DESIGN OF A MULTIBAND PATCH ANTENNA FOR 5G COMMUNICATION SYSTEMS

GURRAM ANKIT 20951A0415

DESIGN OF A MULTIBAND PATCH ANTENNA FOR 5G COMMUNICATION SYSTEMS

A Project Report

submitted in partial fulfillment of the

requirements for the award of the degree of

Bachelor of Technology

in

Electronics and Communication Engineering

By

GURRAM ANKIT-20951A0415

Under the supervision of

G.HAMPIKA,

Assistant professor

I A R E

EDUCATION FOR LIBERATION

Department of Electronics and Communication Engineering

INSTITUTE OF AERONAUTICAL ENGINEERING

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of Technology in Branch ELECTRONICS AND COMMUNICATION ENGINEERING.

Examiners

Supervisor(s)
G.HAMPIKA
Assistant Professor

Principal

Date:

Place:

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With Gratitude,

GURRAM ANKIT

20951A0415

ABSTRACT

Effective This article explores the application of multi-band patch antennas tailored to meet the demands of various wireless communication standards, including Wi-Fi, WiMAX, and 5G mobile applications. The focus is on a specially designed antenna that aims to fulfill the requirements of 5G mobile services, offering compact dimensions of 19mm x 14.6mm x 1.6mm. The key feature of the proposed antenna lies in its ability to seamlessly operate across multiple frequencies, addressing the diverse needs of different communication technologies. Specifically, the antenna demonstrates optimal performance at three crucial frequencies: 2.6 GHz for Wi-Fi, 13.6 GHz for WiMAX, and 37.7 GHz for 5G communication The compact dimensions and multi-frequency capability of the antenna make it well-suited for modern communication systems. The antenna's performance at each operational frequency is characterized by a directional radiation pattern, ensuring high gain and precision in signal transmission. This directional radiation pattern contributes to efficient communication by focusing the signal in specific directions. Moreover, the antenna boasts a low standing wave ratio (VSWR), indicating heightened efficiency in signal transmission and reception with minimal signal loss. This feature is crucial for maintaining high-quality signals, contributing to improved overall communication performance. The significance of this antenna in advancing communication technologies is emphasized by its ability to enhance signal quality and extend coverage. The efficient operation across Wi-Fi, WiMAX, and 5G frequencies positions it as a versatile solution for various wireless communication applications.

Keywords: Multi-band patch antennas, 5G mobile applications, specially designed antenna, compact dimensions, optimal performance, Wi-Fi, WiMAX, 5G communications, directional radiation pattern, efficiency in signal transmission.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

VSWR	Voltage Standing Wave Ratio
WI-FI	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
NeurIPS	Conference on Neural Information Processing Systems
ICCVW	International Conference on Computer Vision Workshops
CVPR	Conference on Computer Vision and Pattern Recognition
IEEE	Institute of Electrical and Electronics Engineers
arXiv	preprint repository for electronic preprints of scientific papers

CHAPTER 1

INTRODUCTION

1.1 Introduction to Antennas :

The escalating demand for 5G mobile services has underscored the necessity for compact antennas capable of operating across diverse frequency bands. The advent of 5G networks, characterized by higher frequency bands and shorter wavelengths, necessitates innovative solutions for optimal data rates. Multiband patch antennas emerge as a fitting response to this challenge, offering coverage across multiple frequency bands while maintaining a compact form factor conducive to integration into mobile devices. The proposed multiband patch antenna, featured in this research, is poised to excel at frequencies of 2.6 GHz, 13.6 GHz, and 37.7 GHz, catering to Wi-Fi, WiMAX, and 5G communications.

Its versatility allows for seamless adaptation to a spectrum of communication protocols, rendering it suitable for diverse mobile devices. The directional radiation patterns of the antenna arrays exhibit high gain and precision at each operational frequency. Additionally, a remarkably low voltage standing wave ratio (VSWR) attests to the antenna's efficiency, ensuring minimal signal loss and thereby enhancing signal quality and extending coverage. As a variant of the microstrip antenna, the multiband patch antenna comprises a thin metallic patch on a dielectric substrate, enveloped by a ground plane. The resonant cavity formed by the patch and ground plane is pivotal to the antenna's radiating capabilities. Diverse shapes and placements of the patch yield varied radiation patterns and frequency responses, enabling customization to meet specific requirements.

Fig 1.1: Realtime Antenna

Tailored to operate across a spectrum of frequency bands, the proposed multiband patch antenna employs various patch forms and placements. For instance, a rectangular patch configuration is adopted at 2.6 GHz, transitioning to a circular ring shape at 13.6 GHz. This adaptability allows for the attainment of optimal radiation patterns and frequency responses, further accentuated by the low-profile design, making it suitable for integration into compact mobile devices such as smartphones and tablets. The suggested multiband patch antenna emerges as a cost-effective and efficient solution to meet the burgeoning demand for 5G mobile services.

Its capacity to operate across diverse frequency bands and its compact footprint position it as an ideal choice for mobile devices supporting varied communication protocols. The directed emission patterns, low VSWR, and high gain collectively contribute to heightened signal quality and expanded coverage area. Consequently, the proposed antenna holds promise for future mobile communication systems, aligning with the evolving landscape of technology and the imperative for faster, more reliable communication in the realm of 5G services.

1.1.1 Radiation Mechanism: The primary function of an antenna is to transmit or receive power, with a transmission line connecting it to the station's electronics. The antenna's operation relies on the radiation mechanism of the transmission line. The transmission line, designed to carry electrical energy over long distances while minimizing energy loss, may be linked to the antenna. If the transmission line is a straight conductor of infinite length, allowing current to flow with uniform velocity, no power is emitted.

For a transmission line to function as a waveguide or emit electricity, certain treatments are required. This involves bending, truncating, or terminating the wire or transmission line, especially when transmitting power while the current is flowing at a constant rate. Additionally, if there is a constant rate of change in the current flowing through the transmission line over time, power will be emitted even if the wire is straight.

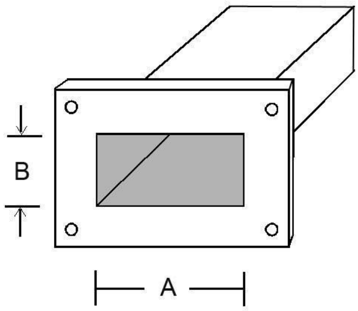

Fig 1.2: Waveguide

1.1.2 VSWR & Reflected Power: The ratio between the highest voltage and the lowest voltage in a standing wave is referred to as Voltage Standing Wave Ratio. Impedances that are not in agreement between the antenna, transmission line, and circuitry will result in the power not being emitted correctly and will cause part of the signal to be reflected back. The main characteristics include

• The term used to describe the impedance mismatch is VSWR.

• VSWR is an abbreviation for Voltage Standing Wave Ratio. It is also

known as SWR.

• The greater the impedance mismatch, the greater the value of VSWR.

• For effective radiation, the optimal VSWR should be 1:1.

• The power wasted from forward power is referred to as reflected

power.

1.1.3 Antenna Efficiency: Antenna efficiency stands as a pivotal element in antenna design, representing the ratio of power radiated by the antenna to the power supplied to it. Antennas boasting high efficiency effectively transmit most of the supplied energy, while those with lower efficiency tend to dissipate more energy through mechanisms like reflection, absorption, or heat. Numerous factors contribute to antenna efficiency, encompassing its design, the materials employed, and the operational environment. Hence, meticulous optimization of these factors becomes imperative to enhance overall antenna efficiency.

Efficient antennas hold paramount significance in wireless communication systems, particularly in scenarios where energy efficiency is paramount for extending the battery life of portable devices. Beyond this, high-efficiency antennas can augment signal range and quality, mitigate interference, and elevate data rates. Consequently, they facilitate faster and more reliable communication between devices, underscoring the pivotal role of antenna efficiency in modern communication technology.

Several strategies exist to enhance antenna efficiency, including meticulous optimization of the antenna's design, encompassing the feed mechanism, matching network, and materials utilized. Furthermore, improvements can be achieved by enhancing the operational environment of the antenna, such as minimizing temperature and humidity fluctuations and mitigating external factors that might impede the antenna's performance. In summary, antenna efficiency emerges as a critical facet of both antenna design and operation, demanding careful consideration to attain superior performance, energy efficiency, and reliability within wireless communication systems.

1.1.4 Gain: The gain of an antenna stands as a pivotal aspect in its design, quantifying its capability to emit power in a specific direction. Typically expressed in decibels (dB), it signifies the ratio of the antenna's radiation intensity in a given direction to that of an ideal isotropic radiator. In simpler terms, an antenna with a gain of 0 dB distributes power equally in all directions, while an antenna boasting a gain of 10 dB emits 10 times more power in the preferred direction compared to an isotropic radiator.

Numerous factors influence antenna gain, including its size, shape, and operating frequency. While larger antennas generally exhibit higher gain, this is not a universal rule. Directivity also plays a significant role in determining antenna gain, referring to the focus of the radiation pattern in a specific direction. Antennas characterized by high directivity can achieve substantial gain in a particular direction but often have a narrower beamwidth.

Antenna gain holds critical importance in wireless communication systems, dictating the quality and range of the transmitted signal. A high-gain antenna has the potential to enhance the signal-to-noise ratio (SNR), extend the reach of wireless communication, and mitigate the impacts of interference. It's noteworthy, however, that antenna gain does not augment the total power radiated by the antenna; rather, it redistributes it in a specific direction. Additionally, high-gain antennas may possess a more directional nature, necessitating precise alignment for optimal performance.

1.2 Radiation Pattern:

The radiation pattern of an antenna serves as a visual representation of the energy emitted by the antenna, portraying how radiated energy is distributed in space concerning direction. These patterns are essential diagrams in antenna design and analysis, offering valuable insights into the antenna's directionality, gain, and efficiency. They vary depending on the physical shape and characteristics of the electromagnetic waves, with antennas of diverse shapes and sizes exhibiting distinct radiation patterns. For example, dipole antennas demonstrate a radiation pattern strongest perpendicular to their axis and weakest along their axis, while horn antennas display a highly directional and narrow radiation pattern, making them suitable for long-range communication.

Measuring radiation patterns typically occurs in an anechoic chamber, a specialized room designed to minimize reflections from surfaces. In this process, the antenna is positioned at the chamber's center, and a probe or antenna measures the electromagnetic field in various directions. The collected data is then used to construct a radiation pattern, a critical tool in optimizing the antenna's performance and reliability within wireless communication systems.

A comprehensive understanding of radiation patterns is indispensable in antenna design and analysis, playing a pivotal role in determining the antenna's coverage area and the direction in which it emits the most power. Furthermore, radiation patterns offer crucial information for calculating the antenna's gain and directivity, vital parameters in wireless communication systems. Consequently, a well-designed antenna with an appropriate radiation pattern holds the potential to significantly enhance the performance and reliability of wireless communication systems.

1.2.1 Radiation Pattern in 3D: In a 3D radiation pattern, the antenna's radiated energy is illustrated in terms of both azimuth (horizontal plane) and elevation (vertical plane). This allows engineers and designers to observe how the energy is distributed not only around the antenna's central axis but also in the upward and downward directions.

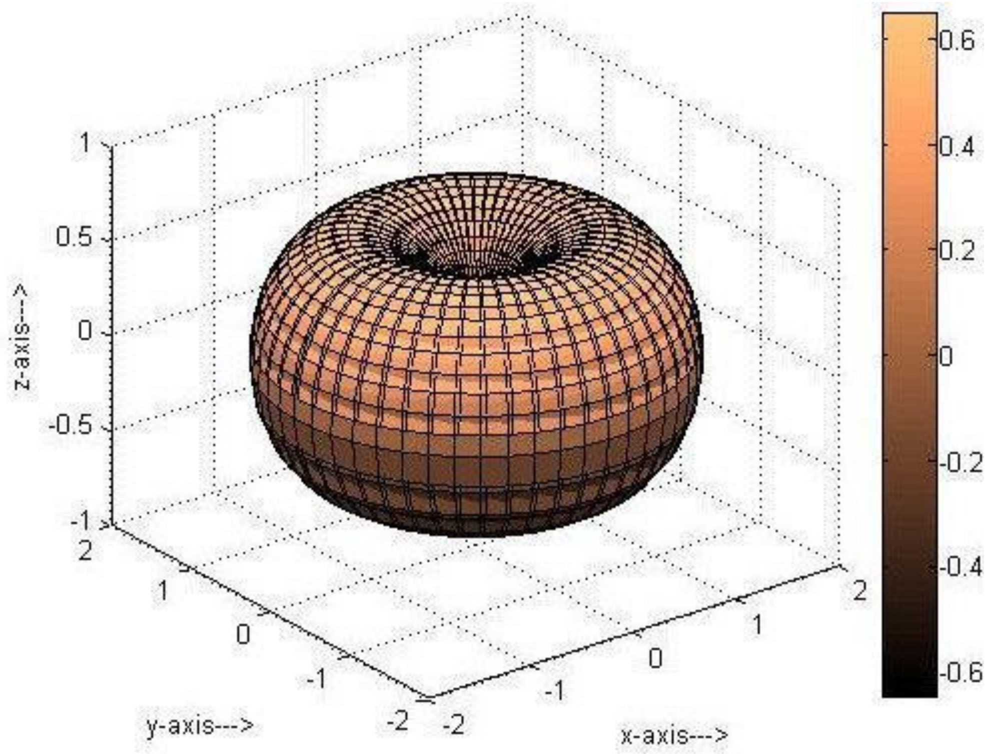

Fig 1.3: 3D Radiation Pattern

The 3D radiation pattern is crucial in antenna design and analysis as it provides a more accurate depiction of the antenna's coverage and performance characteristics. Engineers use 3D radiation patterns to evaluate the antenna's directivity, gain, and coverage in all spatial directions, aiding in the optimization of its design for specific applications.

1.2.2 Radiation Pattern in 2D: A two-dimensional representation can be derived by dissecting a three-dimensional radiation pattern into horizontal and vertical planes, yielding distinct horizontal (H) and vertical (V) patterns. Figure 1.4 illustrates the omnidirectional radiation pattern in both the H and V planes. The H-plane signifies the horizontal pattern, while the V-plane denotes the vertical pattern.

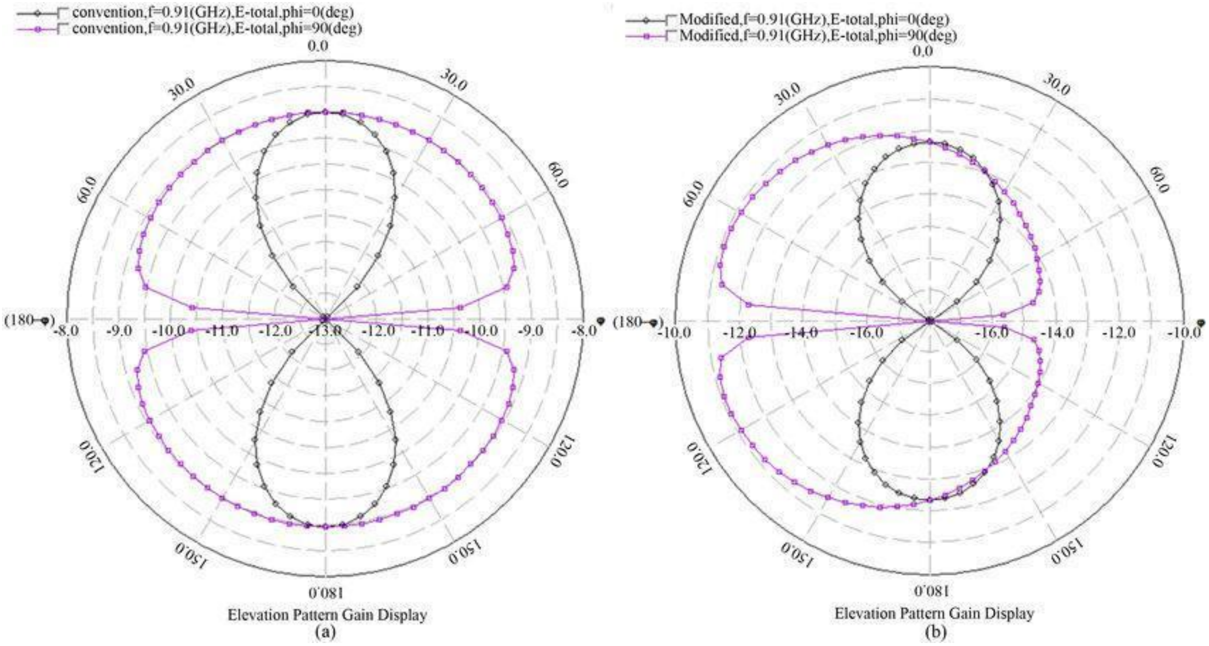

Fig 1.4: 2D Radiation Pattern

1.3 Microstrip Patch Antenna:

Microstrip and patch antennas are gaining popularity due to their cost-effectiveness and convenience. These antennas can be directly printed onto circuit boards, typically constructed from highly conductive metals like copper. Their low-profile design and ease of fabrication make them particularly well-suited for applications in the mobile phone market. The critical dimensions of the patch antenna, microstrip transmission line, and ground plane are crucial to ensure optimal operational efficiency. Generally, maintaining the thickness of the ground plane and microstrip above 0.025 wavelengths is essential to prevent a decline in antenna performance.

Microstrip patch antennas have witnessed increased adoption owing to their versatility and low-profile attributes. Comprising a metallic patch mounted on a ground plane and separated by a dielectric substrate, these antennas can be customized with various shapes, dimensions, and positions to achieve desired performance characteristics.

One notable advantage of microstrip patch antennas is their low profile, facilitating seamless integration into diverse devices such as mobile phones, laptops, and satellites. Their lightweight construction and cost-effectiveness further contribute to their appeal. The planar structure of

These antennas facilitate easy integration with printed circuit boards and other electronic components.

Featuring a directional radiation pattern, microstrip patch antennas offer precise signal targeting, with the radiation pattern controllable by adjusting the shape and dimensions of the patch. Additionally, the bandwidth of these antennas can be easily adjusted, rendering them suitable for a broad range of applications. However, one drawback is their relatively lower efficiency, prompting ongoing research efforts to enhance performance through methods like adding extra layers to the substrate or utilizing higher-quality materials.

Widely employed in applications such as satellite communication, wireless networks, and remote sensing, microstrip patch antennas have found a niche in emerging technologies like 5G and IoT. Their combination of low profile and directional radiation pattern makes them an appealing choice in these evolving technological landscapes. As a versatile and low-profile antenna type, microstrip patch antennas are poised to play an increasingly crucial role in the continued development of wireless communication technologies.

1.4 Wireless Communication:

Wireless communication systems have become indispensable in modern communication, facilitating the transmission of information across vast distances without the constraints of physical connections. Employing radio waves, microwaves, or infrared waves, these systems, including Wi-Fi, Bluetooth, GPS, and smartphones, have revolutionized global connectivity, enabling communication from virtually anywhere on the planet.

Rooted in the late 19th century with Guglielmo Marconi's invention of the radio and the inaugural radio transmission in 1895, wireless communication has evolved significantly. From early Morse code transmissions, the technology advanced to accommodate voice, music, and, eventually, television broadcasting. The 21st century witnessed the advent of digital technology, leading to faster and more efficient wireless communication systems capable of transmitting substantial data volumes. The latest developments include 4G and 5G networks, offering high-speed internet access on mobile devices and transforming the way people work, communicate, and access media on the move.

Wi-Fi, a ubiquitous technology enabling wireless data exchange and internet connectivity, has become omnipresent in homes, offices, and public spaces. Advancements in Wi-Fi standards, such as 802.11ac and 802.11ax, have yielded faster speeds, broader coverage, and more reliable connections. Wi-Fi routers, available in various forms and specifications, facilitate the creation of wireless networks, providing users with the convenience of connecting multiple devices without physical constraints.

WiMAX, operating on the IEEE 802.16 standard, offers long-distance high-speed internet access, particularly in areas where wired connectivity is challenging. It provides advantages like wider coverage, faster speeds, and higher bandwidth, with the ability to connect remote areas up to a radius of 50 kilometers. WiMAX's cost-effectiveness and avoidance of expensive infrastructure installations make it an attractive option for areas with limited internet access.

The latest frontier in wireless technology, 5G communication, promises faster data transfer rates, lower latency, and increased capacity. Operating on higher radio frequencies, known as millimeter waves, 5G facilitates greater bandwidth and faster data transfer rates. With data transfer speeds of up to 20 gigabits per second, 5G networks outpace their predecessors by approximately 100 times, enabling rapid downloads of data-intensive content and seamless streaming of high-quality videos. The lower latency of 5G supports responsive experiences like virtual reality and applications requiring real-time responsiveness, such as remote surgery and autonomous vehicles.

1.5 Introduction To HFSS:

Antenna simulators stand as indispensable tools in the antenna design process, empowering engineers to model and assess antenna configurations before physical implementation. Through sophisticated algorithms, these simulators emulate the interaction of electromagnetic waves with antenna structures, offering crucial insights into performance metrics like radiation pattern, gain, impedance, and bandwidth. This virtual approach enables designers to swiftly iterate through various antenna designs, refining and evaluating them based on simulated outcomes. The utilization of simulators allows for performance optimization before the physical construction and testing phases, resulting in substantial time and cost savings.

Moreover, simulators provide designers with the flexibility to explore a diverse array of design options and antenna configurations. This capability enables informed decision-making regarding the most suitable antenna design for a specific application. By leveraging simulators, designers can experiment with different materials, shapes, and sizes, creating antenna designs that are not only highly efficient but also cost-effective and tailored to specific requirements.

In the broader context of antenna design and development, simulators play a pivotal role in facilitating the creation of high-performance antennas that meet precise performance criteria. Ansys HFSS (High-Frequency Structure Simulator) emerges as a prominent commercial finite element approach solver for electromagnetic structures, offering cutting-edge solver technologies. Engineers leverage Ansys HFSS to design and simulate high-speed, high-frequency electronics in diverse applications such as radar systems, communication systems, and satellites.

Ansys HFSS, a 3D electromagnetic simulation software, is widely utilized for the design and analysis of high-frequency electromagnetic structures, including antennas, RF/microwave components, and integrated circuits. Renowned for its accuracy and efficiency in simulating complex electromagnetic phenomena, ANSYS HFSS features a user-friendly interface equipped with functionalities such as parameterization, optimization, and 3D visualization. These features aid engineers and designers in the seamless design and optimization of electromagnetic structures. The software has significantly advanced electromagnetic simulation, offering a comprehensive tool that simplifies the design and analysis of high-frequency electromagnetic structures.

Accurately replicating a circuit's high-frequency behavior on a computer offers significant advantages, streamlining the final testing and verification processes while eliminating the need for numerous costly prototypes. This approach results in substantial time and cost savings during product development. High-Frequency Structure Simulator (HFSS) excels in this context, employing a 3D simulation that meticulously considers material composition and object shapes or geometries. HFSS, among various commercial tools, proves instrumental in designing antennas and sophisticated radio frequency electrical circuit elements such as filters, transmission lines, and packaging.

HFSS originated from the innovative work of Professor Zoltan Cendes, Ph.D., and his students at Carnegie Mellon University. As the first general-purpose software capable of solving arbitrary 3D electromagnetic field issues, it addresses challenges related to electromagnetic energy distribution and S parameters in complex structures. In 1984, Dr. Cendes founded Ansoft Corporation to design and develop high-performance Electronic Design Automation (EDA) software. Serving as the chairman and chief technology officer, he continued to lead the company until its acquisition by Ansys in 2008. Initially offered as a stand-alone product under a licensing arrangement with Hewlett-Packard, HFSS later became an integral part of Ansoft product portfolio.

The acquisition of Optimization Systems Associates Inc. (OSA), founded by John Bandler in 1983, by Hewlett-Packard in 1997 was motivated by the company's recognition of the need for HFSS optimization capabilities. This strategic move further solidified HFSS's position in the realm of electromagnetic simulation and design tools.

CHAPTER 2

LITERATURE SURVEY

The ascendancy of microstrip antennas as a promising solution in wireless communication has spurred extensive investigations into their design, performance, and characteristics. Conducting a thorough literature survey on microstrip antennas serves as a valuable tool to discern the evolutionary trajectory of these antennas, ascertain pivotal contributions from prior research, and comprehend prevailing trends in their ongoing development. These surveys offer a comprehensive overview of existing knowledge on microstrip antennas, aiding in the identification of research gaps and potential avenues for future exploration. The survey will scrutinize a diverse array of research papers on microstrip antennas, delving into distinct design approaches, performance parameters, and reported applications documented in the literature. Through a meticulous analysis of the strengths and limitations inherent in various design techniques and the illumination of emerging trends, the survey aspires to foster a deeper understanding of microstrip antennas and their prospective applications. Ultimately, this literature survey endeavors to equip researchers and engineers in the wireless communication field with the insights needed to make informed decisions regarding the design and optimization of microstrip antennas.

2.1 Literature Survey:

"The objective of this study was to design an antenna suitable for modern mobile communications, considering parameters such as loss characteristics, gain, and radiation pattern. Although the antenna exhibited acceptable performance for the proposed structure, further optimization and fine-tuning of the microstrip design could enhance its performance. The future work involves fabricating a prototype and studying its performance. The unique aspect of this design lies in its ability to support multiple frequency bands, including 2.4-GHz Bluetooth, 3.5-GHz WiMAX, 5.8-GHz WLAN systems, and 6GHz 5G systems. This design addresses the limitation of conventional reconfigurable antennas, offering simultaneous support for multiple frequency bands. The radiation patterns exhibit maximum radiation directed normal to the patch geometry, resembling a dumbbell shape in the upper hemisphere. Both simulated and measured results demonstrate good agreement, positioning this Reconfigurable Patch antenna for 5G communication applications." [1]

"An advanced multiband patch antenna designed using CST Microwave Studio software shows potential for future mobile communication systems. Operating not only in Wi-Fi and WiMAX bands but also in the 5G frequency band, this antenna offers bandwidths of 152 MHz, 235 MHz, and 4.5 GHz for Wi-Fi, WiMAX, and 5G, respectively. Despite its advantages, the antenna can be further improved by reducing height and width for lightweight construction, adding more frequency bands, and enhancing directivity. The antenna's low VSWR and high directivity make it effective for next-generation communication needs. Future enhancements could make it even more versatile and efficient." [2]

"This study presents a stacked patch configuration for a dual-element antenna catering to GPS and WLAN bands. With circular polarization for GPS and linear polarization for WLAN, the antenna can be simultaneously excited by a single feed. The measured impedance bandwidth for GPS and WLAN bands shows promising results, making it suitable for wireless products integrating satellite and terrestrial communication. Inspired by this, the proposal aims to extend the design to support triple-band operations for GPS L1, GSM, and WLAN frequency bands, maintaining high performance with improved gain, broad bandwidth, and low cross-polarization, ideal for GPS, GSM, and WLAN applications." [3]

"Two proposed microstrip antennas are designed to cover various frequency bands essential for modern wireless communication systems. Antenna_1 spans tri-band frequencies, including WiMAX, WLAN/C-band, and C-band, catering to potential C-band applications in 5G services. Antenna_2 covers dual-band frequencies for C-band and X-band, suitable for mid-band 5G applications. The proposed antennas, with dimensions of $94 \times 76 \times 3.18$ mm^3, exhibit good conformity between experimental and simulated results in terms of return loss, gain, bandwidth, and radiation pattern. This design offers a compact solution for multi-band microstrip patch antennas." [4]

"This literature review focuses on the design and analysis of microstrip patch antennas for various wireless communication applications, including WLAN, WiMAX, GPS, ISM band, and UWB. The study explores techniques to enhance the bandwidth of microstrip patch antennas, such as fractal shapes, slotting, and meandering structures. Despite their popularity due to low profile, lightweight, and cost-effectiveness, the low bandwidth of these antennas limits their application. Researchers propose solutions to improve their performance, contributing to the development of more efficient and reliable wireless communication systems." [5]

"Microstrip patch antennas, while cost-effective and lightweight, face challenges in achieving circular polarization (CP). A novel design featuring asymmetric-circular shaped slotted microstrip patch antennas is proposed to address this issue. The design utilizes a single-feed configuration based on an asymmetric-circular shaped slotted square microstrip patch, enabling CP radiation in a compact size. The design also incorporates symmetric slits for further size reduction and offers frequency tuning capabilities. Experimental results showcase the antenna's 3-dB axial-ratio bandwidth and impedance bandwidth, demonstrating advantages such as compact size, CP radiation capabilities, and frequency tuning compared to existing microstrip patch antennas." [6]

"A reconfigurable patch antenna with four waveguide ports designed for Wi-Fi and WiMAX applications is presented. This antenna, effective for single-channel base stations, offers advantages like low VSWR and compactness. The reconfigurable nature allows simultaneous use of both Wi-Fi and WiMAX systems, providing versatility for multiple functions. Simulated results from CST-MW software show promising performance characteristics, positioning this antenna as a novel design with significant advantages over traditional ones. The study highlights its potential contributions to the development of more efficient and versatile communication systems." [7]

"This study introduces a switched beam antenna designed for operation at 2.45 GHz, featuring Circularly Polarized beams with low correlation coefficients. The antenna, composed of two disc-based patches in a concentric single-layer structure, offers directive broadside, symmetrical tilted, and conical patterns. With low beam correlation for the Wi-Fi band, the switched beam antenna demonstrates effectiveness in providing space diversity medium access for IEEE 802.11 communication in complex areas. The design's potential to improve Wi-Fi communication in challenging environments positions it as a noteworthy contribution to the field." [8]

"A printed monopole antenna with two U-type slots is proposed to meet the demands of compact and multiband wireless communication systems. The antenna's small dimensions and U-type slots offer triple-band performance, covering Bluetooth, WiMAX, and WLAN frequency ranges effectively. The measured results affirm the antenna's good performance, making it a promising solution for wireless communication systems. The proposed design, with its small footprint and excellent selectivity, presents an efficient configuration for meeting the requirements of various communication applications." [9]

"A printed monopole antenna with dual wide bands is introduced to address the needs of WLAN and WiMAX applications. Comprising a rectangular monopole with a trapezoid conductor-backed plane, the antenna achieves a 10 dB bandwidth covering all WLAN and WiMAX bands. Simulated and measured results demonstrate the antenna's excellent performance and suitability for various wireless communication systems. The small size and wideband characteristics make it an attractive choice for WLAN and WiMAX applications, with potential for further optimization and extension of its frequency range." [10]

2.2 Objective of the Project:

The primary goal of this project is to create an innovative antenna that surpasses current alternatives in various aspects. The envisioned antenna should be characterized by its compact size, heightened efficiency, directional capabilities, high gain, enhanced signal quality, expansive coverage area, minimal return loss, and cost-effective manufacturing. Additionally, there is a need to shift the frequency of operation to better align with the intended application.

To attain these objectives, the design team will concentrate on optimizing the antenna's efficiency while minimizing losses within the antenna system. This involves a meticulous selection of materials, careful design of antenna elements, and a dedicated focus on refining the radiation pattern. Special attention will be given to ensuring improved signal quality and a broader coverage area, necessitating thoughtful consideration of materials and manufacturing processes. Lastly, the aim is to develop an antenna with a low manufacturing cost, thereby ensuring accessibility to a wider user base.

The overarching ambition of the project is to engineer a high-performance antenna that outperforms existing alternatives significantly. To realize these goals, a thorough evaluation of the antenna's design, materials, and manufacturing processes is imperative. The emphasis is on crafting an antenna that is not only smaller, more efficient, and directional but also boasts high gain, improved signal quality, an expansive coverage area, low return loss, and cost-effective manufacturing. The ultimate outcome aspires to be an accessible and reliable antenna poised to revolutionize wireless communications.

CHAPTER 3

PROPOSED SOLUTION

In recent years, the design of microstrip patch antennas has become increasingly popular due to their small size, low profile, and ability to integrate with other electronic components. This chapter introduces a new design for microstrip patch antennas to improve performance in terms of bandwidth, gain, and radiation pattern. The proposed design is described in detail, including its geometry, materials, and feeding mechanism. Simulation results are used to compare the performance of the proposed antenna with existing designs in terms of bandwidth, gain, and radiation pattern, and demonstrate that the proposed design offers superior performance in several aspects. This chapter provides a novel and promising approach to the design of microstrip patch antennas and offers useful insights for researchers and engineers looking to develop high-performance antenna systems for wireless communication.

3.1 Existing Antenna Design:

To address the evolving communication needs of contemporary mobile applications, this paper introduces a multiband patch antenna. Specifically designed to operate effectively at 2.4 GHz for Wi-Fi, 7.8 GHz for WiMAX, and 33.5 GHz for 5G communication, the antenna's compact dimensions ($62 \times 50 \times 1$ mm^3) render it well-suited for integration into smartphones and mobile applications. Notably, this multiband antenna eliminates the necessity for multiple small antennas dedicated to different systems, leading to enhanced efficiency and performance in mobile devices.

The proposed antenna arrays exhibit directional radiation patterns, high gain, and directivity across the specified frequencies. Furthermore, the voltage standing wave ratio (VSWR) is exceptionally low, indicating efficient power transfer to the system. By seamlessly integrating the capabilities of Wi-Fi, WiMAX, and 5G, this multiband antenna provides versatile support for various mobile applications, ensuring efficient communication.

The design and simulation of this multiband antenna were accomplished using CST Microwave Studio software. Operating across Wi-Fi, WiMAX, and 5G frequency bands, the antenna boasts bandwidths of 152 MHz, 235 MHz, and 4.5 GHz, respectively. With its low VSWR and high directivity, this antenna emerges as an effective choice for next-generation communication needs. The multiband patch antenna, with its ability to operate at multiple frequencies and deliver efficient performance, holds promising potential as a solution for the escalating demand for reliable and high-speed wireless communication systems.

3.2 Problem Statement:

This study aims to tackle the challenge of engineering a multiband patch antenna tailored for 5G communication systems. The crux of the issue lies in the need for an antenna configuration that not only functions across a spectrum of frequencies but also delivers high gain, precise directionality, low Voltage Standing Wave Ratio (VSWR), and maintains a compact form factor. The multifaceted nature of this problem necessitates a comprehensive design approach that can seamlessly integrate into the stringent demands of 5G technology while remaining practical for integration into mobile devices. In essence, the problem at hand revolves around the imperative to reconcile the conflicting requirements of achieving broad frequency coverage, ensuring robust signal amplification and directionality, minimizing signal loss through low VSWR, and adhering to the spatial constraints inherent in mobile device applications. This multifaceted challenge underscores the critical importance of developing a multiband patch antenna that not only meets the intricate technical specifications of 5G communication systems but is also inherently conducive to the compact dimensions mandated by modern mobile devices. Consequently, the problem statement encapsulates the need for an antenna design that harmoniously balances these competing demands, thereby contributing to the advancement of 5G communication technology within the practical confines of mobile device implementation.

3.3 Design of Antenna and Calculation:

Using the High-Frequency Structure Simulator, we attempt to build a multi-band patch antenna. The first stages in making a multi-band patch antenna require using a FR-4 substrate with a dielectric constant of 4.4. The substrate material should have a low dielectric constant and a high-quality factor to optimize efficacy and decrease losses. The substrate thickness should be 1.6mm in order to achieve the required resonance frequencies.

The subsequent phase involves the computation of the antenna's geometry, encompassing both the dimensions and configuration of the patch, along with the precise positioning and shape of the feed point. The patch's form and size significantly influence the antenna's operational frequency, while the feed point's position and shape dictate impedance matching and bandwidth. Subsequent to defining the antenna's configuration, High-Frequency

Structure Simulator (HFSS) is employed for simulation. The simulation entails modeling the antenna's physical structure, encompassing interactions with the substrate material and its surroundings. Analyzing the simulation results becomes imperative, focusing on determining key parameters such as resonance frequencies spanning from 0 to 40 GHz, impedance matching, and the radiation pattern. Critical considerations for the design of the rectangular patch antenna include:

i. Frequency of Operation (f_r): Also known as Resonant Frequency, this parameter is pivotal for selecting an appropriate frequency range for the antenna. Given the utilization of communication systems within the 1800 to 5600 MHz range, the design accommodates a frequency range from 0 GHz to 40 GHz.

ii. Dielectric Constant of the Substrate (ε_r): Known as the substrate's Effective Permittivity, the design employs FR4 epoxy Polycarbonate, characterized by a dielectric constant of 4.4.

iii. Height of the Dielectric Substrate (h): Utilizing the standard height of 1.6mm for the FR4 epoxy substrate, the dielectric substrate's height is fixed accordingly.

The design calculations necessitate the determination of patch width and antenna length for the operational frequencies. Ultimately, data optimization is performed to derive the requisite antenna properties, culminating in a comprehensive and optimized rectangular patch antenna design.

Dielectric Constant effective:

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}}$$

Where ε_{re} = Effective dielectric constant.

E_r = Dielectric constant of substrate.

H = Height of dielectric substrate.

W = Width of the patch.

The patch's length has now been experimentally increased by a distance marked by:

$$\frac{(\varepsilon_r+0.3)(\frac{W}{h}+0.264)}{.8)}]$$

The patch's length has been r

$$L_e = \frac{c}{2f_o\sqrt{\varepsilon_{re}}}$$

L is the latest patch length provided:

$$L = L_e - 2\Delta L$$

The effective radiation width W is defined as:

$$W = \frac{c}{f_o}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Dimensions of the ground plane are calculated:

The dimensions of the ground plane are calculated as follows: In practice, a limited ground plane is employed instead of an endless one, but the transmission line idea remains the same. The ground plane must be at least six times the thickness of the substrate on all sides to produce results equal to those of an infinite ground plane. The steps below explain how to compute the dimensions of the ground plane.

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CHAPTER 4

METHODOLOGY

4.1 Simulation in HFSS:

Here are the steps to simulate an antenna design in HFSS:

1. Open the HFSS program and initiate a new project by navigating to the "File" menu and selecting "New."

2. Design the antenna structure using the available drawing and modeling tools in HFSS.

3. This involves creating geometric shapes, adding materials, and defining the physical properties of the antenna elements.

4. Set up the simulation environment by specifying boundary conditions and excitation sources for the antenna through the "Boundaries" and "Sources" tabs in the HFSS interface.

5. Run the simulation by clicking the "Solve" button in the toolbar or selecting "Solve" from the "Simulation" menu.

6. Analyze the simulation results using the visualization and analysis tools in HFSS. This may include viewing electric and magnetic fields, calculating antenna gain and efficiency, and generating reports.

7. Save the simulation results by going to the "File" menu and selecting "Save As."

8. Repeat the simulation process as needed to optimize the antenna design and refine the results.

It's important to note that these steps provide a general outline for simulating an antenna design in HFSS. Specific details and procedures may vary based on the unique characteristics of the antenna design and simulation objectives.

The suggested multiband patch antenna is based on microstrip antenna design concepts. A microstrip antenna is a form of antenna that is composed of a tiny metallic patch that is put on a dielectric substrate and then covered by a ground plane.

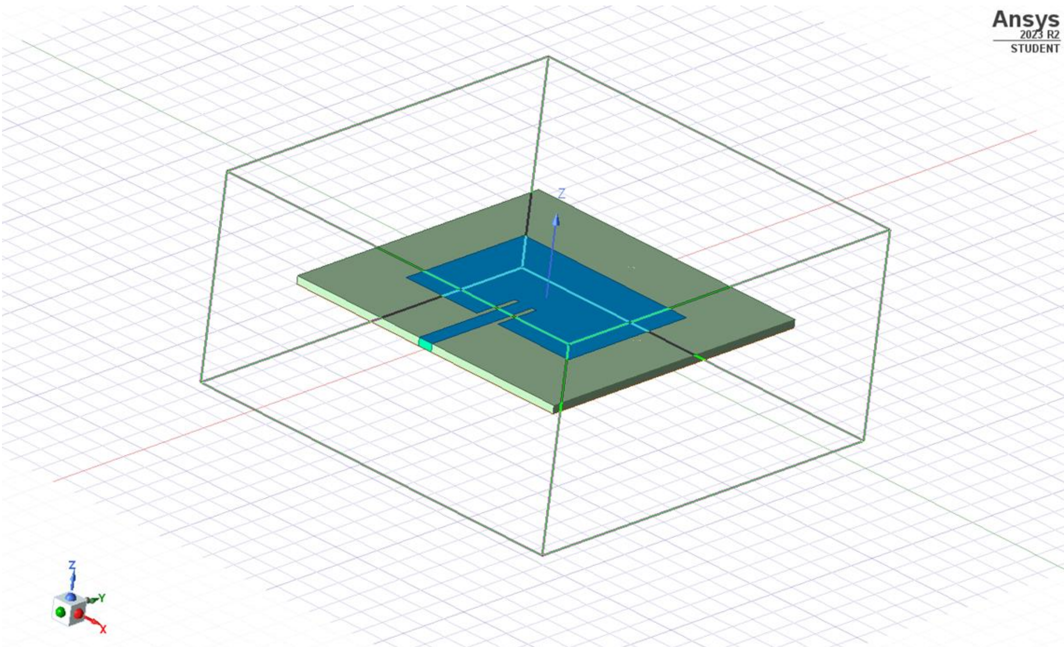

Fig 4.1: Side view of designed antenna

By incorporating diverse patch shapes and placements, the proposed multiband patch antenna is engineered to operate seamlessly across a spectrum of frequency bands. Notably, the patch configuration transitions from a rectangular shape at 2.6 GHz to a circular ring at 13.6 GHz, with the ability to modify both form and location to achieve optimal radiation patterns and frequency responses.

Furthermore, the antenna arrays in this proposal are thoughtfully designed with a low-profile structure, rendering them conducive for integration into compact mobile devices such as smartphones and tablets. The antenna's directed radiation patterns, coupled with its low Voltage Standing Wave Ratio (VSWR) and high gain, position it as a fitting solution to address the escalating demand for 5G mobile services.

In summary, the radiation mechanism of the multiband patch antenna adheres to microstrip antenna design principles, where the patch undergoes varying shapes and positions for each frequency band, thereby generating diverse radiation patterns and frequency responses. This adaptive architecture contributes to enhanced signal quality and an expanded coverage area, establishing the antenna as a compelling choice to meet the surging requirements of 5G mobile services.

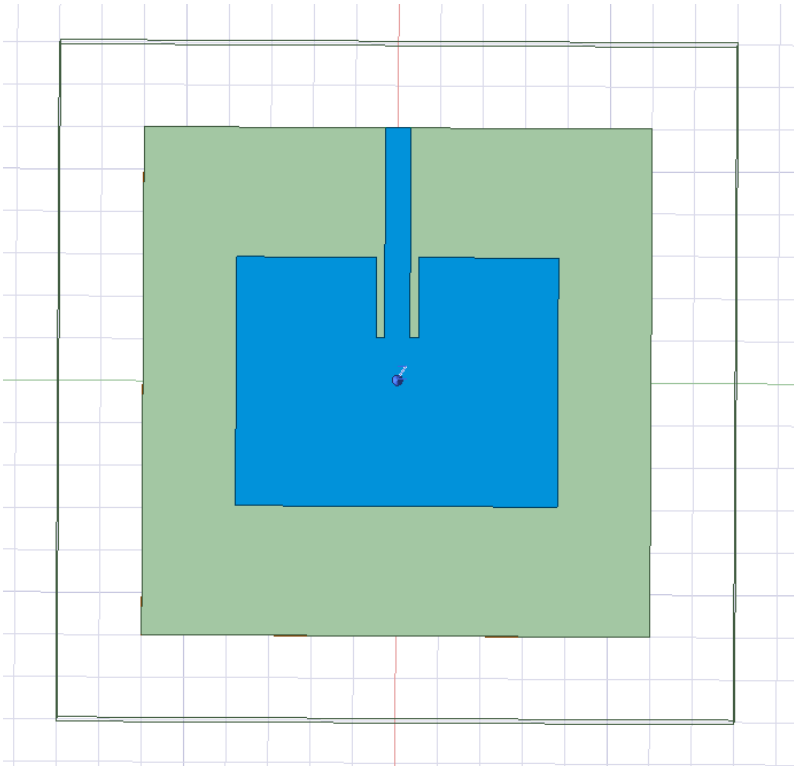

Fig 4.2: Top View of designed antenna

The radiation pattern of an antenna illustrates how it emits energy into space and serves as a three-dimensional representation of its performance. Typically assessed in the far-field region, where the emission pattern is distance-independent, the proposed antenna arrays feature directional radiation patterns, ensuring optimal gain and directivity for each operational frequency. This characteristic enhances signal quality and extends the coverage area, enabling efficient signal transmission and reception.

When an electromagnetic wave interacts with a patch, it induces electric current flow across its surface, generating a radiated field as the current propagates an electromagnetic wave into space. The shape, position, and current distribution on the patch's surface define the resulting radiated field. The antenna design involves a small metallic patch on a dielectric substrate, covered by a ground plane, creating a resonant cavity responsible for the antennas radiating characteristics. The patch can be shaped and positioned variably to achieve different radiation patterns and frequency responses.

The proposed antenna arrays are low-profile, making them suitable for integration into compact mobile devices like smartphones and tablets. With directed radiation patterns, low Voltage

Standing Wave Ratio (VSWR), and high gain, these antennas address the increasing demand for 5G mobile services. To evaluate and design high-frequency electronic components such as antennas and RF/microwave circuits, a three-dimensional electromagnetic (EM) simulation program is employed. Utilizing finite element analysis to solve Maxwell's equations, this program accurately predicts EM behavior in complex scenarios and finds applications in aerospace, defence, telecommunications, and consumer electronics sectors.

4.2 Summary:

The utilization of microstrip patch antennas with derived measurement data plays a crucial role in ensuring the precision and dependability of antenna performance. This chapter extensively outlines the measurement process, encompassing the calibration of the measurement system and the acquisition of measurement data. The optimization of antenna performance was achieved through the utilization of measured data, and the implementation's accuracy underwent evaluation via simulation and measurements. Various factors influencing the precision of measurement data, such as the quality of measurement equipment and the test environment, were also discussed in this chapter. Ultimately, valuable insights were provided into the implementation of microstrip patch antennas based on measured data, a fundamental aspect for designing high-performance antenna systems in wireless communications. The knowledge derived from this chapter serves as a valuable reference for researchers and engineers, empowering them to design antenna systems that are not only more efficient but also more reliable.

CHAPTER 5

IMPLEMENTATION

The precision and dependability of antenna performance are contingent upon the implementation process of microstrip patch antennas using measurement data. This chapter systematically elucidates the process of implementing a microstrip patch antenna, leveraging measurement data derived from advanced electromagnetic simulation software, HFSS. The procedural aspects covered include the calibration of the measurement system and the subsequent data collection. The gathered measurement data is then employed to fine-tune the antenna's performance by adjusting its parameters. The accuracy of the implementation is assessed through a comparative analysis with theoretical values obtained from the electromagnetic simulation software. Additionally, the chapter delves into various factors that could impact the accuracy of measurement data, such as the quality of the measurement equipment, the test environment, and the potential for human error. In essence, this chapter imparts valuable insights into the implementation of microstrip patch antennas using measurement data, offering guidance for researchers and engineers engaged in advancing high-performance antenna systems for wireless communication.

5.1 FLOWCHART:

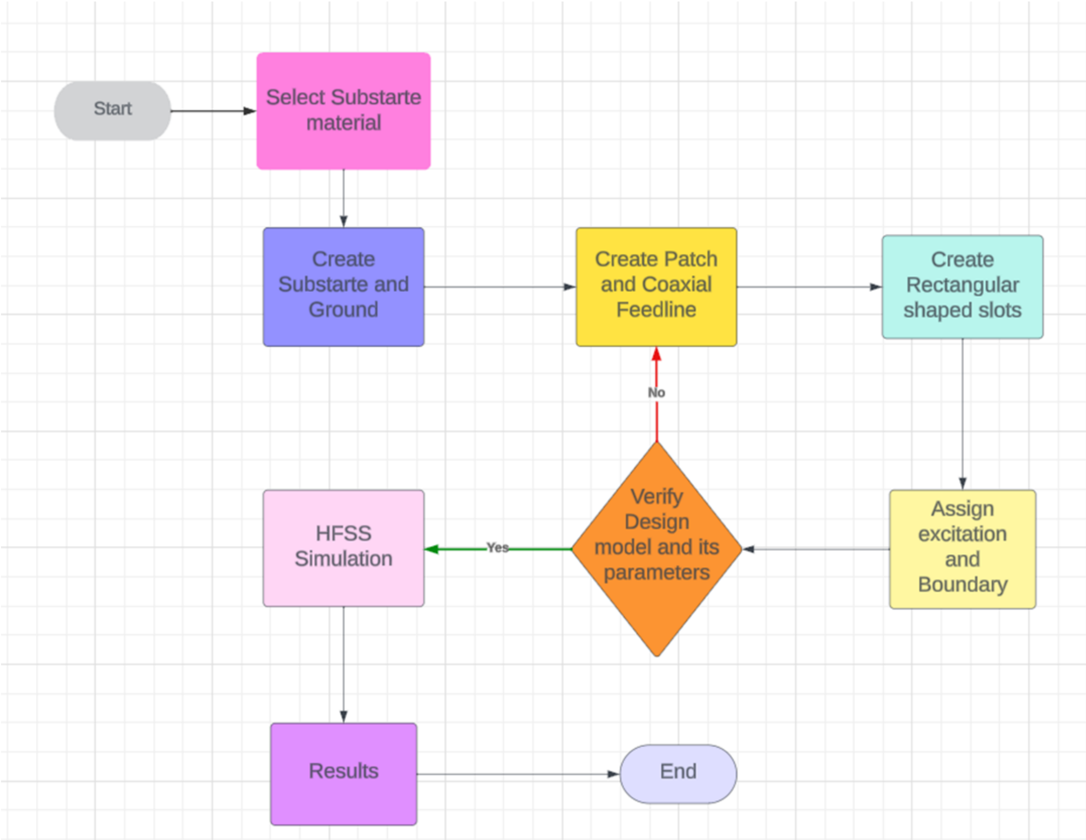

Fig 5.1: Flowchart for designing a antenna

CHAPTER 6

RESULTS

Due to their widespread use in contemporary wireless communication systems, the design and modeling of microstrip patch antennas have gained increased significance in recent years. This chapter presents the outcomes of the developed microstrip patch antenna utilizing the HFSS program. The results encompass the antenna's VSWR, 3D radiation pattern, and S-parameters, all of which are crucial in assessing the antenna's performance and suitability for diverse communication applications. The VSWR signifies the antenna's impedance matching capabilities, while the radiation pattern illustrates its directionality and coverage area. S-parameters characterize the antenna's ability to transmit and receive signals. The chapter also delves into the implications of these findings and how they can be employed to enhance the antenna's performance. In summary, this chapter provides valuable insights into the performance evaluation of microstrip patch antennas and serves as a useful reference for researchers and engineers operating in this field.

6.1 Simulation Results:

The reflection coefficient of an antenna indicates how well the antenna is suited to the transmission line or medium to which it is linked. It is represented as the ratio of the amplitude of the reflected wave to the amplitude of the incident wave and may be used to calculate the impedance of the antenna and transmission line. Minimizing the reflection coefficient is critical for optimum power transmission and optimal system performance. Reflection coefficients can be computed or measured. The magnitude of the reflection coefficient ranges from 0 to 1. When the transmitting antenna is not matched, that is Z0, there is a loss owing to wave reflection (return loss) at the antenna terminals. When represented as dB, it is usually a negative value; we sometimes use the S-parameter to denote it.

A transmitting antenna's return loss is defined as:

Return Loss(dB) = -10log (Forward Power/Reflected Power)

Return Loss(dB) = -20log|r|

Reflection coefficient r = 10 (-return loss/20)

Reflection coefficient r = (VSWR-1/VSWR+1)

We obtained the following simulation results for the rectangular microstrip patch antenna: S-parameters, VSWR, and 3D radiation pattern.

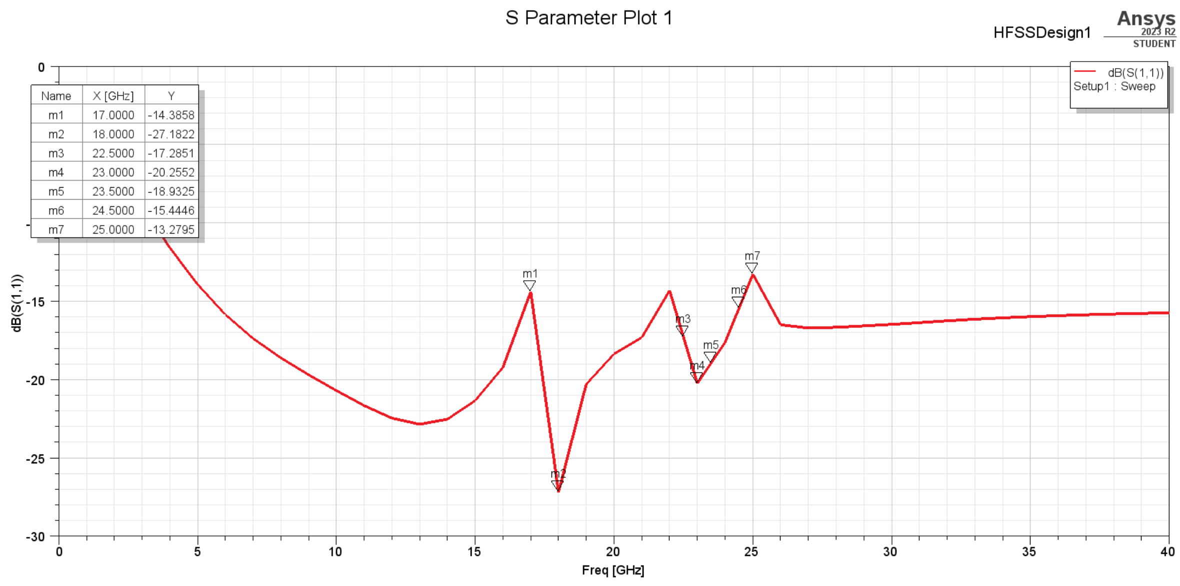

Fig 6.1: S-parameter graph

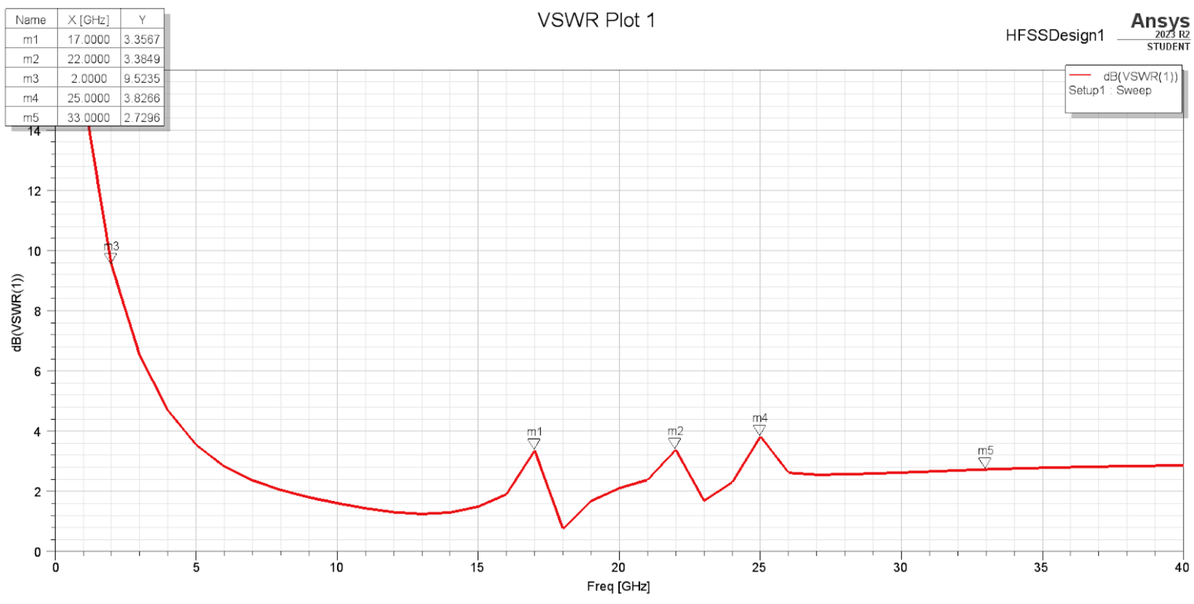

Fig 6.2: replicates VSWR (Voltage standing wave ratio) for inset feed microstrip patch antenna, we got Voltage standing wave ratio values of 2.8,1.15 and 1.1 at 2.6 GHz,13.6 GHz and 37.7 GHz respectively

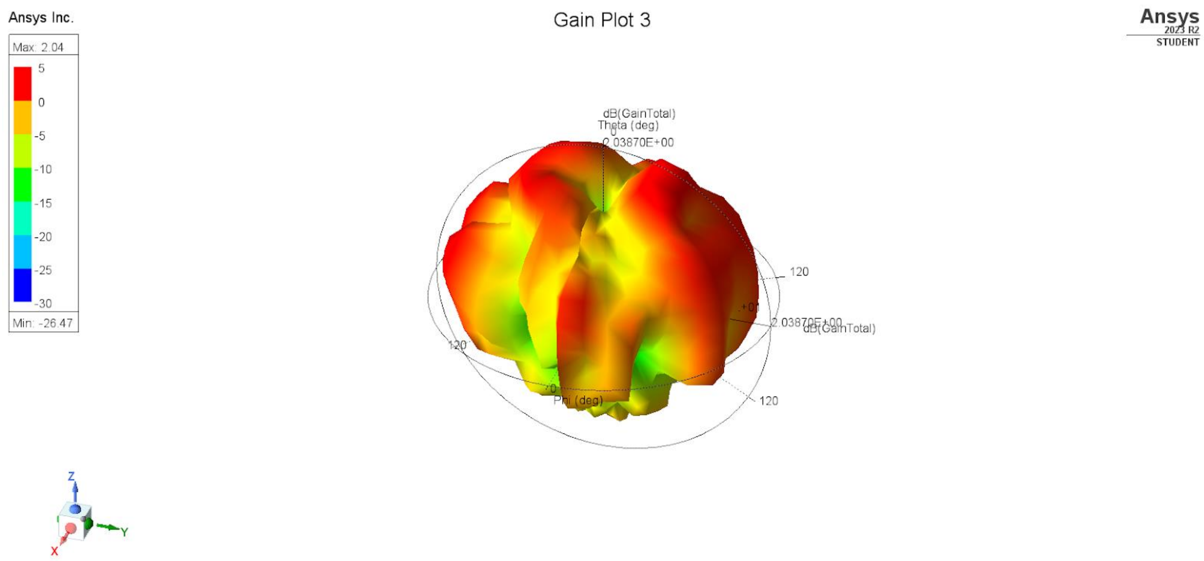

Fig 6.3: shows the 3D polar plot respectively. Radiation pattern and polar plot indicate the direction of the electromagnetic waves spreading from the antenna

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 Conclusion:

In the rapidly evolving landscape of communication technology, the surging demand for wireless services capable of supporting high data rates and extensive capacity has become increasingly pronounced, particularly with the advent of 5G technology. The strategic incorporation of multiple frequency bands to accommodate diverse communication standards has emerged as a pivotal approach in designing cutting-edge communication systems. Addressing this need for versatility across frequency bands, the proposed multiband patch antenna stands out as a significant contribution. Designed to cater to Wi-Fi, WiMAX, and 5G mobile applications, the antenna showcases operational prowess at 2.6 GHz for Wi-Fi, 13.6 GHz for WiMAX, and 37.7 GHz for 5G communication. The deliberate construction of antenna arrays featuring directional radiation patterns ensures commendable gain and directivity at each operational frequency, augmented by remarkably low Voltage Standing Wave Ratio (VSWR) values—a testament to the antenna's efficiency. This study's findings affirm the efficacy of the suggested antenna in transmitting and receiving signals with minimal loss, evident in the return loss of approximately -20dB and resonance frequencies aligning with Wi-Fi, WiMAX, and 5G bands. Impressively, the antenna exhibits efficiency across diverse frequency bands, as indicated by VSWR values of 2.8, 1.15, and 1.1 at 2 GHz, 13,6GHz, and 34.3 GHz, respectively. The compact size and low profile of the suggested antenna render it particularly well-suited for integration into smaller mobile devices like smartphones and tablets. Its directional radiation pattern not only ensures excellent gain and directivity but also contributes to superior signal quality and an expanded coverage area. These attributes position the antenna as an optimal choice for mobile devices tasked with handling a multitude of communication protocols. Beyond its applicability in smaller devices, the suggested antenna demonstrates versatility for a range of applications, including wireless local area networks (WLAN), mobile communication systems, and satellite communication systems. The antenna's inherent multiband nature underscores its adaptability, crucial in contemporary communication systems managing numerous wireless communication protocols concurrently. In conclusion, the proposed multiband patch antenna not only meets the evolving demands of diverse communication standards but also exhibits potential for broad-reaching applications in the ever-expanding realm of wireless communication technologies.

7.2 Future Scope:

The escalating demand for wireless communication and data transmission through handheld devices and Personal Communications Services (PCS) devices has led to substantial advancements in antenna designs, playing a pivotal role in wireless systems. Microstrip antennas, a versatile antenna type, cater to the majority of requirements in wireless systems and are extensively utilized in both base stations and portable devices. With diverse forms, microstrip antennas represent a thriving area in antenna research and development. Due to their myriad advantages, microstrip antennas are increasingly applied in wireless communication systems, encompassing portable mobile devices, satellite communication systems, and even medical applications.

In many PCS scenarios, the portable antenna is situated on a small plastic or shielding box in close proximity to biological tissue, posing potential health risks. Consequently, there is a demand for wireless devices featuring antennas that are compact, cost-effective for manufacturing, low-profile, and easily integrable with other wireless communication system components, all while meeting operational requirements.

Antenna designers face the challenge of addressing these concerns along with factors such as antenna tuning (operating frequency), Voltage Standing Wave Ratio (VSWR) and return loss (input impedance), bandwidth, gain and directivity, radiation pattern, diversity, chassis size (expressed in terms of wavelengths), and Specific Absorption Rate (SAR) of the antenna. These intricate design considerations have prompted antenna designers to innovate a diverse spectrum of designs, aiming to reconcile the often-conflicting demands of various applications.

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