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Original Article

Design of Microstrip Patch Antenna for Radar and 5G Applications

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Abstract *- From IG to 4G, there have been four generations of advancements in mobile wireless technology. The use of the internet by more people is currently causing growth in wireless communication technology. Higher data rates are drawing a lot of attention due to wireless transmission's lack of flexibility, poor quality, lost connections, and insufficient coverage. The current (4G) generation of wireless connectivity is unable to satisfy customer needs. At the moment, several mobile technologies operate on the 900, 1800, 2100, and 2300 MHz frequencies. Low frequencies result in extensive coverage and minimal attenuation. 5G wireless communication research has been implemented to address this issue. The new version (5G) has several key benefits, including a larger bandwidth, improved cell resolution, and the capacity to offer tens of thousands of users data speeds of at least one gigabit per second. Most 5G research takes place between 6 GHz and 100 GHz. One of 5G's objectives is to connect millions of devices. This technology might be used in smart homes. Higher frequency bands have recently seen a lot of scholarly interest in the development of Ku-band antennas (12-18 GHz). The Ku band is used for a variety of things, including broadcast satellite services, fixed satellite police radar systems, and television transmission over networks. Several literature reviews on Ku-band and 5G antennas have recently been published. Mobile phones use Microstrip patch antennas more frequently due to their small size, affordable price, and lightweight nature. Examples include biological applications, aircraft, satellite communications, radars, and more. A microstrip antenna has good return loss, voltage standing wave ratio (VSWR), and capacity. Patch antennas have a number of advantages, such as low weight, low profile planar design, inexpensive manufacturing, and microwave integrated circuit technology that enables integration. For the purpose of creating a microstrip patch antenna, the dielectric substrate has a ground plane on one side and a radiating patch on the other. Feeding is accomplished using an electromagnetically connected (EMC) microstrip patch antenna with a coaxial probe and a microstrip line. The E-shape microstrip patch antenna is ideal for wireless communications systems, medical applications, mobile phones, pagers, GPS, radar systems, and satellite communications systems, as well as military applications such as rockets, aircraft missiles, and other similar devices. One of the antenna types in the telecommunications industry that isexpanding quickly is the microstrip antenna.*

Keywords *- IOT, Wireless Communication Network, Industrial IOT Application, IOT Smart Cities, IOT in Agriculture.*

I. INTRODUCTION

Microstrip patch antennas provide several benefits over other antennas, including their small size, low profile, ease of fabrication and integration, and low cost. Microstrip antennas with properly spaced slots produce excellent bandwidth, resonant frequency, gain, impedance, and return loss. The antennas are fed with the use of feeding mechanisms. Microstrip feed line, coaxial feed, aperture coupling feeding, and proximity coupling feeding. The manufacturing ease, price, hardware implementation, impedance matching, and unwanted radiations brought on by the feeding technique are considered while selecting the feeding approaches. [19]. An important component of wireless communication is the microstrip patch antenna. It has a dielectric substrate, a thin copper- or gold-colored metallic patch, and a ground plane. The ground plane and patch are isolated from the dielectric substrate. Numerous forms, such as circular, rectangular, square, elliptical, triangular, and dipole, are available for patch antennas[20].

The patch antenna offers a wide range of configurations due to its expanding use in wireless communication. In recent years, wireless communication has seen significant expansion [7]. Patch antennas are simple to design, and lightweight and all Fields/areas are spread across the substrate, which is inexpensive [8]. Using the ultra-high-frequency (UHF) or microwave sector of the radio-frequency (RF) spectrum, a radar instrument is used to examine the function and movement of objects [9]. Radar uses electromagnetic fields that reflect precipitation at particular frequencies to follow storm systems. [10]. Air traffic control, aircraft navigation, and sea navigation all use radar equipment and specialized radar maps. The company that works with NASA [11] creates extraordinarily accurate topographical maps of the earth's surface. The International Telecommunications Union (ITU) has designated frequency bands of 28, 38, 60, and 73 GHz for 5G mobile communications [12]. Wireless communication is a cutting-edge technology that is widely used in current applications. It was modern technology that had advanced at a breakneck speed. 5G mobile communication is a technology with a wireless application presently. High-speed wireless data transport is possible with 5G wireless mobile communication, which uses millimeter wave technology. Because of its wireless data transfer capability, this technology has been applied to various fields, including the Internet of Things (IoT), Smart Cities, and so on[13].

The upcoming 5G technology calls for antennas with previously unseen features on a user terminal, like beam forming capability of the radiation pattern to do spatial scanning. [14, 15]. This requirement poses many design obstacles, primarily in the millimetric wave bands, such as achieving an acceptable trade-off between technological design issues and commercial goals such as low cost, small size, radiation efficiency, antenna gain, and broadband performance [16]. Among other choices, microstrip antennas with coplanar radiation elements and feeding networks appear to be a solid solution for achieving a functional part with a good balance of performance and manufacturing complexity for 5G applications. In LTCC technology, microstrip antennas printed on Duroid substrate exhibit good performance compared to standard designs [17-18]. In the development of modern wireless communications, such as the Global Positioning System (GPS), wireless local area networks, mobile communication systems, and microwave sensors, patch antennas have been more significant.

A microstrip patch antenna for radar and 5G applications will be introduced and built to address these problems; as a consequence, this antenna is designed to operate with a bandwidth of between 3.1 GHz and 10.6 GHz. There are some issues or problems in the previous antennas, such as:

- due to the flexibility, inadequate coverage, low quality, and lost connections
- low bandwidth

II. LITERATURE REVIEW

Microstrip patch antennas for wireless Applications are the challenges and issues of developing Microstrip patch antennas and system applications discussed in this paper and the concepts of patch antenna systems for 5G applications.

A. History of Antenna

Any radio device needs an antenna to function. An antenna or aerial, as used with a transmitter or receiver, is the interface between radio waves traveling across space and electric currents flowing through metal conductors. A radio transmitter sends an electric current to the Antenna's terminals during transmission, and the Antenna emits the energy from the current as electromagnetic waves (radio waves). An amplifier receives an electric current from an antenna at its terminals after intercepting a portion of a radio wave's energy. An antenna is a collection of conductors (elements) that are electrically linked to a receiver or transmitter. Omnidirectional antennas transmit and receive radio waves equally in all horizontal directions. On the other hand, unidirectional antennas preferentially transmit and receive radio waves in a single direction (directional, high- gain, or "beam" antennas). An antenna may incorporate non- transmitter components such as parabolic reflectors, horns, or parasitic devices that steer radio waves into a beam or other desired radiation pattern.

The first antennas were built by German physicist Heinrich Hertz in 1888 as part of his groundbreaking research to demonstrate the existence of waves predicted by James Clerk Maxwell's electromagnetic theory. Hertz placed dipole antennas at the center of parabolic reflectors for transmitting and receiving. For designing practical antennas for long-distance wireless telegraphy, Guglielmo Marconi won the Nobel Prize in 1895 [21- 24].

Figure 1: Antenna

a. Basic Types of Antenna

Antennas are divided into various types depending on

- The physical structure of the Antenna.
- The frequency ranges of operation.
- The mode of operations

b. Physical Structure

Following are the types of antennas according to the physical structure.

- Wire antennas
- Aperture antennas
- Reflector antennas
- Lens antennas
- Microstrip antennas
- Array antennas

c. Frequency of Operation

Following are the types of antennas according to the frequency of operation.

- Very Low Frequency (VLF)
- Low Frequency (LF)
- Medium Frequency (MF)
- High Frequency (HF)
- Very High Frequency (VHF)
- Ultra-High Frequency (UHF)
- Super High Frequency (SHF)
- Microwave
- Radio wave

d. Mode of operations

Following are the types of antennas according to the modes of applications –

- Point-to-point communications
- Broadcasting applications
- Radar communications
- Satellite communications [25].

Table 1: Summary of Antenna Types and Applications

Type ofAntenna	**Examples**	**Applications**
Wire Antennas	Dipole antenna,Monopole antenna, Helixantenna, Loop antenna	Personal applications, buildings, ships,automobiles, space crafts
ApertureAntennas	Waveguide (opening), Hornantenna	Flush-mountedapplications,aircraft, spacecraft
ReflectorAntennas	Parabolic reflectors, Corner reflectors	Microwave communication,satellite tracking, radio astronomy
Lens Antennas	Convex-plane, Concave-plane, Convex-convex, Concavo-concave lenses	Used for veryhigh-frequency applications
MicrostripAntennas	Circular-shaped,Rectangular shaped metallicpatch above the ground plane	Aircraft, satellites, missiles, cars,mobile phones, etc.
Array Antennas	Yagi-Uda antenna, Microstrip patch array, Aperturearray, Slotted waveguide array.	Used for very high gain applications, mostly when needed to control the radiation pattern.

B. Concepts of Microstrip Patch Antenna

Because microstrip is the most innovative and successful antenna technology ever,. Its success is due to well- known benefits.

However, it has significant disadvantages, the most notable of which are the inherent narrow bandwidth, narrow impedance, low axial ratio (AR), tiny gain, reduced power handling capability, and low efficiency. Several approaches for increasing bandwidth have been explored and discussed in. The inventor of practical microwave patch antennas is considered the father. Deschamps invented the microstrip antenna in the United States in 1953. Galton and Bassinet of France patented a 'flat' aerial that may be used in the UHF band in 1955. Despite being created, the patch antenna was not utilized for a long time. Byron created the first microstrip radiator. The sidewinder missile's first on a data link, then on the semi-active seeker in the sprint missile. The construction of a microstrip radiator did not become active until the early 1970s, when there was an immediate need for low-profile conformal antennas on emerging next-generation missiles. In the early 1970s. This receiving wire was a directed strip a few wavelengths long and half a wavelength wide. A dielectric strip separated this receiving wire from the ground plane. The strip was fed at irregular intervals using coaxial connections along the emanating edges and is used as an array. Munson pioneered a novel type of microstrip wrap-around antennas appropriate for missiles in 1974 by combining a microstrip radiator with a microstrip feednetwork on the same substrate.

The condition of patch antennas may have been characterized in the early 1980s; most of the studies concentrated on the features of rectangular, circular, annular-ring, and equal triangular patches, which were mainly established theoretically (through the cavity model) and proven experimentally. Broadside radiation patterns are typical of the lowest mode [27-42]. The use of microstrip patch antennas is crucial for wireless communication. It has a ground plane, a thin copper or gold metallic patch, and a dielectric substrate. Patch antennas come in various sizes and shapes, including circular, rectangular, square, elliptical, triangular, and dipole. The most common geometries for Microstrip antennas are circular and rectangular. The most demanding applications, particularly 5G applications, utilize these two patch antennas [43–44].

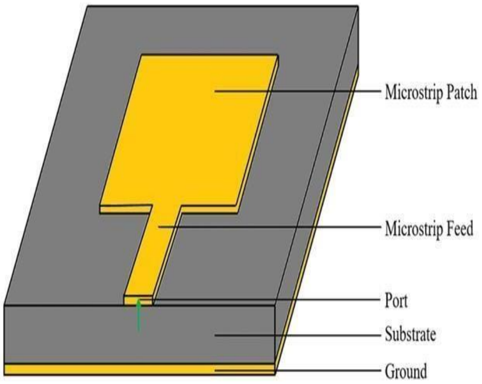

Figure 2: Microstrip Patch Antennas

a) The Advantages or Benefits of a Microstrip Patch Antenna

- The advantages or benefits of a microstrip antenna are as follows:
- They function at microwave frequencies, where designing conventional antennas is impractical.
- Any PCB may easily have microstrip-based antennas engraved on it, making it simple to debug problems while designing and developing products. The results from the microstrip design are visible and reachable from the top. As a result, they are simple to build and pleasant on the device's curved surfaces. As a result, their integration with MICs or MMICs is simple.
- By feeding the patch antennas to symmetry along the center line, other undesirable modes are least likely to be excited.
- The microstrip patches are simple to etch and come in various shapes, including rectangular, square, and triangular.
- Because of their cheaper manufacturing costs, they can be produced in large quantities.
- They can accommodate various frequency bands (dual, triple).
- They support both linear and circular dual polarization.
- Their weight is light.
- They are durable when mounted on the gadgets' solid surfaces.

b) Drawbacks of Microstrip Patch Antenna

The following are some drawbacks of microstrip antenna:

- Printed dipole antennas, microstrip patch antennas, and microstrip slot antennas produce spurious radiation.
- It provides poor gain and low efficiency due to conductor and dielectric losses.

- Its reduced power handling capacity and higher cross-polarization radiation levels.
- It has a reduced impedance bandwidth by nature.
- Feeds and other junction points radiate from the microstrip antenna construction [26].

C. Radar Communication Microstrip Patch Antenna Analysis and Design

Due to their attractive qualities, such aitsir affordability, portability, and low-profile planar design that can be readily made conformal to the host surface, microstrip patch antennas have become more and more popular in recent years. To overcome some of the shortcomings of patch antennas, such as poor gain, low efficiency, low directivity, and restricted bandwidth, incisions in the ground must be made, patch height must be increased, substrate thickness must be decreased, and substrate permittivity must be increased. The aforementioned methods can also increase the bandwidth of the patch antenna as a percentage. This patch antenna is designed using an FR4 (Flame Retardant 4) circuit board, which offers excellent performance throughout the production process. In this instance [45].

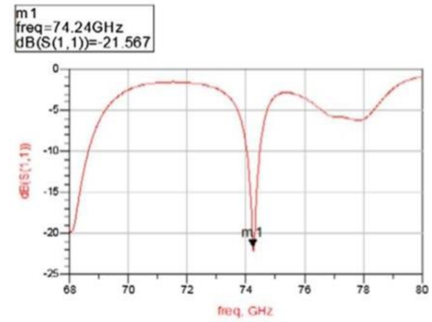

Figure 3: Simulated Reflection Coefficient of HG11 Z.

a) Design and Analysis of a slotted Microstrip Antenna for 28 GHz 5G Communication Networks

Millimeter wave bands are used by the fifth generation (5G) of mobile communication technologies to boost user capacity and achieve high data rates. Low profile, lightweight, high gain, and simple structure antennas are needed for 5G communication systems to preserve dependability, mobility, and efficiency. Due to the low atmospheric absorption rate of electromagnetic waves at 28GHz, this study intends to construct a directed single-element slotted microstrip antenna with a small size that can function at that frequency for 5G applications. The suggested antenna is simulated using High- Frequency Structure Simulator (HFSS) software on an FR4 substrate with 4.4 dielectric constant, 0.8 mm thickness, and 0.02 loss tangent. The patch has been altered to meet the needs of the intended Antenna [47].

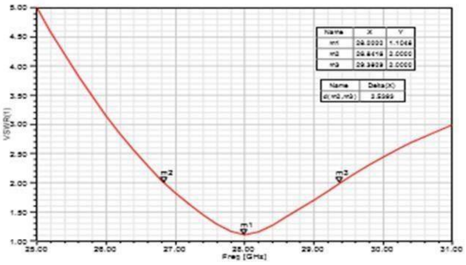

Figure 4: Return Loss versus the Frequency of Antenna

b) Microstrip Antenna for 5G Broadband Communications: Overview of Design Issues

This contribution offers two real implementation scenarios for single-patch antennas at 28GHz and 60GHz. The design problem of reconciling antenna performance criteria and manufacturing constraints is described. We will look at the impact of three distinct design difficulties on this fundamental part of an array antenna (47).

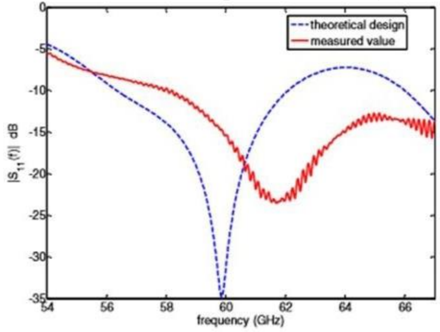

Figure 5: Comparison of Theoretical and Experimental Parameter s11(f) for the Prototype Fabricated at60GHz I

c) The Communication Solution for LTE System under Radar Interference Circumstance

Based on Resolution 223 of the World Radiocommunication Conference from that year. The Third Generation Partnership Project (3GPP) has launched Long Term Evolution (LTE), the next generation of mobile communications, on the frequency bands of 1710-1885MHz, 2300-2400MHz, and 2500-2690MHz[1,2]. The wireless communication system has sped up the development of 3GPP LTE. Additionally, LTE version R9, the executive standard for LTE, was released in March 2010. The Time Division Long Term Evolution (TD-LTE) system was developed by the Chinese Mobile Communication Corporation (CMCC) and is currently being tested and utilized across the country [48].

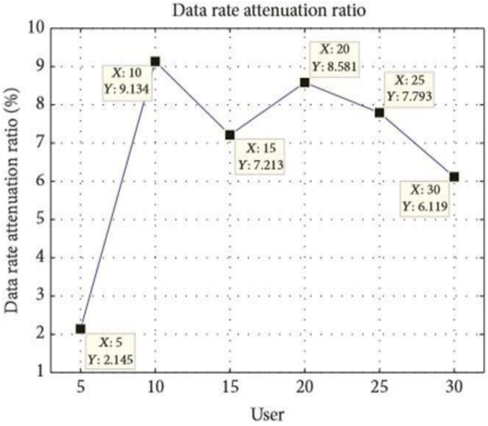

Figure 6: Data Rate Attenuation Ratio

d) For 5G communication, Mm Wave novel Multiband Microstrip patches antenna design:

This study presents a novel mmWave multiband patch antenna for 5G communication. The maximum bandwidths of the 5G millimeter wave antenna's resonances at 37 and 54 GHz bands are 5.5 and 8.67 GHz, respectively. The microstrip technique used to create the 5G mmWave multiband antenna has the following benefits: lightweight, low cost, low profile, high gain, and efficiency. The 5G antenna was created with CST MWS mog software. It has a small form factor and measures 7.2x5.0x0.787 mm3. The 5G multiband antenna achieves gains of 5 and 6 dBi, respectively. It is easy to use for 5G connectivity and to integrate into smart devices. Index terms include mmWave, 5G Communication, 5G Microstrip Antenna, and Multiband 5G Antenna [49].

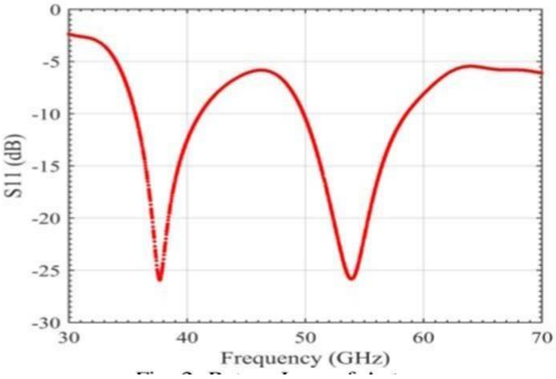

Figure 7: Return Loss of Antenna

e) Design of a Millimetre Wave Microstrip Patch Antenna and Its Array for 5G Applications

For 5G applications, a millimeter wave microstrip patch antenna and related array are recommended. The Rogers RT Duroid 5880 substrate, which has a standard thickness of 0.787 mm, a relative dielectric constant (r) of 2.2, and a tan of 0.0013, serves as the foundation for the 5G Microstrip patch. The antenna has a bandwidth of 1.318 GHz, a return loss of -19.5 dB, and a resonance frequency of 24.85 GHz. A 1x4 element array with tapered line feeding makes up the suggested antenna. There are four separate frequencies in the antenna array: 23.2 GHz, 27.09 GHz, 31 GHz, and 42.5 GHz.

The Antenna and its array can be used for 5G mobile communication due to their tiny size. There is a discernible increase in gain with the variety of antennas. Index terms include Microstrip Patch, Bandwidth, 5G, Antenna Array, and

Tapered Line [50].

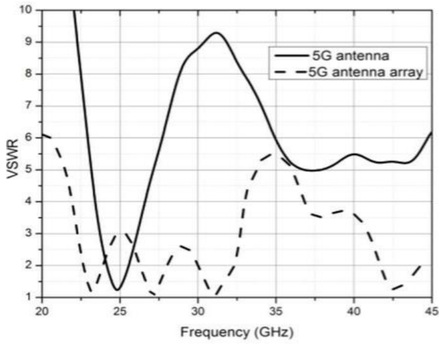

Figure 8: VSWR Plot for 5G Antenna and 5G Antenna Arrayin the 20-45 GHz

f) Design of Wideband Microstrip Antenna with Parasitic Element For 4G/LTE Application:

This study describes the design of a wideband microstrip antenna for mobile communication, namely 4G/LTE. The frequency ranges used by 4G/LTE applications include 850 MHz, 900 MHz, 1800 MHz, and 2300 MHz. As a result, designing a wideband antenna offers an option for supporting all of these bands in a single antenna. One way to achieve the wideband antenna standard that can be employed is to include parasitic components in a rectangular microstrip patch antenna.

The Antenna is built on an FR4 substrate with a dielectric constant of 4.6 and a thickness of 1.6mm. Copper material with a thickness of 0.035mm was used for the ground plane, feed line, patch, and parasitic components. This approach yields a frequency band ranging from 793.66 MHz to a bandwidth of 1707.64 MHz. Between 850-900 MHz, an approaching omnidirectional radiation pattern is observed, with major variations at 1800-2300 MHz. The gain rises as the operating frequency increases. The maximum improvement in the 1800- 2000 MHz frequency is 4.47 dB. The antenna design result can be used for 4G/LTE applications due to the properties of this Antenna [51].

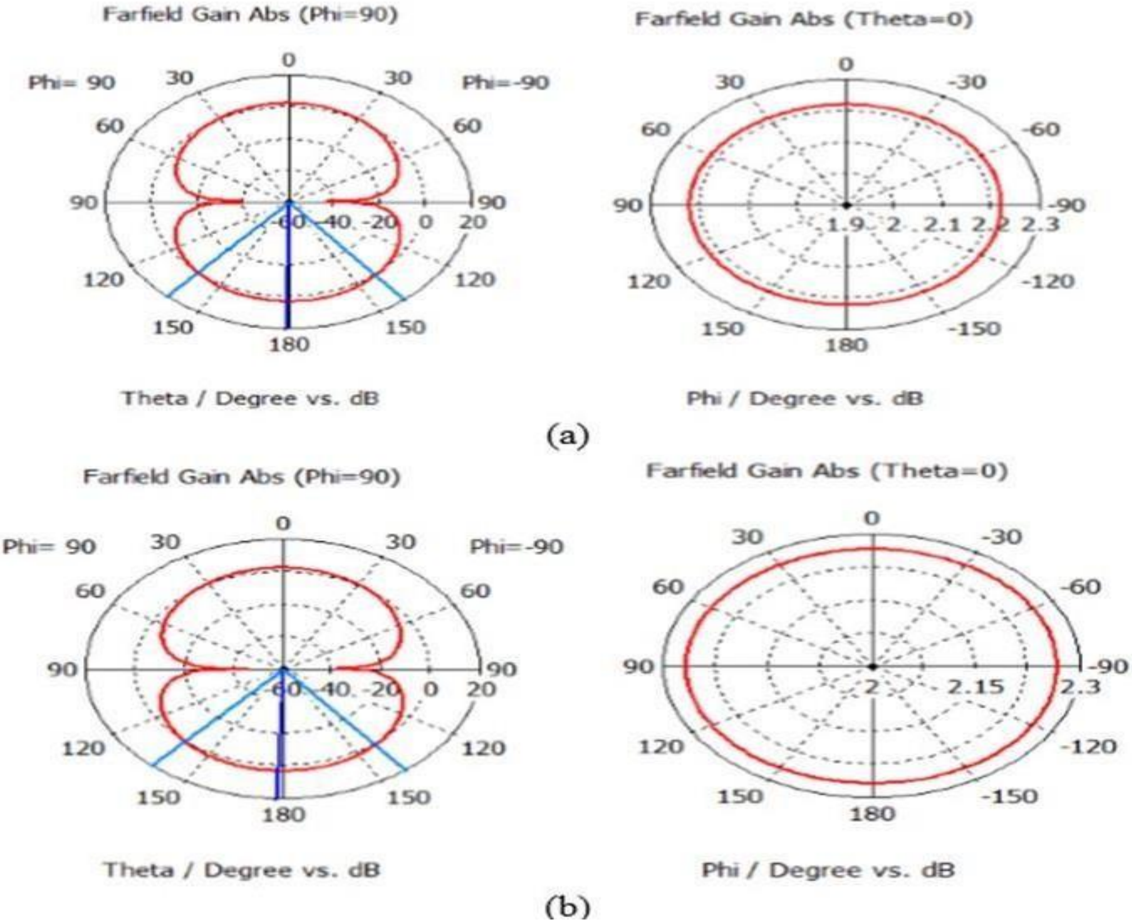

Figure 9: Radiation of the Proposed Antenna 900 MHz

g) Compact reconfigurable dual frequency microstrippatch antenna for 3g and 4g mobile communicationtechnologies:

This article introduces a groundbreaking, compact, frequency-diverse patch antenna. This Antenna may be altered to switch between the two mobile communication standards, 3G and 4G, by changing the mode of two PIN diodes from ON-ON to OFF-OFF. The prototype of this Antenna has been created and examined. The Antenna is printed on a 1.5 mm thick FR4 substrate and has a simple shape and compact structure. Its measurements are 45, 38, and 1.5 mm3. The measurement results supported the computer forecasts regarding frequency diversity performance [52].

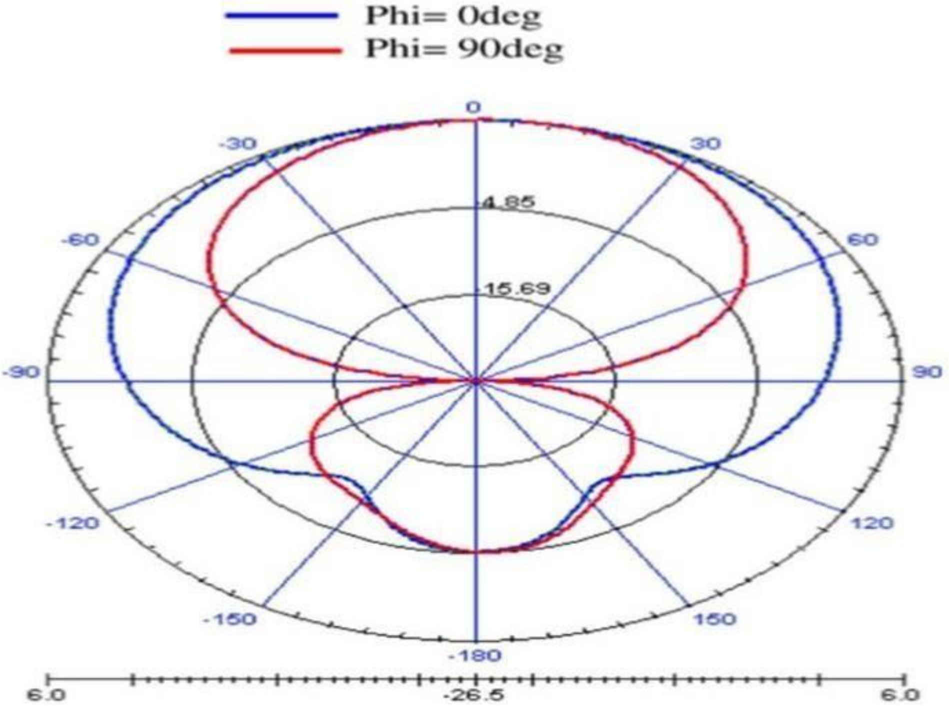

Figure 10: E- and H-plane Radiation Patterns for the Proposed Reconfigurable Antenna at 2.6 GHz for theOFF– OFF State

III. RESEARCH PHASES

The main stages of the investigation are depicted in the flowchart in Figure 3.1. The literature review occurs in phase I, as shown in Figure 3.1, where the effort has focused on analyzing the prior and current works to proceed to phase II. Phase III of this project has seen the fabrication and testing of the project's finalized designs from phase II. Figure 3.1 illustrates the research process flowchart in the four sections. The details of these phases are discussed briefly in the following subsections.

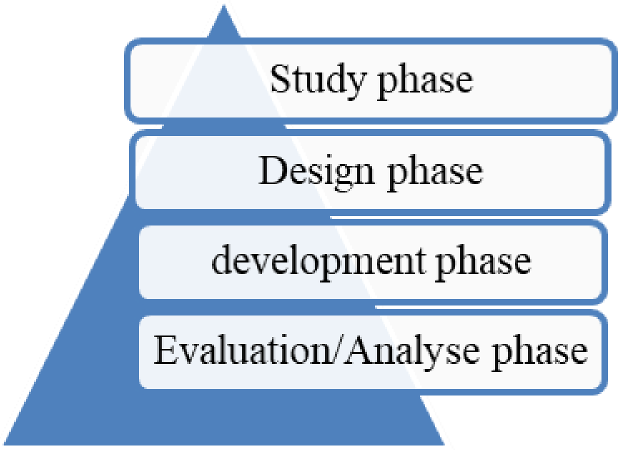

Figure 11: Research Process Flowchart

The main challenges of creating a microstrip antenna for wireless applications during the research phase are discussed. The issues with dual-band antennas for radar and 5g applications are demonstrated in these sentences. Due to its size and profile, the planar patch antenna was selected for the defective ground structure technique.

A. Design Framework:

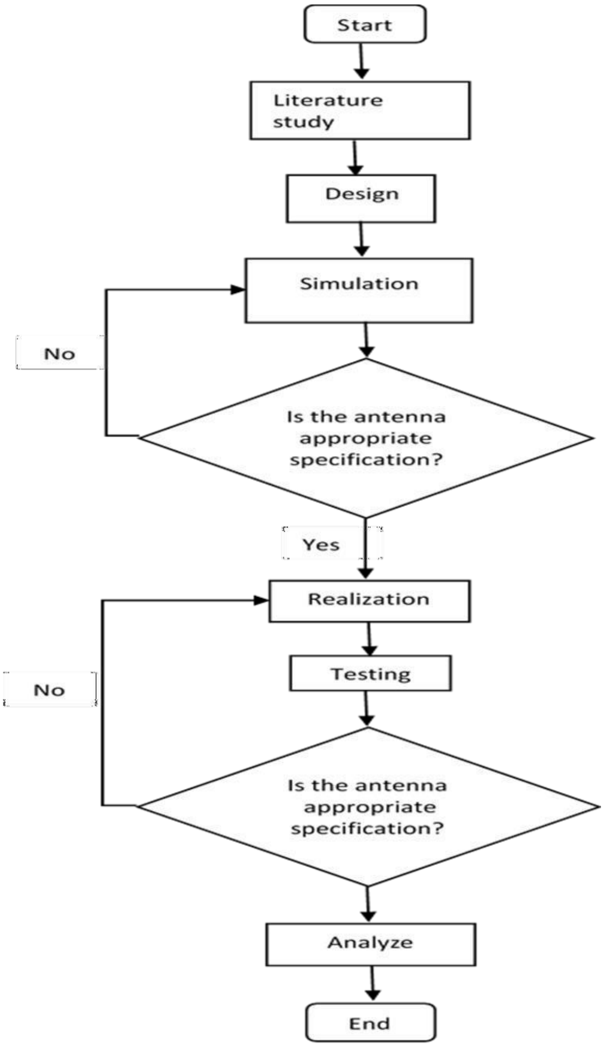

Figure 12: Design Framework

B. CTS Microwave Studio Simulation and Formulation

The following formulas are used for designing antennas of a single operating frequency. The computed dimensions of the proposed Antenna will be obtained using these formulas, and then necessary adjustments will be added to the measurements to satisfy UWB specifications.

$w=c/(2f\sqrt{((\varepsilon_r+1)/2)})$ 3–1

Where w is the width of the Antenna, c is the speed of light, f is the frequency, and ε_r Is the permittivity of the substrate

$\varepsilon_{reff}=(\varepsilon_r+1)/2+(\varepsilon_r-1)/2[1+12\, h/w\ ]^{(-1/2)}$ 3–2

Table 2: Parameter’s Value

Parameter	Value
W	29.72mm
Ereff	3.936
ΔL	0.738m
Leff	24.38mm
L	22.904mm

The investigation of the intended Antenna was carried out using the CST Microwave Studio computer model. The CST

MWS time domain solver's analytical approach is based on FIT, which was employed in this study to analyze dual band antennas. Thomas Weiland introduced the Finite Integral Technique in 1977 and has since undergone continuous improvement. Clemens and Weiland used discrete electromagnetism with the FIT in 2001 for efficient numerical simulations of complex geometries on modern computers. The time domain solver in the CST program was used to simulate the intended Antenna since it produces accurate and speedy results. The S-parameters, radiation pattern, gain, and other data for the Antenna may be extracted using the CST program.

a) Step 1

Design substrate using FR4 material (er=4.3, thickness 1.6)

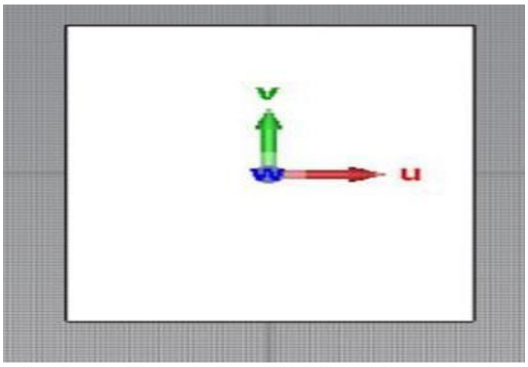

Figure 13: Substrate

b) Step 2

Design ground using copper material thickens (0.035)

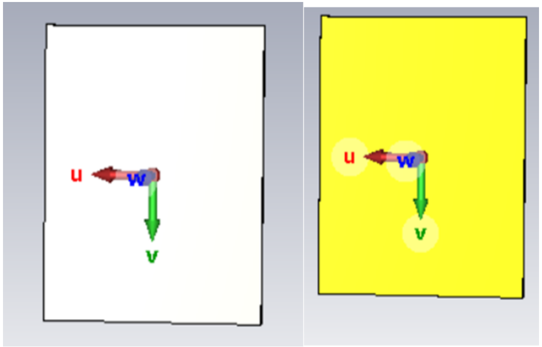

Figure 14: Ground

c) Step 3

Design patch using copper material thicken (0.035)

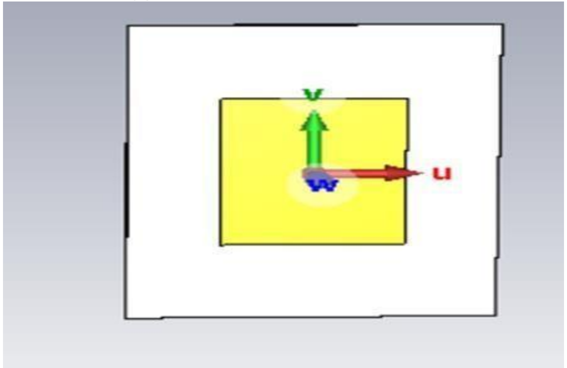

Figure 15: Patch

d) Step 4

Slot near feeding to improve the gain of Antenna and bandwidth

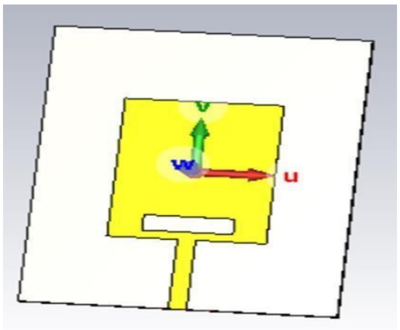

Figure 16: Improve the gain of Antenna and bandwidth

The selection of a material, such as a dielectric substrate, begins the fabrication process. An appropriate and comparable substrate must be chosen to offer a common platform for all feeds to be replicated. Instead of modeling or creating different feeds on multiple substrates, this minimizes any differences. The selected substrate is FR4.

This section describes the research's methodology. A thorough description of the steps in the research process has been provided. The design, modeling, and measurement of the UWB planar antenna are described during the design process.

IV. VALIDATION RESULT OF DESIGN MICROSTRIP ANTENNA

This research used CST Microwave Studio, a high- performance EM field simulator that is commercially accessible, to construct and simulate rectangular microstrip patch antennas. We have successfully created dual microstrip patch antennas with an operational frequency of 3.1GHz utilizing FR-4 substrate materials with r =4.3 and annealed copper for ground and patch.

A. Antenna Design

The 5G patch antenna and the suggested radar's geometry are designed at an operational frequency range of 3.1GHz. The FR4 material used to build this Antenna has a 4.3 dielectric constant. The FR4 substrate height specification is 1.6mm. The substrate measures 29.72 x 22.902 mm ". The ground and substrate dimensions are 29.72 x 22.902 mm ". A patch with a 50-feeding probe is connected through the ground plane. The suggested Antenna sizes are calculated using the well-known microstrip antenna formula.

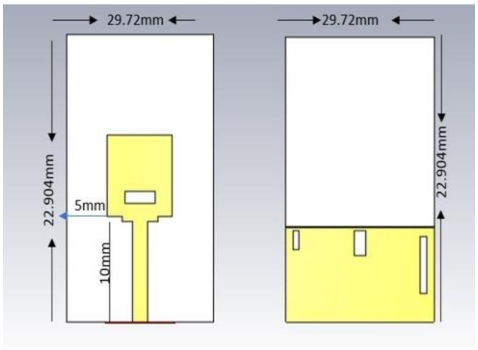

Figure 17: Front and Back View of the Designed Antenna

The Antenna was designed and simulated using the CST Microwave Studio simulator program. The simulation results for the patch antenna's bandwidth, input impedance, and return loss (RL) are displayed. The slot inside the radiating patch controls the antenna impedance matching and antenna impedance bandwidth. It is an impedance matching component. The slit inside the radiating patch can also be used to reduce the size of the proposed Antenna. Furthermore, the rectangular steps do not significantly affect the total impedance bandwidth of the Antenna. Set the step and slot dimensions to L = 10 mm and w = 5 mm, respectively.

B. Effect of the Antenna Parameters on its Performance

The S- Parameters are employed in antenna theory to establish how input and output ports relate, such as how to patch antennas should be a perfect radiator rather than a perfect absorber. The return loss is the official terms for the SI I parameter. All of the power is reflected when the S11 value is 0B. An antenna must have an S11 of less than -10dB to function properly. Additionally, it can be demonstrated that the patch's slot and the feed gap width (d) have a sizable impact on the reflection coefficient impedance bandwidth. The impedance matching between the radiating patch and the feed line can be easily modified by altering these two parameters. It achieved the highest impedance by changing the patch's width.

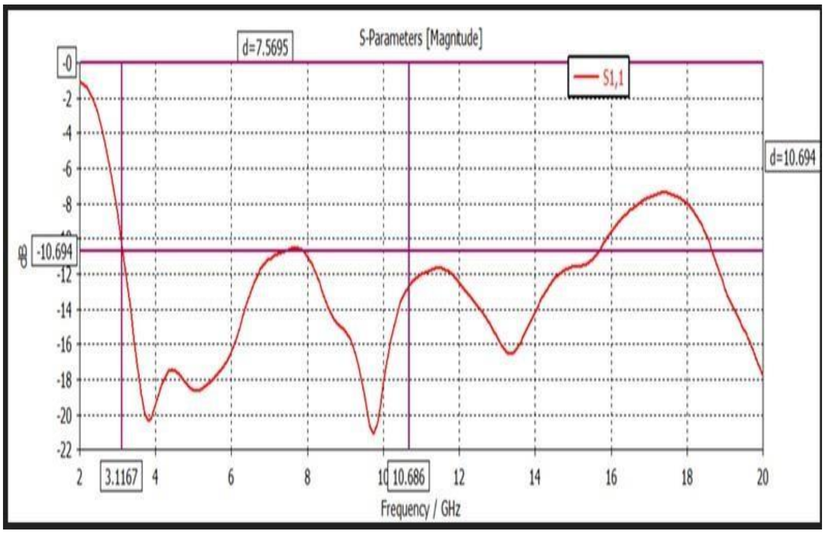

Figure 18: S11 Parameter for Antenna Design

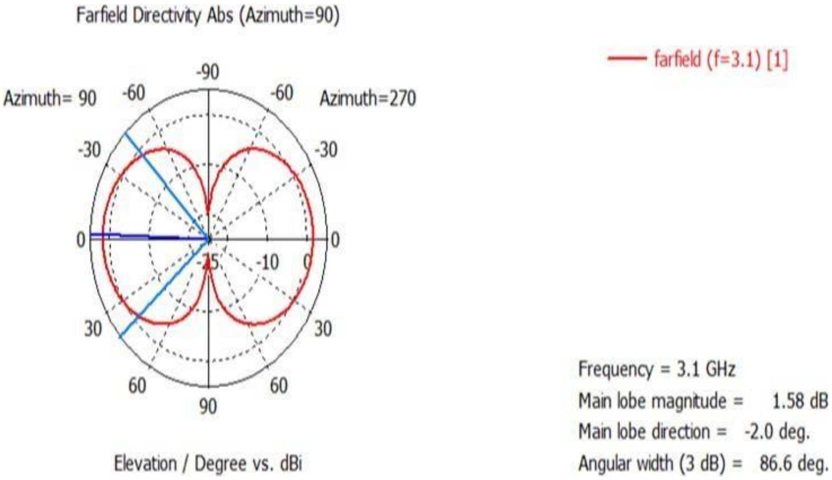

Figure 19: Radiation Pattern

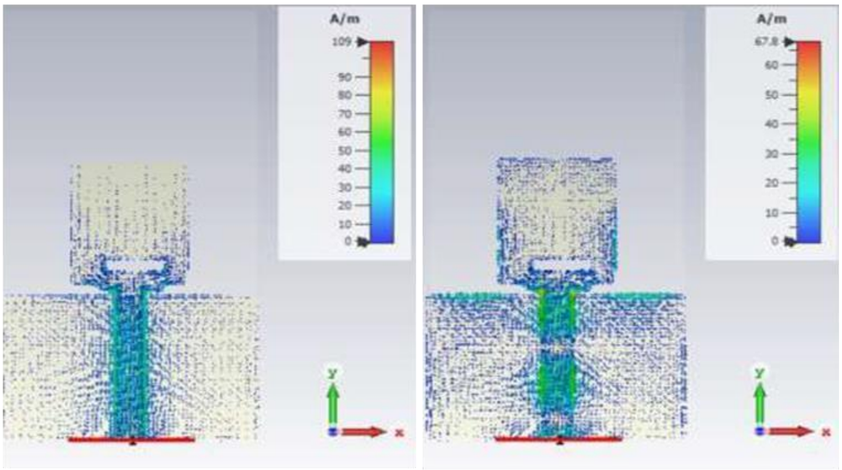

Figure 20: Simulated Surface Current at 3.1 GHz for slot width 5mm

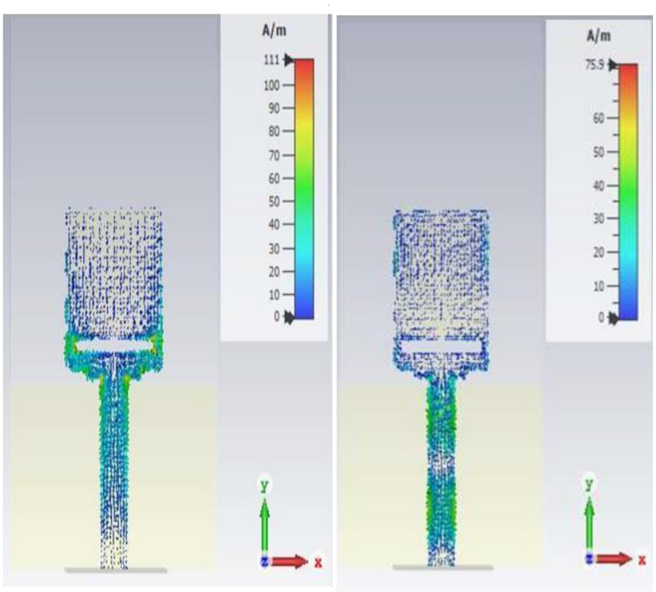

Figure 21: Simulated surface current at 3.1 GHz for slot width 5m

V. CONCLUSION

For radar and 5G applications, we suggest a brand-new microstrip antenna design. Patch antennas withrectangular slots deliver the desired outcome. The basic microstrip patch operates at 3.1 GHz in a single band with a return loss of -10 dB, a bandwidth of 900 MHz, and a gain of 7.57 dB. (without rectangular slots). Due tothe addition of rectangular slots, the antenna has evolved into a dual band antenna with one band's properties being comparable to those of the prior design. The recommended antenna designs aimed to provide good performance in terms of gain and bandwidth while maintaining a reflection coefficient of around -10dB. Utilizing the CST microwave, the radiation pattern of the desired antenna is also evaluated and decided studio tool.

Recommendation

The following are exciting themes that deserve further development in the future: This also gives thenecessary information for choosing substrate and their properties for better results.

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