also small clearance.

The antenna elements of the MIMO design are fed using the coplanar waveguide feeding mechanism in order to operate at sub-6 GHz 5G communication (3.4–3.8 and 3.8–4.2 GHz). Compared with probe-fed and microstrip-fed antennas, coplanar waveguide (CPW)-fed antennas can easily achieve the wideband impedance matching. Therefore, CPW-fed antennas are widely used and becoming increasingly popular in wireless applications owing to their attractive features such as compact size, conformal status, their light weight sand ease of fabrication and integration with wireless communication systems. The paper is organized as follows: The design and characteristics of the diversity antenna element are represented in the MIMO performance and radiation characteristics of the proposed 5G smartphone antenna array .It investigates the radiation behavior of the designed smartphone antenna array in the vicinity of the user. The proposed structure has beam simulated by using the Ansoft HFSS Ssoftware [3].

CHAPTER 3

EXISTING METHOD

A new tri-band monopole antenna for multi input multi output (MIMO) operation is reflected grounded antennas are generally used because they satisfy all the conditions, but they aren't practical due to their fairly big size and their 3D figure. So the world is moving to MIMO antennas. MIMO technology can enhance data transmission speed and gives a resistance to multiple path fading which has been extensively delved. The MIMO antenna is designed on FR4 Substrate, whose tri band performance is generated by antenna design. The comparison leads one to the conclusion that the suggested MIMO antenna provides foregoing antenna properties as well as superior accomplishments, which are necessary for the modern handheld devices that are moving towards 5G wireless systems.

CHAPTER 4

PROPOSED TRIPLE BAND MIMO DESIGN

A 4-antenna array for multiple-input multiple output (MIMO) applications in future fifth generation (5G) mobile terminals is presented in this paper. The antenna array consists of four triple band antennas which can cover 5G new radio (NR) including n77 (3.3-4.2GHz) and n79 (4.4-5GHz), and 5GHz-wireless wide area network (WLAN) operation in 5.15-5.85GHz. The proposed antenna array was fabricated and measured. The measured total efficiency over 60% and isolation better than 14dB between each port were obtained. Envelope correlation coefficient (ECC) and channel capacity (CC) were also analyzed to evaluate the antenna performance. Besides its emotional features 5G frequentness face a implicit problem related to low penetration power due to which the signal fades and gets weaker while transmitted from transmitter to receiver using one antenna at each end. In order to enhance the range of transmitted signal, Multiple Input Multiple Affair (MIMO) systems are used. MIMO antennas can be a better result especially when dealing with compact battery powered bias.

It has been observed that it's veritably delicate to gain a high gain using a single antenna so multiple antennas are to be used. Massive MIMO wireless access technology is the answer to this global demand. Massive MIMO technology groups together antennas at both transmitter and the receiver to provide high spectral and energy efficiency using relatively simple processing. Given the worldwide need for an efficient spectrum, a limited amount of research has been conducted on massive MIMO technology. Thus, several open research challenges are still in the way of this emerging wireless access technology. It provides an extensive overview of massive MIMO systems, highlighting the key enabling technologies for 5G and beyond networks. Although massive MIMO offers immense benefits for 5G and 6G networks, there are still various deployment challenges such as pilot contamination, channel estimation, pre coding, user scheduling, hardware impairments, energy efficiency, and signal detection that needs to be addressed before we can achieve its promised advantages. Furthermore, this paper outlines the recent trends such as terahertz communication and application of machine learning and deep learning technology for massive MIMO systems.

We hope that this paper will motivate the researchers currently working on 5G and beyond networks field to find new paths and open problems to tackle in the coming years. The lower power requirements of beam forming antennas for transmitting signals to the intended user and cost reductions result in the lower power consumption and amplifier costs of massive MIMO systems. Massive MIMO systems are assisted by beam forming processes to reduce the power consumption of the entire system by computing the optimal quantity of antenna elements that meet several essential criteria for manipulating energy-efficient massive MIMO systems. For each specified power consumption of each BS, the overall energy efficiency is relatively unaffected by the number of working antenna elements in the cell; thus, a common number of working antennas can be implemented for the entire cells in the system to obtain high cost-effectiveness and overall energy efficiency.

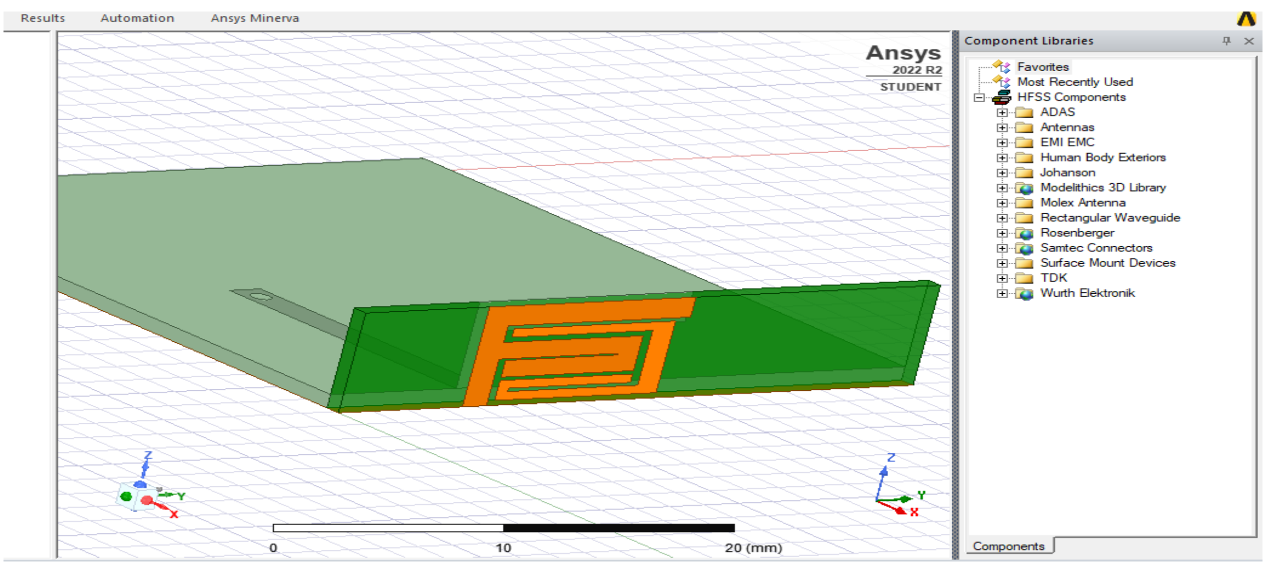

FIG NO: 4.1 ANTENNA DESIGN

TOOLS USED

Software requirement:

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.

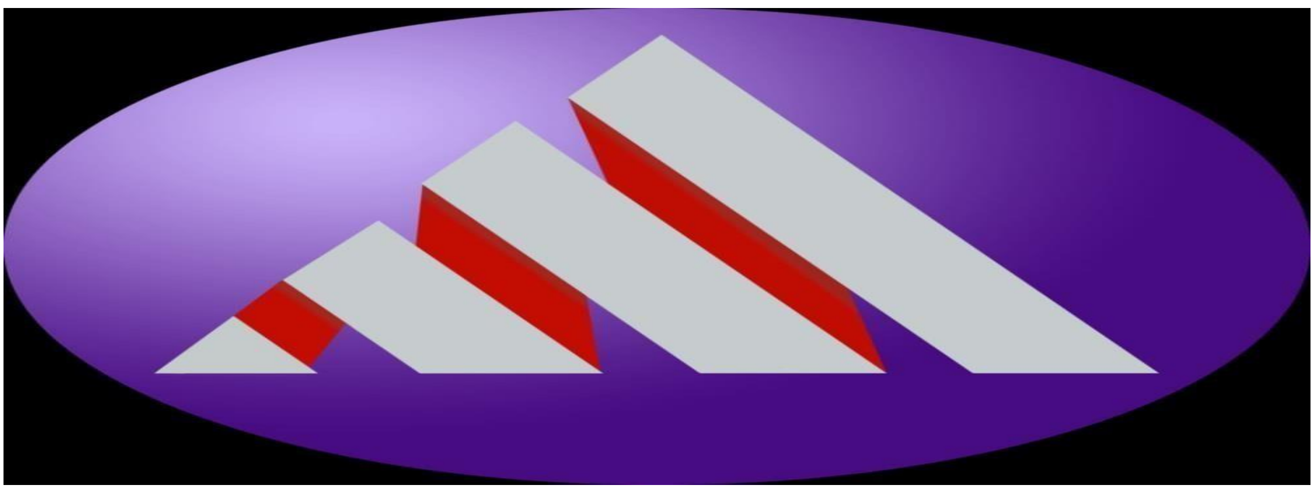

FIG NO : 4.2 HFSS SOFTWARE

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 behavior of objects such as automobiles. 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 software is little difficult to understand but once you design few basic filters or antennas, it will be easy for you to design further implementations. The HFSS integral equation (HFSS-IE) solver uses the method of moments technique to solve for the sources or currents on the surfaces of conducting and dielectric objects in open regions. HFSS-IE is effective for radiation and scattering studies of large, mostly conducting structures.

CHAPTER 5

EXPERIMENTAL TECHNIQUES

The structural parameters of Meta material Inspired antenna obtained on the basis of theoretical rectangular waveguide model which is one of the finest models for the explanation of the working for this type of antenna structures. With the theoretical calculation antenna has been simulated and optimized by EM Talk Micro strip Patch Antenna and Micro strip Line calculator. The design of antennas was explained in following steps. First step was to choose the operating frequency (fr) at which the antenna to be designed. In present investigation, the proposed micro strip patch antenna was designed at operating frequency 2.4 GHz. The second step was selection of substrate material with required values of input design parameters such as permittivity, dielectric loss tangent, to miniaturize size of antenna with increased performance.

MATERIALS ARE USED:

Antennas can be designed with different substrates to achieve the desired performance. The substrates are chosen taking into consideration the ease of fabrication and its biocompatibility when compared to other semiconductors. The selection of height and dielectric constant of the substrate helps in achieving high directivity and better radiation efficiency.

SIMULATION & RESULTS:

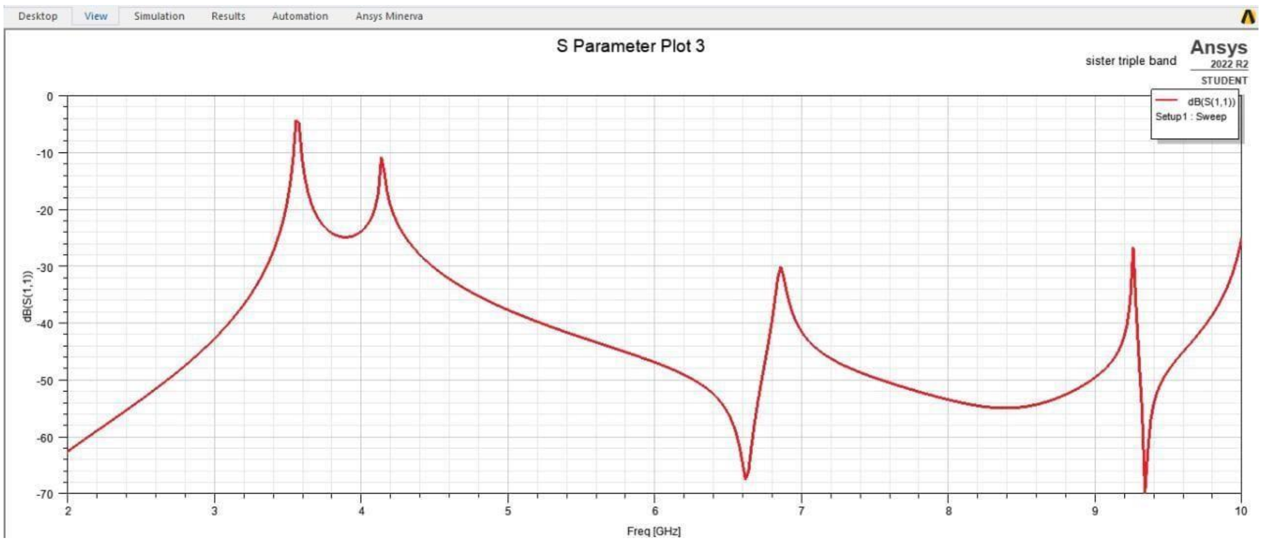

FIG NO : 5.1. S PARAMETER

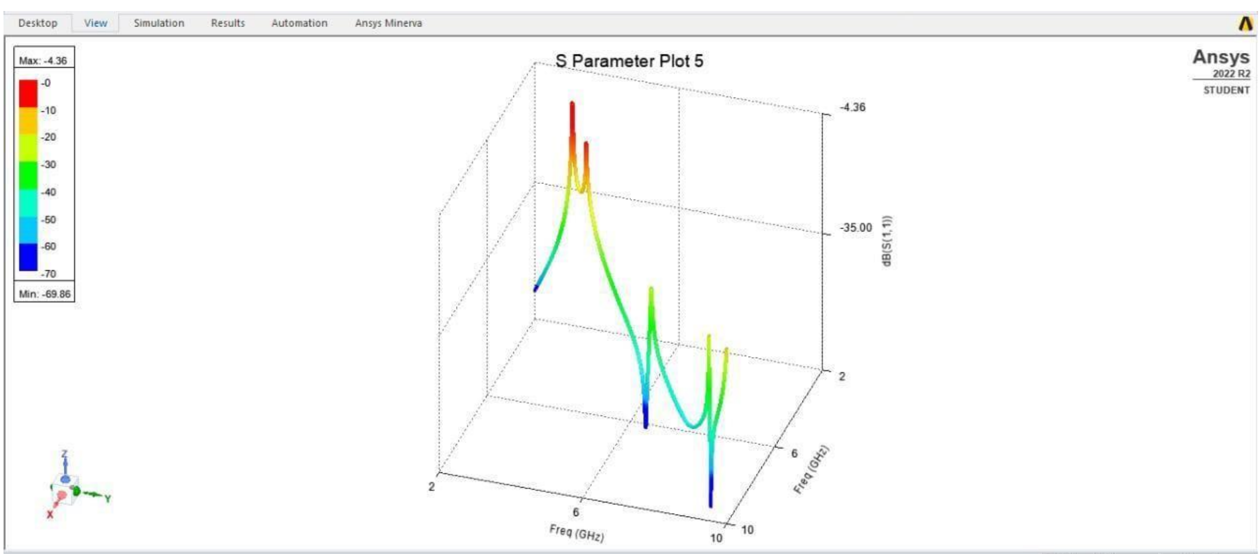

FIG NO : 5.2 VSWR PARAMETER

CHAPTER 6

SCOPE FOR IMPROVEMENT

- ❖ The experimental radiation patterns of the constructed antennas could not be obtained and compared with the theoretical patterns.
- ❖ Though we were able to simulate several patch antennas, we were unable to fabricate one and compared the practical and simulated results.
- ❖ A more complete study of different field solvers and simulators (such as sonnet, etc.) could not be made we were only able to focus on HFSS.

CHAPTER 7

RESULTS AND DISCUSSION

The radiation characteristics for inset patch antenna as a meta-material unit cell for frequency ranges 9 GHz to 12 GHz are analyzed. The Fig. 2 shows electric field pattern near resonance of such a structure. Further, we create the model of 4×4 array of such unit cell as basic MIMO cell. The Fig. 3 shows the good resonance of such meta-material antennas array having S11 around -16 dB and low mutual coupling less than -10 dB. From this design, we found the highly directed beam pattern with 6.88 dB gain along the direction of maximum radiation. The 3-D radiation pattern, azimuthal and elevation pattern for such antennas. Moreover, we can find the correlation coefficient and diversity gain using equation 1 and 2 for such antenna in order to analyse mutual coupling and interference between numbers of antenna arrays

The transmission coefficient, reflection coefficient, and S parameters of antenna design are discussed in the following. The MIMO antenna design which is proposed here can support a broadband range from 3.3 GHz to 6.0 GHz with a reflection coefficient less than −6 dB (3 : 1 VSWR).

CHAPTER 8

CONCLUSION

In this paper, we presented the design of antennas for use in massive MIMO wireless communication system. We discussed the overall architecture of full dimension MIMO used for next generation cellular technology. The meta material inspired inset patch antenna solves the problem of size constraint, mutual coupling, channel correlation and produces a highly directed beam pattern. The qualitative design and analysis of such antenna will enable energy and spectrum efficient future wireless connectivity between thousands of users.

CHAPTER 9

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TRIPE-BAND MIMO ANTENNA FOR 5G MOBILE APPLICATIONS

Dr.Dhamodaran.M	Padmavathi.S	Naveena.K	Pavipraveena.G	Pavithra.G,
Professor	UG Scholar	UG Scholar	UG Scholar	UG Scholar

Department of Electronics and Communication Engineering
M.Kumarasamy College of Engineering, Karur

Abstract - In this paper, a multiple input multiple output (MIMO) 4-antenna array is proposed and designed for 5G mobile terminal communication. The antenna array is composed of four triple-band antennas placed along the long edges on both sides of the terminal. It adopts a bent structure to achieve miniaturization and can cover the ISM (Industry Science Medicine) frequency band of 2370-to-2450MHz, and the 5G operating frequency bands of 3510-to-3610MHz and 4830-to-5080MHz allocated by the Ministry of Industry and Information Technology. The proposed antenna array achieves >40% total antenna efficiency, and >-15dB isolation between each two ports. The measurement results of the fabricated antenna array demonstrate in-line performance based on the simulation results, offering a feasible approach for 5G mobile terminal applications.

Keywords - 5G communication, triple-band, miniaturization, mobile terminal.

M.KUMARASAMY
COLLEGE OF ENGINEERING
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Thalavapalayam, Karur-639 113, Tamilnadu.

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HoD / ECE


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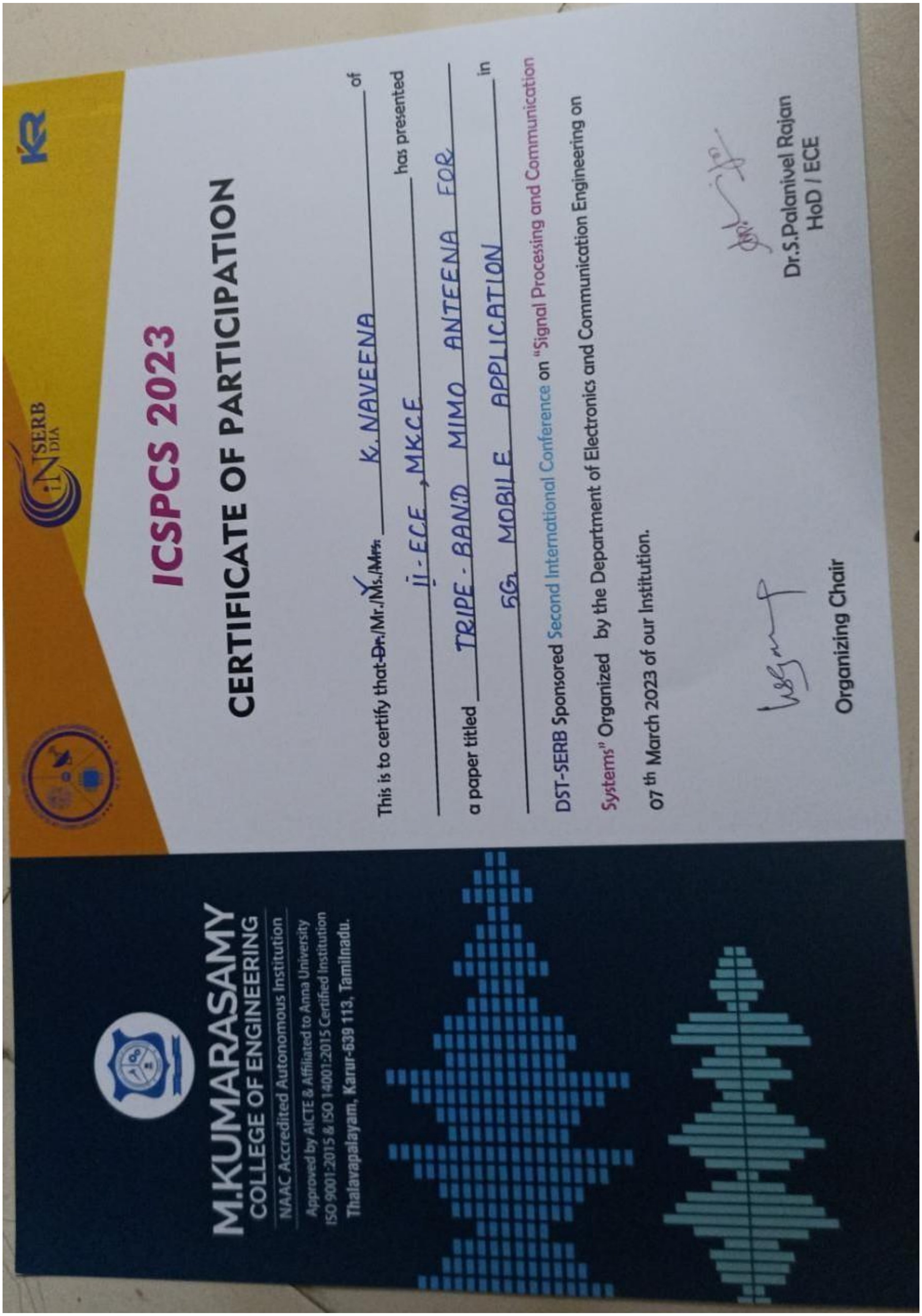

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