A Minor Project Report on

"Performance Analysis of MIMO Antenna"

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DECLARATION

We hereby declare that the matter embodied in this report entitled "**Performance Analysis of MIMO Antenna**" submitted to KLE Technological University for the course completion of Minor Project (24EECW302) in the 6th Semester of Electronics and Communication Engineering is the result of the work done by us in the Department of Electronics and Communication Engineering , KLE Dr. M. S. Sheshgiri College of Engineering, Belagavi under the guidance of Dr.Prabhakar M, Department of Electronics and Communication Engineering. We further declare that to the best of our knowledge and belief, the work reported here in doesn't form part of any other project on the basis of which a course or award was conferred on an earlier occasion on this by any other student(s), also the results of the work are not submitted for the award of any course, degree or diploma within this or in any other University or Institute. We hereby also confirm that all of the experimental work in this report has been done by us.

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CERTIFICATE

This is to certify that project entitled "**Performance Analysis of MIMO Antenna** " is a bonafide work carried out by the student team of " **Abhay Genuche (02FE22BEC001)** , **Akshata Babaleshwar (02FE22BEC004)** , **Kartik Maradi (02FE22BEC035), Ramakrishna Lokare (02FE22BEC066)**". The project report has been approved as it satisfies the requirements with respect to the minor project work prescribed by the university curriculum for B.E. (VI Semester) in Department of Electronics and Communication Engineering of KLE Technological University Dr. M. S. Sheshgiri Belagavi campus for the academic year 2025.

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1.	
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Abstract

This paper presents a comprehensive performance analysis of Multiple Input Multiple Output (MIMO) antenna systems, emphasizing their significance in enhancing wireless communication efficiency. MIMO technology leverages multiple transmitting and receiving antennas to improve data throughput, link reliability, and spectral efficiency without requiring additional bandwidth or power. The study investigates key performance metrics such as gain, S parameters, field energy, and Simulation results and theoretical analysis demonstrate the superior performance of MIMO systems compared to traditional single antenna configurations. The findings underscore the critical role of MIMO in meeting the growing demands of next-generation wireless networks, including 5G and beyond.

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Chapter 1

Introduction

1.1 Problem Statement

The design and implementation of Multiple-Input Multiple-Output (MIMO) antenna systems are crucial for modern wireless communication due to their ability to enhance data rates, reliability, and spectral efficiency. However, optimizing their performance under various environmental and operational conditions remains a challenge. This project focuses on analyzing key physical parameters such as field distribution, S-parameters, and propagation characteristics to evaluate MIMO antenna behavior. Understanding these aspects will aid in improving antenna design and ensuring efficient signal transmission in complex, real-world scenarios.

1.2 Motivation

MIMO antennas play a critical role in enhancing wireless system efficiency. To ensure optimal performance, it is essential to analyze physical parameters such as S-parameters, gain, and propagation constant. This analysis helps in understanding signal behavior, minimizing losses, and improving antenna design without considering data transmission metrics.

1.3 Objectives

- To analyze S-parameters: Evaluate the reflection and transmission characteristics of the MIMO antenna to assess impedance matching and isolation between elements.

- To measure antenna gain: Quantify the directional power radiation to determine the efficiency and effectiveness of signal transmission.

- To study the propagation constant: Investigate how signals attenuate and phase-shift through the medium to understand wave behavior in the antenna environment.

- To optimize physical design: Use the results of parameter analysis to guide improvements in antenna geometry, spacing, and material selection.

1.4 Literature Survey

Ahmad et.al designed a compact four-port MIMO antenna operating in the Ka-band for future 5G devices. The antenna exhibits wideband behavior, high gain, and low mutual coupling between ports. Simulation and measurement results confirm good S-parameter performance, with isolation better than 20 dB and gain exceeding 7 dBi. Advantages include compact size, high isolation, and suitability for high-frequency applications. Disadvantages include increased design complexity and sensitivity to fabrication tolerances due to high-frequency operation.

Zhang *et al.,* designed a wideband MIMO antenna for WLAN applications, operating in the frequency bands of 2.4–2.4835 GHz and 5.15–5.85 GHz. The antenna exhibited measured S-parameters with reflection coefficients below 10 dB and isolation better than 15 dB. The peak gain and radiation efficiency were measured, showing consistent performance across the operating bands. The advantages include wideband operation and good isolation between ports. Disadvantages include potential size constraints for integration into compact devices.

Kumar *et al.,* developed a high-gain MIMO antenna with enhanced isolation for WLAN applications. The antenna achieved measured S-parameters with reflection coefficients below 10 dB and isolation better than 15 dB across the operating bands. The peak gain and radiation efficiency were evaluated, demonstrating satisfactory performance. The advantages include high gain and improved isolation. Disadvantages include potential challenges in achieving compact designs without compromising performance.

Biswal *et al.,* proposed an eight-element circularly polarized (CP) MIMO antenna for modern wireless communication systems. The antenna demonstrated wide impedance bandwidth (5.08–5.95 GHz), high gain (4.9 dB), and low envelope correlation coefficient (ECC ¡ 0.1), making it suitable for MIMO applications. The isolation between ports was measured at 20 dB, and the channel capacity was calculated at 40.5 bps/Hz. The advantages include high gain, low ECC, and wide bandwidth. Disadvantages involve increased size due to the higher MIMO order and potential modifications in performance when a large conductive sheet is attached to the ground plane.

Chapter 2

System Design

2.1 Block diagram

FIGURE 2.1: Block diagram

2.2 Functional block diagram

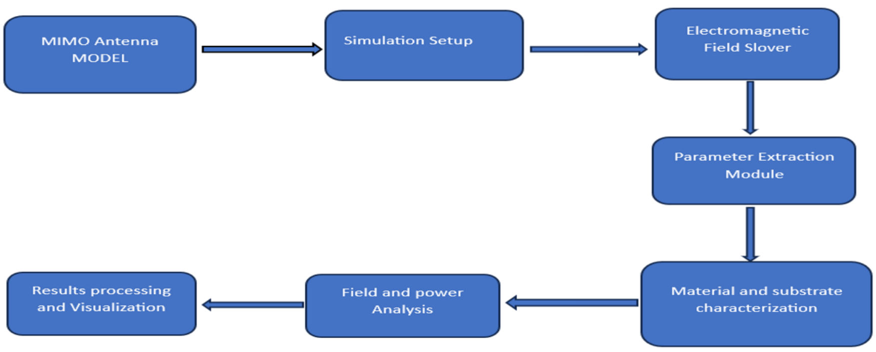

FIGURE 2.2: Functional block diagram

2.3 Gantt chart

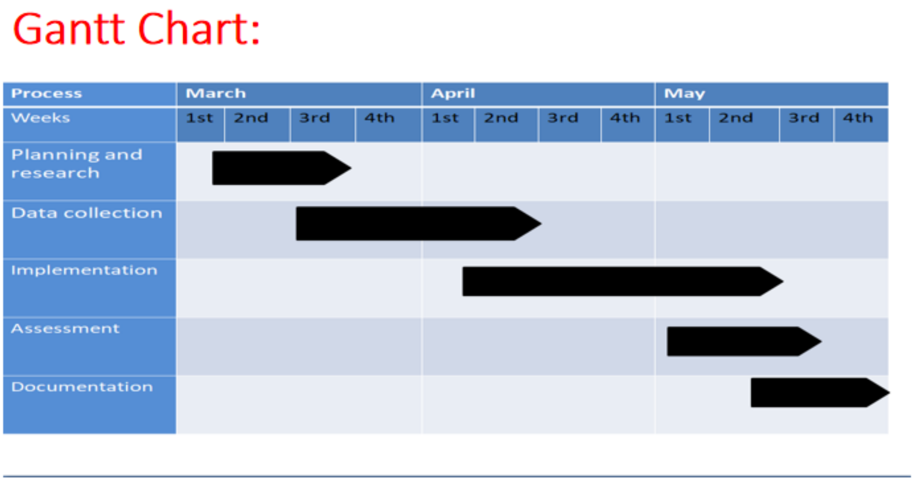

FIGURE 2.3: Gantt chart

2.4 Work breakdown structure

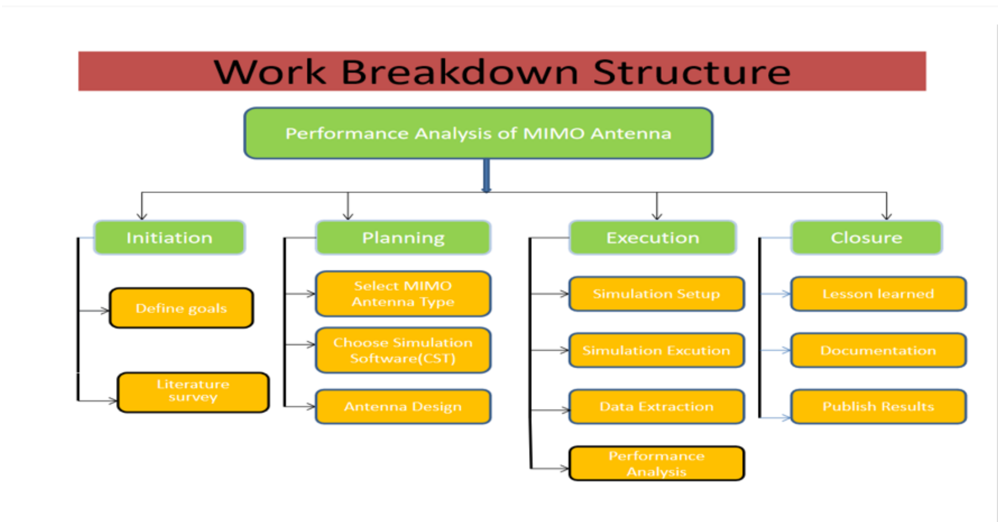

FIGURE 2.4: Work breakdown structuren

Chapter 3

Implementation

- **Simulation Tool:** CST
- **Antenna Type:** Microstrip Patch
- **Operating Frequency Range :** 0.01 - 6 GHz
- **Number of Antennas:** 2×2, 4×4 MIMO configuration.
- **Substrate Model:** FE-4(lossy).

MIMO Antenna Performance Analysis Processing Steps

1. **Design the MIMO antenna structure in CST.**
2. **Set the simulation frequency range.**
3. **Assign waveguide ports to antenna elements.**
4. **Define boundary conditions and mesh settings.**
5. **Simulate to extract S-parameters (e.g., S11, S21).**
6. **Analyze electric and magnetic field distributions.**
7. **Evaluate field energy within the structure.**
8. **Measure propagation delay between antenna ports.**
9. **Export simulation results for interpretation and reporting.**

Chapter 4

Optimization

Optimization in MIMO antenna performance analysis focuses on refining design and simulation parameters to ensure accurate and efficient evaluation. In this project, key parameters such as S-parameters, field energy, and propagation delay were analyzed using CST Studio Suite. The S-parameters help assess return loss and isolation between antenna elements, which are critical for ensuring proper signal transmission and minimal interference. Field energy analysis provides insights into how electromagnetic energy is distributed and stored in the antenna structure, guiding adjustments to improve efficiency. Propagation delay measurements are essential for understanding timing differences across antenna paths, which can affect system synchronization. Optimization becomes crucial to fine-tune antenna geometry, port placement, and simulation settings to obtain accurate results within reasonable computational time. Over-simplified or poorly configured models can lead to misleading outcomes, while overly complex setups may increase simulation time without adding value. Therefore, balancing model complexity with simulation efficiency is key to achieving meaningful and timely results in the MIMO antenna design process.

Chapter 5

Results and Outcomes

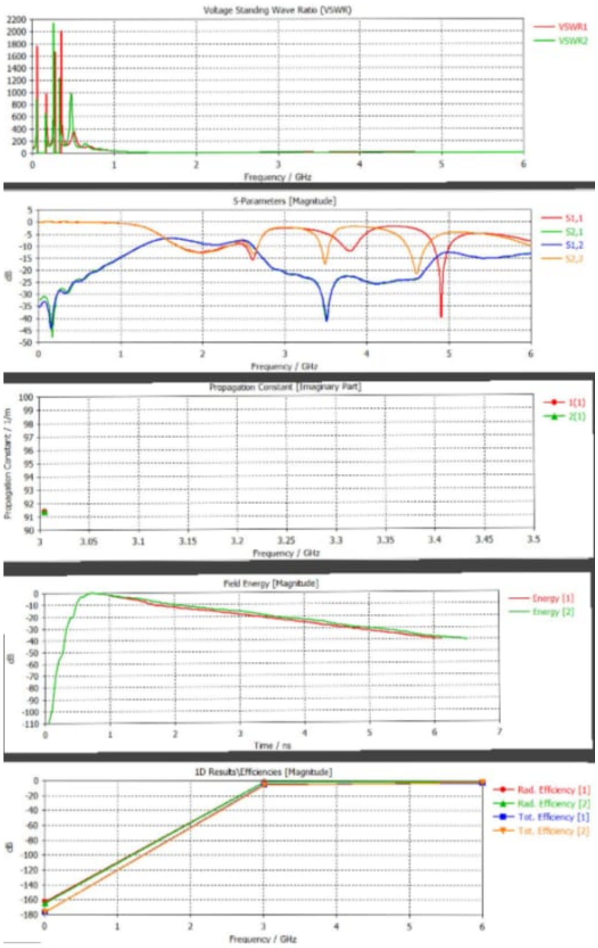

Figure 5.1: Results

Conclusions

The CST-based simulation workflow effectively demonstrates a structured approach to analyzing the performance of MIMO antenna systems. By focusing on the extraction and interpretation of S-parameters, the design's return loss and inter-element isolation were quantitatively evaluated, offering insights into signal integrity and impedance matching. Field energy analysis provided a spatial understanding of electromagnetic energy distribution, helping validate the antenna's resonant behavior. Propagation delay measurements further added depth to the assessment by revealing timing discrepancies across the antenna structure. The step-by-step simulation process, from model design to result visualization, forms a practical and adaptable framework for evaluating key performance metrics. This approach allows users to iteratively refine their designs based on real-world criteria, ensuring the final antenna configuration is both functionally efficient and suitable for high-performance communication applications.

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