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Novel Compact MIMO Antenna for 5G Communication

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***Abstract* — The swift advancement in wireless communication technologies, specifically the onset of 5G communication, requires small yet more efficient Multiple Input Multiple Output Antenna to fulfill the rising need for high data transfer speed, reliability, high throughput, support the increased bandwidth requirements and ensuring that the size, weight of the antenna is minimized and number of antenna is also reduced. Demand for 5G communication is very high. So, new technologies are introduced such as array antennas, MIMO antennas etc…Hence, a new compact MIMO antenna configuration, with two different elements is proposed for 5G communication. The first element of this MIMO antenna is a T-shaped microstrip monopole antenna which is fed by a microstrip line and the square patch is the second element of the antenna which is also fed by a microstrip line. Generally, industries have divided the 5G frequency band into two categories, that is mm-Wave band and Sub-6 GHz band. This mm-Wave band includes frequencies above 24 GHz and extends up to 100 GHz and the Sub-6 GHz band includes frequencies below 6 GHz. This optimized antenna generates different multiband frequencies in the Sub-6 frequency band to transmit particular data over the air. This antenna should be designed in such a way that it should possess a high directivity, and low interference and low voltage standing wave ratio value.**

Keywords - CadFeko tool, 5G communication, MIMO Antenna, Network, Sub - 6 frequency band.

I. INTRODUCTION

The need for small and effective Multiple-Input Multiple-Output (MIMO) antennas that can handle high data rates, reduced latency, and seamless connectivity in a variety of communication scenarios is growing with the introduction of 5G technology. However, because of the strict requirements imposed by the frequency bands, bandwidth, size limits, and integration complexity, designing MIMO antennas for 5G systems is fraught with difficulties.

Miniaturization and Compactness - Conventional MIMO antennas frequently fail to achieve the small form factor needed for incorporation into contemporary communication devices, including tablets, smartphones, and Internet of Things gadgets.

It is a major problem to develop tiny MIMO antennas while preserving performance criteria like diversity gain, bandwidth, and efficiency.Bandwidth and Frequency Compatibility: mmWave frequencies are among the several frequency bands that 5G operates in. It is a difficult issue to design MIMO antennas that span various frequency ranges and provide enough bandwidth to accommodate large data rates.

Another level of difficulty is making sure that backward compatibility with legacy frequency bands is maintained.Radiation Efficiency and Diversity Gain: In multipath situations, MIMO systems must have both efficient radiation characteristics and diversity gain in order to ensure reliable communication.

It is difficult to design MIMO antennas with high radiation efficiency, low correlation, and sufficient diversity gain, particularly in compact form factors where performance might be negatively impacted by mutual coupling between antenna parts.

Effective separation between antenna elements is necessary to reduce interference and provide dependable communication in multiple-input multiple-output (MIMO) systems. It is still very difficult to provide adequate isolation without sacrificing compactness or antenna performance.

1.1 Background of the work

Innovative methods for antenna design, optimization strategies, material selection, and manufacturing procedures are needed to meet these problems. Creating a revolutionary small MIMO antenna solution specifically for 5G communication systems is the main goal of this research project.

The aforementioned issues will be the main focus of the project, which will employ sophisticated optimization techniques, creative design processes, and experimental validation. The ultimate objective is to provide a dependable and effective solution for small MIMO antenna systems, hence advancing 5G communication technologies.Review of the Literature: Examine the body of research on small MIMO antennas for 5G connectivity. Find the most recent patents, publications, and research papers on the design of compact MIMO antennas.

Recognize the state-of-the-art methods, difficulties, and solutions in 5G compact MIMO antenna design. Determine the various MIMO antenna configurations—such as printed antennas, planar arrays, or conformal antennas—that are appropriate for small designs.5G Wavelength Ranges: Recognize whether frequency bands are available locally or worldwide for 5G connectivity.

Determine the relevant frequency ranges, such as mmWave and sub-6 GHz bands. Based on the desired 5G bands, ascertain the frequency range that the small MIMO antenna needs to operate in.Antenna specifications: Specify the dimensions, radiation pattern features, polarization diversity, isolation, and other criteria for the compact MIMO antenna.

Configuration of Antenna: Examine various MIMO antenna configurations, such as 2x2, 4x4, or higher-order MIMO systems, that are appropriate for small designs.Consider the trade-offs that each design has between complexity, performance, and antenna size. Efficiency and Radiation Pattern:

Examine the tiny MIMO antenna's radiation pattern requirements in light of the intended coverage area and beamforming capabilities. To provide the best possible power transmission and reception, evaluate the antenna design's efficiency.

Simulation and Modeling of Antennas: To model and simulate various antenna designs, use electromagnetic simulation software such as HFSS, CST Microwave Studio, or FEKO. To get the intended performance metrics, do simulations to improve the feed network, matching networks, and antenna shape.Fabricating and Testing Prototypes:

Produce prototypes of the compact MIMO antenna designs by the application of suitable manufacturing processes.Assessment of Performance: Analyze the tiny MIMO antenna prototypes performance in practical settings, taking connection reliability, data rate, and channel capacity into account. Evaluate the designed antennas performance against current solutions and relevant standards and specifications.

Enhancement and Repetition: Iterate the design process in response to user feedback and the outcomes of the performance evaluation. Adjust the antenna design settings to improve performance even more or to solve any problems found.

II. EASE OF USE

A. LITERATURE SURVEY

The primary objective of doing literature research is to gain an understanding of the fundamentals of antenna designing and to access the latest approaches, various frameworks, technologies, and smart models for 5G communication. This aids in producing innovative ideas and solutions to the existing problems in our day to day life.

[1]. Cholavendan Munusami; Rajeshkumar Venkatesan (2024) - This paper presents a novel compact boat-shaped dual-band MIMO antenna for 5G WLAN application. Each individual rectangular patch has stubs, defective ground plane and a ring

resonator located on a ground plane to generate 2.3 GHz and 5.2 GHz for dual-band and make a low profile, with low VSWR value, increased bandwidth and high gain.

[2]. Muhammad Jaafer Riaz; Ayesha Sultan; Muhammad Zahid; Anum Javed; Yasar Amin; Jonathan Loo (2021) - This paper presents the need for 5G communication due to overcrowded frequency bands of 2G, 3G, and 4G communications. So, to accommodate large internet traffic and to provide high data transfer speed 5G frequency bands are introduced by FCC. The proposed MIMO antenna consists of 7 elements each of them operating in 37 GHz which is the mm-wave band and the gain of every single element is 7.7 dBi.

[3]. A. Devi Deekshitha; N. Radha; V. Preethi; Kunal Srivastava; Sanjeev Kumar (2023) - The MIMO antenna described in this paper is small and well isolated, making it suitable for millimeter-wave (5G) communication without the need for an additional decoupling structure. Two spanner-shaped antenna components and a microstrip feed-line were used to build the MIMO architecture that is displayed. By arranging the components apart, the antenna's isolation between them is improved without the need for extra decoupling design. The antenna dimension is 14 mm ×6 mm × 0.76 mm and operates at frequency range of 26.8 GHz to 29 GHz.

[4]. Steven Gao (2019) - This paper presents a tedious problem of how to create good isolation between densely packed antennas. An overview of several modern approaches, including the utilization of parasitic elements, neutral lines, metamaterials, electromagnetic band gap (EBG), etc. It is demonstrated that these strategies might provide good isolation up to roughly 20 dB when the distance between the antenna elements is about half of a wavelength; however, if the distance between the antenna components is lowered further, the performance rapidly degrades. Next, a method for designing antennas known as Common-Mode/Differential-Mode (CM/DM) is introduced. It is demonstrated that the CM/DM approach may produce strong isolation of more than 20 dB when the antenna elements have zero distance between them.

[5]. S. Rahman ; S. Alam ; M. Haque ; N.S. Siddique ; M.H. Sagor (2018) - This work presents the design of transparent and flexible coplanar waveguide fed (CPW) antennas operating from 23 GHz to 29.6 GHz. To accomplish conformance, AgHT transparent conductive material is used to model a V-shaped antenna over a Polyethylene Terephthalate (PET) substrate. The antenna's V-shaped construction was then changed to a T shape by altering the angle between its arms. It has been shown how the frequency, gain, and radiation pattern changed as a result.

[6]. Mahmoud Nazzal ; Mehmet A. Aygül ; Hüseyin Arslan (2020) - This paper updates the fundamental needs for effective channel modeling for 5G and beyond, identifies the current and anticipated obstacles, and highlights the primary initiatives undertaken in this area by top academic and industry organizations. Machine learning (ML)-based channel modeling as a viable channel modeling technique and update the framework for channel modeling and estimation based on compressed sensing (CS).

[7]. E.G. Abakasanga ; E.I. Adegoke ; R.M. Edwards (2018) - In order to construct fifth generation wireless communications (5G), this paper looks at signal detection methods for MIMO systems. In a Rayleigh fading channel with M-PSK signal input, the performances of coherent and non-coherent detection algorithms in single input multiple output (SIMO) and MIMO systems are examined. Alamouti space time block codes (STBC) and the receiver diversity approach utilizing maximum ratio combining (MRC) were both investigated. The analysis of both plans describes the shortcomings of each and offers a basis for choosing the one that will work best for 5G MIMO systems. The bit error rate (BER), ergodic capacity, and outage probability were the simulated metrics used to benchmark the detection methods under investigation.

III. THEORY OF PROBLEM

A. PROBLEM DEFINITION

In the current trend, high speed communication, reliability and efficiency is very essential. The frequency bands used for 2G, 3G, and 4G communications became overcrowded, so to accommodate huge internet traffic, new frequency bands were needed to be allocated, which were later allocated by the Federal Communication Commission (FCC). Demand for 5G communication is very high. So, new technologies are introduced such as array antennas, MIMO antennas etc… which are highly rated and operate on a particular frequency.

AIM OF THE PROJECT

The goal is to create a small, effective antenna system specifically for 5G networks by creating a revolutionary compact MIMO antenna for 5G communication. In order to meet the demand for high-speed, compact solutions for 5G communication, this antenna seeks to provide high data rates, enhanced connectivity, and dependable performance while being tiny enough to integrate into small devices or infrastructure.

B. HOW ANTENNA WORKS

A device made to send or receive electromagnetic waves is called an antenna. It functions according to electromagnetic principles. Electromagnetic radiation is produced by the antenna when an alternating current (AC) passes through it. Waves of this radiation travel over space delivering data for wireless communication, TV broadcasts, and radio transmissions.

The conductive components that make up antennas can be as simple as a straight wire or as complicated as an array of elements. The frequency of electromagnetic waves that the antenna can efficiently transmit or receive depends on the size and shape of its constituent parts. In general, shorter antennas work better at higher frequencies, whereas longer antennas work better at lower frequencies.

An electromagnetic wave causes a voltage to be induced in an antenna's constituent parts. After that, this voltage is either applied to the antenna for transmission or processed by electrical circuits for reception. Thus, antennas facilitate communication over a range of frequencies and distances by acting as a bridge between electrical equipment and the electromagnetic spectrum.

IV. IMPLEMENTATION AND WORKS

A. FEKO TOOL

With the aid of CADFEKO, electromagnetic field simulation tools, users can examine how antennas, RF (Radio Frequency) components, and other electromagnetic
devices behave Suitable for addressing a broad variety of antenna types, including as reflector, horn, and aperture.
It is quite helpful for developing and refining antennas.
Because of CADFEKO's flawless integration with a variety of computer-aided design programs, users can import and manipulate pre-existing CAD models.

- CADFEKO provides tools for simulating electromagnetic fields, helping users analyze the behavior of antennas, RF (Radio Frequency) components, and other electromagnetic devices.
- Suited to solve a wide range of different antenna types including horn , aperture ,reflector etc..
- It is particularly useful for designing and optimizing antennas.
- CADFEKO integrates with various computer-aided design software, allowing users to import and work with existing CAD models seamlessly.

B. FEEDING LINE OFFSET :

To enhance the MIMO antenna element impedance matching at lower frequencies, the feeding 50 Ω microstrip lines are moved away from the symmetrical location with regard to the square ring patch element.
For a characteristic impedance of 50 Ω on a FR-4 substrate ($\varepsilon r = 4.4$, $h = 1.57$ mm, and $\tan\delta = 0.02$), the width of the microstrip line was found to be 3 mm. Its dimensions are 13 mm in length and 35 mm on the square-shaped dielectric substrate side. A square slot with a side of 24 mm has been put into the ground plane.The MIMO antenna under investigation

The element displays dual band behavior, and an offset, d, of the feeding line location enhances the antenna input impedance matching while lowering the second resonance band's resonant frequency. The antenna exhibits wideband behavior with acceptable impedance matching for d = 6 mm, from 4.4 to 7.6 GHz.

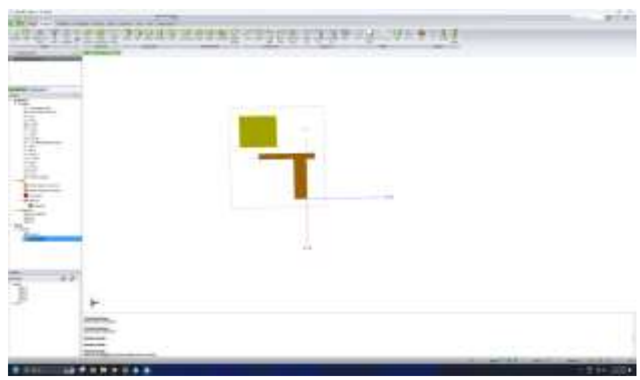


FIGURE : 4.1 square and t shape antenna

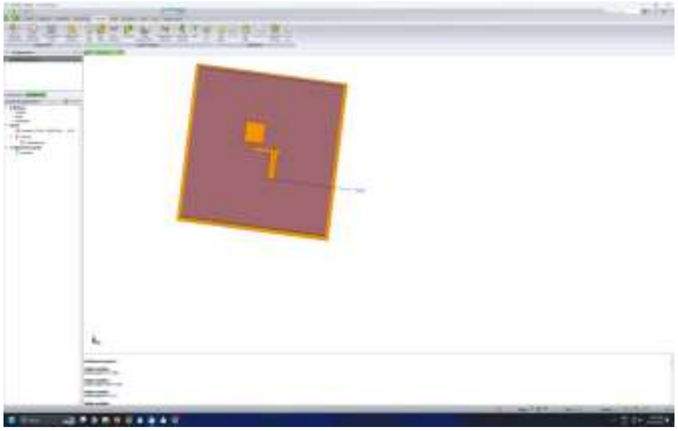


FIGURE : 4.2 square and t-shaped patch antenna with ground plane and dielectric substrate

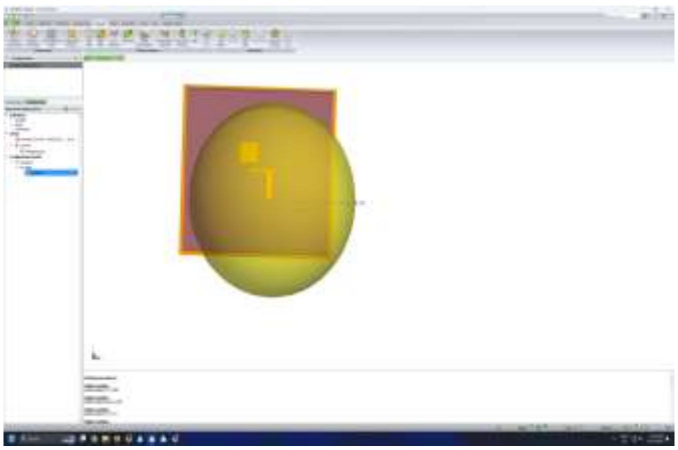


FIGURE : 4.3 far field antenna

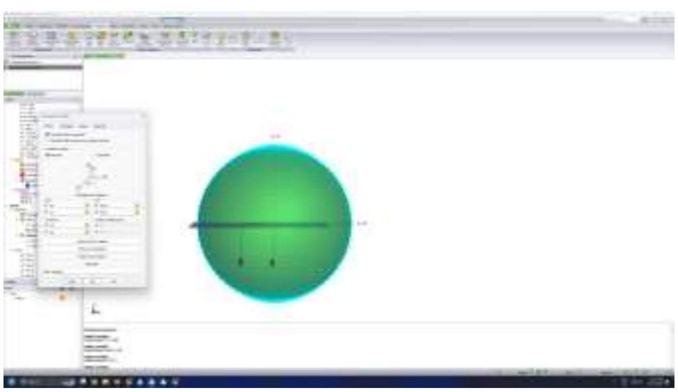
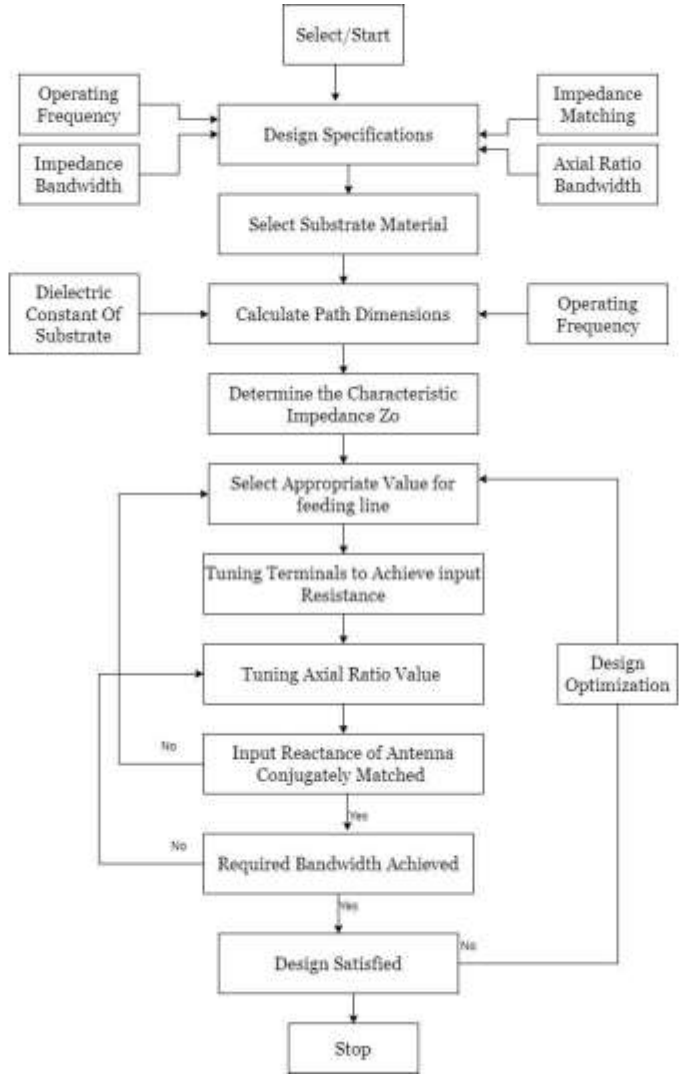


FIGURE : 4.4 near field antenna

IV. RESULT AND DISCUSSION

A. FLOW CHART :



A. PROCEDURE:

1.Describe the needs for the design:

Establish the needs and parameters for the antenna design first. This covers variables like radiation pattern, gain, polarization, impedance matching, frequency range, bandwidth, and so on.

2. Choose an antenna type:

Considering the application and design specifications, select the right kind of antenna. A variety of common antenna types are available, including wire, patch, horn, microstrip, and more.

3. Establish Antenna Geometry:

Create the antenna's geometric structure using FEKO's modeling tools. This entails specifying the antenna elements' dimensions, form, and composition.

4.Explain Excitation:

Indicate the antenna's excitation source, such as a voltage or current source. This establishes the radiation properties of the antenna and specifies how it is driven. Establish the polarization, phase, amplitude, and frequency of the stimulation.

5.Mesh Production:

Create a mesh for the antenna geometry with the meshing tools provided by FEKO. The mesh should be computationally efficient and sufficiently precise to accurately capture the antenna's electromagnetic behavior . Depending on the complexity of the antenna and the required level of simulation accuracy, adjust the mesh density.

6.Run a simulation of electromagnetic fields:

Conduct the electromagnetic simulation using FEKO to evaluate the effectiveness of the antenna. Radiation patterns, impedance, S-properties, and far-field distributions are just a few of the electromagnetic parameters that FEKO will calculate.

7.Reprocessing and Interpretation:

Use the post-processing tools provided by FEKO to analyze the simulation results. Plots of far-field radiation, near-field radiation, and other pertinent data should be visualized. Utilizing the simulation findings, extract performance parameters including gain, directivity, efficiency, bandwidth, and VSWR.

8.Optimization (Optional):

Optimize the antenna if necessary to satisfy specific design goals or enhance its performance. FEKO provides optimization algorithms that can change antenna parameters automatically in order to accomplish desired results. Establish optimization constraints and goals, such as return loss minimization or gain

V. CONCLUSION

A 3.5 GHz dual-polarized MIMO antenna was demonstrated. By positioning a conductive patch (antenna #2) and a planar T-shaped monopole (antenna #1) on opposing sides of the dielectric substrate, resonances in the required frequency range could be achieved, giving rise to the antenna's structure.

The findings demonstrate that the suggested MIMO antenna can function in both polarizations in the 5G system's lower band. Additionally, because it measures just 35 by 35 by 1.6 mm and is small in size, it is a strong contender for MIMO system applications that call for low profile and diversity.

Furthermore, the suggested antenna functions within the lower UWB range, spanning from 3.1 to 5.2 GHz. Prototype antennas were built and measured, and the findings of the simulation (WCIP and Ansoft HFSS) and measurements agreed well, verifying the validity of the analysis that was developed.

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