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DESIGN OF MIMO ANTENNA WITH HIGH ISOLATION FOR UWB APPLICATION WITH DIFFERENT SUBSTRATE MATERIALS

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Abstract: The wireless communication industry is currently experiencing a tremendous growth in the area of Radio Frequency (RF) and antenna design. Researchers are trying to find new ways to design antennas with high data rates and low power consumption. Ultra-wide band (UWB) MIMO (Multiple Input Multiple Output) antenna design is an ultimate choice for short-range wireless applications. For UWB technology, the frequency spectrum, ranging from 3.1 to 10.6 GHz (7.5 GHz bandwidth), has been officially allotted by the Federal Communication Commission (FCC) in USA. Hence, the use of MIMO antenna concepts for UWB technology offers a potential solution for data rate enhancement with low power consumption. Despite having various benefits, MIMO technologies in communication systems are accompanied by some challenges that need proper attention. One of them is to achieve compactness of the overall design while maintaining a good performance. Achieving compactness increases the mutual coupling due to current flow among the ports, which results in poor diversity gain, low radiation efficiency, and low gain. Through proper isolation between the antenna elements, high mutual coupling is avoided. Different methods have been explored and proposed by researchers to enhance isolation among the antenna elements. This project explores the design of Multiple-Input Multiple-Output (MIMO) antennas tailored for Ultra-Wideband (UWB) applications, focusing on achieving high isolation between antenna elements. To achieve high gain and better VSWR, different substrate materials used in this project are: 1. ROGGERS 4003 2. FR4 EPOXY 3. ROGGERS R03006(tm) 4. AIR 5. ROGGERS R04350(tm).

Index Terms **- Antennas, MIMO, Substrate materials, simulation, Gain, VSWR, Return Loss.**

I. INTRODUCTION

A high-isolation compact MIMO (Multiple-Input MultipleOutput) antenna for UWB (Ultra-Wideband) applications addresses the growing need for efficient wireless communication systems capable of transmitting large amounts of data across a wide frequency range. This paper explores the design and implementation of a compact MIMO antenna system optimized for UWB applications, focusing on achieving high isolation between antenna elements while maintaining a small physical footprint. The allocation of the frequency band 3.1– 10.6 GHz by the Federal Communications Commission (FCC) for low-power emission in 2002 opened up opportunities for UWB communication systems, which offer advantages such as low power consumption and high data rates. However, the inherent limitation of UWB systems to short-range communication due to their low transmitted power necessitates innovative approaches to enhance data rates and overcome issues like multipath fading. One such approach is the utilization of MIMO technology, which has proven to be an efficient technique for increasing channel capacity without requiring additional power or bandwidth. However, implementing MIMO in UWB systems presents challenges, particularly in designing antennas with high isolation among elements operating within the UWB frequency range. The compact nature of UWB antennas exacerbates issues related to mutual coupling between antenna elements, posing a significant challenge in designing MIMO antennas with compact structures and low mutual coupling. **II. OBJECTIVE**

The objective of designing a Multiple Input Multiple Output (MIMO) antenna for Ultra-Wideband (UWB) applications is to achieve high isolation between antenna elements while covering the wide frequency range of UWB signals (3.1 GHz to 10.6 GHz). High isolation ensures minimal interference, maintaining signal orthogonality crucial for reliable communication. The antenna must be compact, robust, and cost-effective for practical deployment, often in space-constrained or harsh environments. Achieving directional characteristics and gain while preserving diversity across antenna elements is essential. The design process involves selecting suitable topologies, optimizing electromagnetic properties through simulation, configuring antenna arrays, designing feeding networks, and validating prototypes. By meeting these objectives, the designed MIMO antenna system can support efficient and reliable UWB communication across various applications, including wireless connectivity, radar systems, and IoT devices.

II. METHODOLOGY

A. Flow Chart Designing Multiple-Input Multiple-Output (MIMO) antennas involves several key considerations to ensure optimal performance in terms of coverage, capacity, and efficiency. Here's a general outline of the steps involved in designing MIMO antennas:

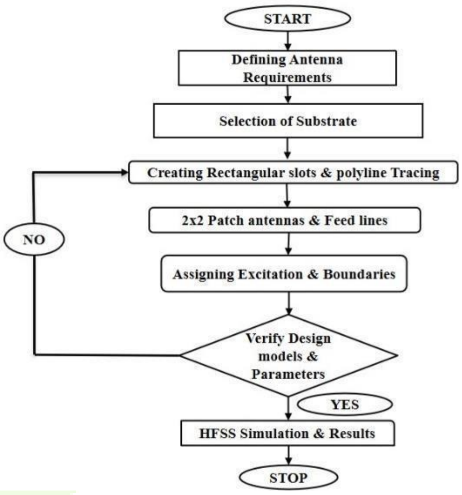


Fig-1: Flow Chart

START:

DEFINING ANTENNA REQUIREMENTS: The first step involves defining the specifications of the antenna, which could include factors like operating frequency, desired radiation pattern, gain requirements and size constraints. SUBSTRATE SELECTION: Here, the designer selects the material that will form the base of the antenna. This material, often referred to as the substrate, has specific electrical properties (dielectric constant and loss tangent) that influence the antenna's performance.

CREATING RECTANGULAR SLOTS AND POLYLINE TRACING: This stage translates the defined antenna requirements into the physical design. It involves creating rectangular slots and tracing polylines on the chosen substrate. Polylines are essentially a series of connected straight lines that form the conductive elements of the antenna. The specific shapes, sizes, and placements of these slots and lines will depend on the desired antenna characteristics. ASSIGNING EXCITATION AND BOUNDARIES: In this step, the designer specifies how the antenna will be fed with a signal (excitation) and how the electromagnetic field will behave around the antenna (boundaries). This might involve defining feed ports for connecting the antenna to a transmitter or receiver and setting radiation boundary conditions to simulate the antenna's behavior in free space.

VERIFICATION DESIGN MODELS AND PARAMETERS: Once the initial design is complete, the model is simulated to assess its performance. Electromagnetic simulation software is likely used to analyze factors like the antenna's scattering parameters (S-parameters), which provide information about its impedance matching, reflection, and transmission characteristics. Other parameters like radiation pattern and gain might also be evaluated at this stage. SIMULATION RESULTS: The simulation results are then analyzed to determine if the design meets the initial requirements defined at the beginning.

YES PATH: If the simulation results are satisfactory, the process moves towards design finalization.

NO PATH: If the performance doesn't meet expectations, the designer goes back to modify the design parameters (such as the shapes and sizes of slots and polylines) and repeat the simulation process (as shown by the loop back to the "Creating Rectangular Slots and Polyline Tracing" step). This iterative process of design, simulation, and refinement continues until the desired antenna performance is achieved.

STOP: Once a design meets the specified requirements through simulation, the process concludes. The final design can then be fabricated and tested in a real-world setting.

III. SOFTWARE TOOL: HFSS

HFSS, developed by ANSYS, is a premier electromagnetic simulation software. It's used across industries for highfrequency electronic component and system design. With advanced Finite Element Method (FEM) solvers, HFSS accurately models electromagnetic behavior in complex structures. It offers intuitive geometry creation, automated meshing, and supports both frequency and time domain analyses.

Engineers leverage HFSS for antenna design, RF/microwave circuits, and more. Parametric analysis and optimization tools streamline design exploration. Integrated within the ANSYS ecosystem, HFSS enables comprehensive multi-physics simulations. In essence, HFSS empowers engineers to efficiently design, analyze, and optimize electromagnetic systems for diverse applications.

Fig-2: Software

Problem Definition: Define design objectives, frequency range, and constraints.
Geometry Creation: Model the structure using HFSS's tools or import CAD files.
Meshing: Generate a mesh over the geometry for accurate simulation.
Material Assignment: Assign material properties like dielectric constants.
Excitation: Define sources like ports or transmission lines.
Boundary Conditions: Set appropriate simulation boundaries.
Solver Setup: Configure simulation settings and choose solver type.
Simulation: Run the simulation and monitor progress for accuracy.
Post-Processing: Analyze results using HFSS's tools. **Post-Processing:** Analyze results using HFSS's tools.
Optimization: Perform optimization studies if needed.
Verification and Validation: Compare simulated results with measurements or analytical solutions.

IV. MIMO Antenna

A high compact MIMO (Multiple Input Multiple Output) antenna should briefly highlight the importance of MIMO technology, the challenges posed by compact device designs, and the objectives of the proposed antenna design: In the era of demanding wireless communication needs, MIMO technology has emerged as a cornerstone for enhancing data rates and reliability. However, implementing MIMO in compact devices like smartphones and wearables presents challenges due to space limitations. To address this, high compact MIMO antennas are essential. This paper introduces a design aimed at overcoming size constraints while maintaining crucial performance metrics. By focusing on size reduction and isolation enhancement, our goal is to create a compact antenna system capable of delivering reliable wireless communication in small form factor devices.

V. IMPLEMENTATION

STEPS TO DESIGN MIMO ANTENNA:

INTRODUCTION:

In this chapter, we discuss about how to design of MIMO antenna with high isolation for UWB application using HFSS. The following are the steps to design a design of MIMO antenna with high isolation for UWB application using HFSS **STEP-1**: OPENING A HFSS: To access Ansoft HFSS, click the start button, select All programs and select AHFSS 15.0

STEP-2: CREATE A NEW PROJECT: To create a new project: In HFSS desktop, select the menu item File> New. A new project is listed in the project tree in the Project Manager window

STEP-3: INSERTING AN HFSS DESIGN: To insert the HFSS design, Check protect>Insert HFSS Design, The new design is listed in the project tree. It is named HPSS Design.The 3D Modeler window appears to the right of the project Manager **STEP-4:** SELECTING THE SOLUTION TYPE: To set the Solution Type,Click HFSS > Solution Type,The Solution Type dialog box appears, Select one of the solution type that is Driven Model,Click on Ok Button.

STEP-5: SET MODEL UNIT: To set the Model units of measurement, Select the menu item modeler > units,The Set Model Units dialog box appears,Select unit: mm, Click ok button.

STEP-6: Creating Two Ground Planes for 2x2 MIMO Antenna :Select the menu items draw rectangle by clicking on symbol Using the coordinate entry fields, enter rectangle position as x:0, y:0, z:0, press the enter key.

STEP-7: 24 Rectangular Slots for Definite Antenna Structure

STEP-8: Polyline Tracing- To get the Arbitrary Shape of Antenna

STEP-9: resultant structure after Polyline Tracing

STEP-10: Creating Monopole antenna & Adding feed lines

STEP-11: Resultant Monopole antenna .

STEP-12: Creating Mirror Image for Monopole 1 which results in Monopole 2

STEP-13: Radiation Box: Select the menu item Draw > box, Select attribute tab from the properties window,Change the name as Radiation box ,To change the material select edit > select air, Right Click on Radiation Box > Assign Boundary > Radiation

STEP-14: Create substrate

STEP-15: Create Radiation Setup: Select the menu item HFSS> Radiation > Insert far field setup > Infinite sphere,Right click on setup1 > Add Frequency Sweep

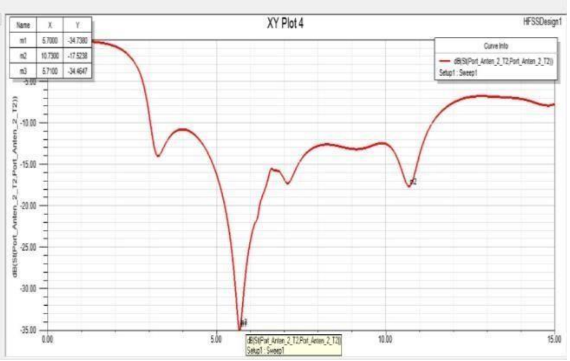
Step 16: Assign Excitation: Right click on source > Assign Excitation > Wave port

STEP-17: Validation Check: Select the menu item HFSS > Validation Check, If no errors click on close button

STEP-18: ANALYZE ALL: Select the menu item HFSS> Analyze All In Progress Window it displays the solution process, If there are no errors message area displays the normal completion of simulation is successful.

VI. SIMULATION OUTPUTS MATERIAL: FR4 Epoxy

FR4 is a class of printed circuit board base material made from a flame retardant epoxy resin and glass fabric composite. FR stands for flame retardant and meets the requirements of UL94V-0. FR4 has good adhesion to copper foil and has minimal water absorption, making it very suitable for standard applications **.**



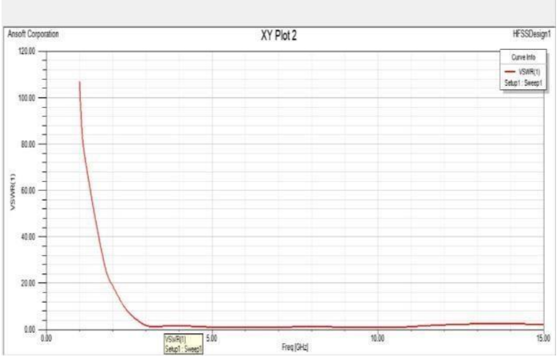


Fig-3: Return Loss **Fig-4: VSWR**

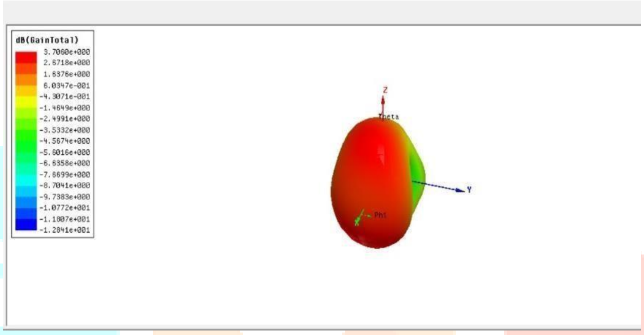


Fig-5: Gain

RETURN LOSS: The MIMO Antenna Shows a Resonant peak at 5.07GHz and gives return loss.
VSWR: The VSWR OF the proposed model is found to be almost 1.16.
GAIN: The MIMO antenna gives a gain value equal to -9.7DB

MATERIAL: ROGGRS4003

ROGERS 4003 is a popular high-frequency laminate material used in the fabrication of printed circuit boards (PCBs).

It offers excellent electrical performance at microwave frequencies and is commonly used in RF and microwave applications.

Fig-6: Return Loss

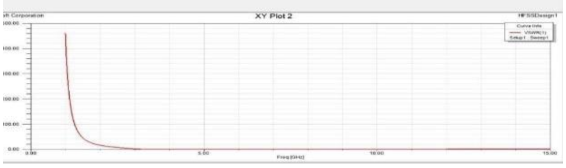


Fig-7: VSWR

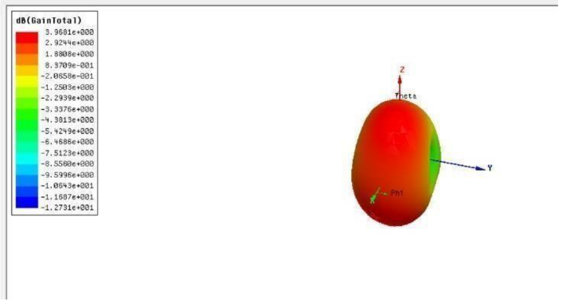


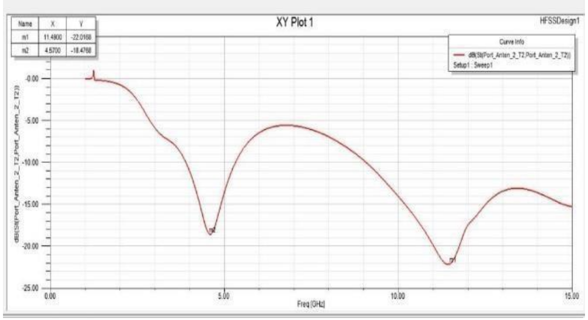
Fig-8: Gain

RETURN LOSS: The MIMO Antenna Shows a Resonant peak at 11.07GHz and gives return loss value equal to -27.67DB VSWR: The VSWR OF the proposed model is found to be almost 1.20.

GAIN: The MIMO antenna gives a gain value equal to -9.5db.

MATERIAL: AIR

Air substrate materials are lightweight, porous materials designed for applications in aerospace, packaging, and insulation. Composed of airfilled voids within a solid matrix, they offer excellent thermal insulation and structural integrity while reducing weight. Common materials include aerogels, foams, and honeycomb structures, ideal for various industries requiring lightweight and insulating materials.



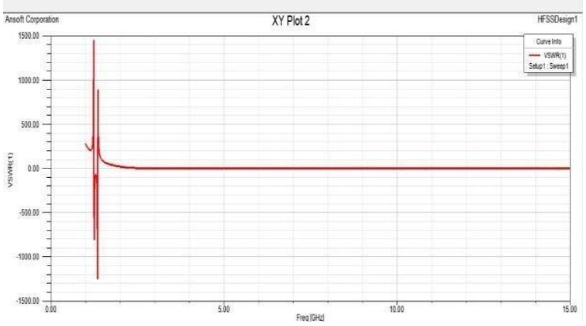


Fig-9: Return Loss **Fig-10: VSWR**

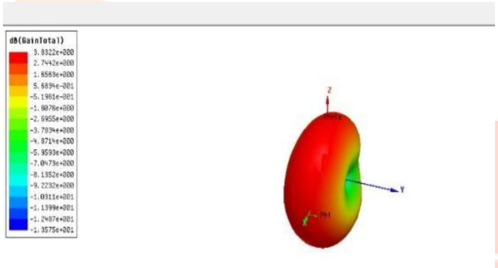
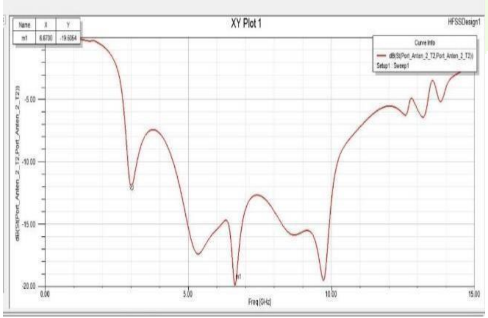


Fig-11: gain

MATERIAL-ROGGERSR04350(TM)

Rogers R04350™ :substrate material is a high-frequency laminate designed for RF/microwave applications. With a dielectric constant of 3.5 and low-loss tangent, it offers excellent signal integrity. Its low moisture absorption and thermal stability make it suitable for high-performance circuits in communication systems, radar, and aerospace applications.



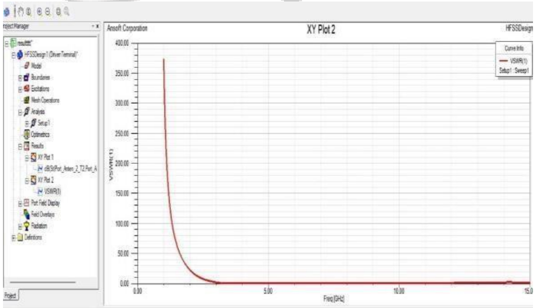


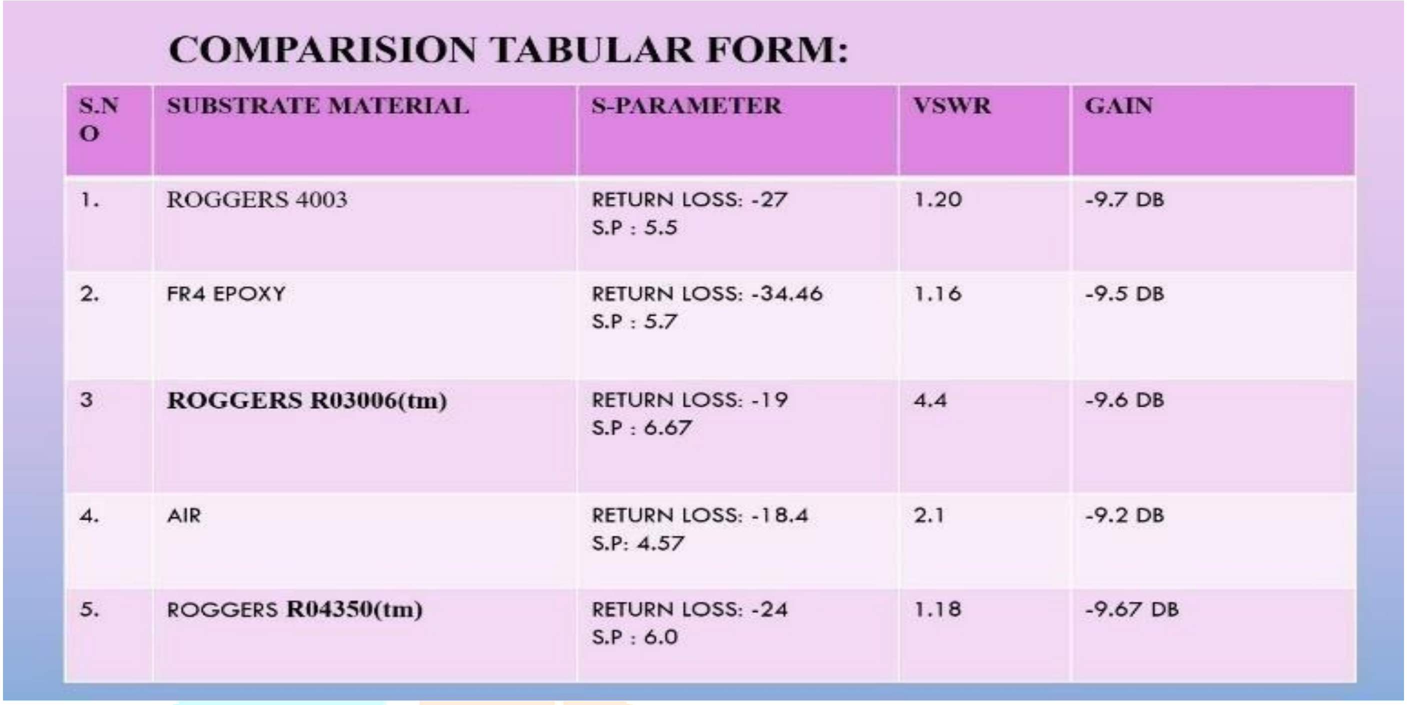
Fig:11-Return Loss Figu:12- VSWR

Fig:13-Gain

RETURN LOSS: MIMO Antenna Shows a Resonant peak at6.057GHz and gives return loss value equal to -24db. **VSWR:** VSWR OF the proposed model is found to be almost 1.18

GAIN MIMO antenna gives a gain value equal to -9.6DB.

VII.COMPARISION TABLE:



COMPARISION TABULAR FORM:

S.NO	SUBSTRATE MATERIAL	S-PARAMETER	VSWR	GAIN
1.	ROGGERS 4003	RETURN LOSS: -27 S.P : 5.5	1.20	-9.7 DB
2.	FR4 EPOXY	RETURN LOSS: -34.46 S.P : 5.7	1.16	-9.5 DB
3	**ROGGERS R03006(tm)**	RETURN LOSS: -19 S.P : 6.67	4.4	-9.6 DB
4.	AIR	RETURN LOSS: -18.4 S.P: 4.57	2.1	-9.2 DB
5.	ROGGERS **R04350(tm)**	RETURN LOSS: -24 S.P : 6.0	1.18	-9.67 DB

VIII. CONCLUSION:

The design of MIMO antennas with high isolation for UWB applications represents a frontier of wireless communication innovation. Advancements in antenna structures enable compact, broadband antennas with improved isolation. Integrated arrays simplify system integration, potentially miniaturizing UWB devices.

The MIMO antenna has proven to be a promising solution for wideband applications. Through simulations conducted using HFSS, it has demonstrated favourable characteristics which are Return loss is -34, VSWR is 1.16 and GAIN value is -9.5db and improved impedance matching.

These features make it suitable for various wireless communication systems operating across multiple frequency bands. Further experimentation and optimization could lead to even better performance, solidifying its position as a versatile option in antenna design for wideband applications.

IX. FUTURE SCOPE:

The future of designing MIMO antennas with high isolation for ultra-wideband (UWB) applications holds promise in several key areas. Advancements in antenna structures and materials can lead to compact, broadband antennas with improved isolation characteristics. Integrated antenna arrays will simplify system integration miniaturization for UWB devices. Beamforming and spatial processing algorithms tailored for UWB MIMO systems can enhance signal quality, while polarization diversity may mitigate fading effects.

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