Design of DGS Integrated MIMO Antenna for the IoT Application

Report for Project Stage II [EC 881]
Group no. 11
B. Tech in Electronics and Communication Engineering

B. P. Poddar Institute of Management & Technology

under

Maulana Abul Kalam Azad University of Technology

Under the supervision of

Dr. Susmita Biswas

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CERTIFICATE

This is to certify that the project work, entitled "DESIGN OF DGS INTEGRATED MIMO ANTENNA FOR THE IoT APPLICATION" submitted by ROUHI RAY, SUPARNA BHOWAL, SUSHMITA SINGH, SHANU MONDAL have been prepared according to the regulation of the degree B. Tech in Electronics & Communication Engineering of the Maulana Abul Kalam Azad University of Technology, West Bengal. The candidates have partially fulfilled the requirements for the submission of the project work.

---------------------------------------	**---------------------------------**
(Signature of HOD)	**(Signature of the Supervisor)**
Dept. of Electronics & Comm. Engg.	**Dept. of Electronics & Comm. Engg**

(Signature of External Examiner)

ACKNOWLEDGEMENTS

It is a great pleasure for us to express our earnest and great appreciation to DR. SUSMITA BISWAS ma'am, our project guide. We are very much grateful to her for her kind guidance, encouragement, valuable suggestions, innovative ideas, and supervision throughout this project work, without which the completion of the project work would have been difficult one.

We would like to express our thanks to the Head of the Department, DR. IVY MAJUMDAR for her active support.

We also express our sincere thanks to all the teachers of the department for their precious help, encouragement, kind cooperation and suggestions throughout the development of the project work.

We would like to express our gratitude to the library staff and laboratory staff for providing us with a congenial working environment.

Date: 26.05.2023

(Full Signature of the Students)

B. Tech in Electronics & Comm. Engg.

Department of Electronics & Comm. Engg.

B.P. Poddar Institute of Management & Technology

TABLE OF CONTENTS

DEPARTMENTAL MISSION, VISION, PEO, PO, PSO

Departmental Vision:

To emerge as a premier department for studies in Electronics and Communication Engineering.

Departmental Mission:

- Imparting innovative educational program through laboratory and project-based teaching-learningprocess for meeting the growing challenges of industry and research.
- Providing an inspiring and conducive learning environment to prepare skilled and competent engineers and entrepreneurs for sustainable development of the society.
- Creating a knowledge centre of advanced technologies committed to societal growth using environment-friendly technologies.

Program Educational Objectives (PEOs):

- Graduates of Electronics and Communication Engineering will be able to use latest tools and techniques to analyze, design and develop novel systems and products to solve real life problems.
- Graduates of Electronics and Communication Engineering will have strong domain knowledge, skills, and attitude toward employment in core and allied industries, higher studies and research or will become successful entrepreneurs.
- Graduates of Electronics and Communication will exhibit ethical values, professionalism, leadership, communication and management skills, teamwork, and multi-disciplinary approach to adapt current trends in technology through life-long learning.

Program Outcomes (POs):

1. **Engineering Knowledge:** Apply the knowledge of Mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem Analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design / Development of Solutions:** Design solutions for complex engineering

problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. **Conduct Investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities withan understanding of the limitations.
6. **Engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues, and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and Teamwork:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effectivereports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project Management and Finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long Learning:** Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSO):

- Students will acquire knowledge in Advance Communication Engineering, Signal, and Image Processing, Embedded and VLSI System Design.
- Students will qualify in various competitive examinations for successful employment, higher studies, and research.

<u>TITLE</u>: Design of DGS Integrated MIMO Antenna for the IoT Application

<u>AIM</u>: To design DGS Integrated MIMO Antenna

<u>OBJECTIVE</u>:-

(i) To design MIMO Antenna without DGS
(ii) To design DGS
(iii)To design MIMO antenna with DGS
(iv)To use this MIMO Antenna in IoT Application

<u>PO & PSO MAPPING</u>:-

PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	P012	PSO1	PSO2
1	3	3	3	3	3	2	2	3	1	3	3	3	2

Note: Correlation levels are as defined:

1: Slight (Low) 2: Moderate (Medium)

3: Substantial (High). If there is no correlation, put "-"

<u>JUSTIFICATIONS OF MAPPING</u>:-

PO/PSO MAPPED	LEVEL OF MAPPING	JUSTIFICATION
PO1	1	In this project we have applied knowledge of MIMO Antenna to find solutions to our problem, an engineering specialization to the solution of problems related to MIMO antenna.
PO2	3	Identify, formulate, research literature to analyse MIMO antenna
PO3	3	In our work we have considered societal, and electrical considerations
PO4	3	We have taken the help of previously published research papers to implement a solution.
PO5	3	We are designing our project with the help of ANSYS High Frequency Structural Simulator (HFSS) software.

PO6	3	Our project is helpful for society. Basically it is used in Wireless Communication.
PO7	2	Our project has a big impact on wireless communication
PO8	2	We abided by the ethical principles and professional ethics while working on this project.
PO9	3	We made this project with good team management and good spirits.
PO10	1	We are able to clearly communicate our project through effective reports, design documentation and presentations
PO11	3	This project will help us to work as a team and inculcate professional skills in us.
PO12	3	This is part of lifelong learning and helps us to know more about antennas and how they are used in a variety of applications.
PSO1	3	This project will help us to acquire knowledge in Advance Communication engineering in wireless communication
PSO2	2	This project will help us in higher studies and research work.

ABSTRACT

The present and future wireless communication systems, WiFi, fourth generation (4G), fifth generation (5G), Beyond5G and sixth generation (6G), are a mixture of many frequency spectrums. Therefore, multifunctional antenna modules with a common or shared aperture that operate on multi-band frequency spectra are highly desirable. This project presents the design and analysis of a compact MIMO (Multiple Input Multiple Output) antenna for wireless communication. The MIMO antenna is designed with size optimization considering the operating frequency at 2.4 GHz. The required mathematical calculation has been performed. The antenna is designed using ANSYS High Frequency Structure Simulator (HFSS) software. The designed antennas were simulated. The antenna would be fabricated and the results would be measured after the simulation. The result of this proposed compact MIMO antenna system shows wide bandwidth, high data rate and good amount of physical and virtual size reduction, which are promising proposed compact MIMO antennas suitable for next generation wireless application systems.

In IoT applications, MIMO can be particularly useful in environments with a large number of wireless devices, such as smart homes, industrial automation, and transportation systems. MIMO can improve the reliability and quality of wireless connections by mitigating the effects of interference and signal attenuation caused by obstacles such as walls, buildings, and other devices. MIMO also enables multiple antennas to transmit data simultaneously, which can increase the overall data throughput and reduce latency. This is especially important in IoT applications where real-time data transmission is critical, such as in remote monitoring, security and surveillance, and emergency response systems. Some of the popular wireless technologies used in IoT applications are Wi-Fi, Bluetooth, WLAN, and ZigBee, which operate in the 2.4 GHz to 5 GHz frequency band. These wireless standards are capable of handling high transmission rates over short distances.

ACTIVITY CHART

ODD SEMESTER:

JOB	15^{th} - 31^{st} July	1^{st} - 15^{th} Aug	16^{th} - 31^{st} Aug	1^{st} - 15^{th} Sep	16^{th}- 30^{th} Sep	1^{st} – 15^{th} Oct	16^{th} – 31^{th} Oct	1^{st} – 1^{th} Nov	16^{th} - 30^{th} Nov
0^{th} Review			✓						
Learning HFSS Software	✓	✓							
Extensive Study of Microstrip Antenna				✓					
Designing a Microstrip Antenna					✓	✓			
Designing Antenna Array							✓		
Midterm Evaluation							✓		
Final Evaluation for Odd Semester									✓

EVEN SEMESTER:

JOB	1^{st} - 31^{th} Jan	1^{st}- 28^{th} Feb	1^{st} - 31^{st} Mar	1^{st}- 30^{th} Apr	1^{st} – 15^{th} May	16^{th} -30^{th} May
Further optimization and verification of results	✓					
Midterm Evaluation				✓		
Final Evaluation for Even Semester						✓

CHAPTER 1: INTRODUCTION

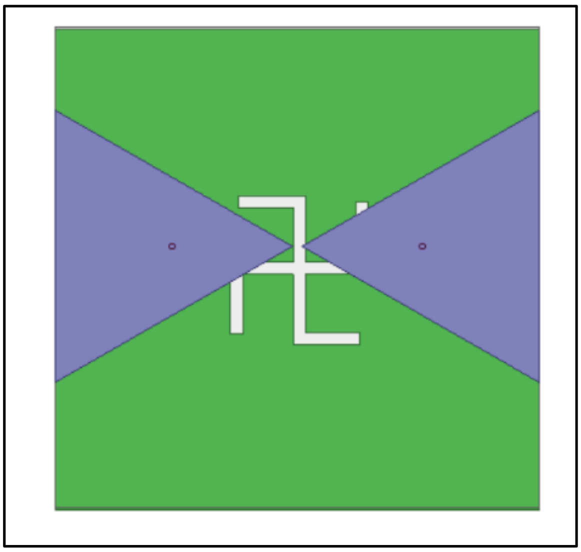
MIMO (multiple input, multiple output) is an efficient transmission technology used in modern wireless communication. As the name suggests, MIMO uses multiple antennas to transmit and receive. Combining multiple transmission sources increases data transmission speed and system efficiency. Smart devices with 802.11n wireless standard support MIMO technology.
MIMO (multiple input, multiple output) is an antenna technology for wireless communication in which multiple antennas are used both at the source (transmitter) and at the destination (receiver). Antennas at each end of the communications circuit are combined to minimize errors, optimize data rates, and improve radio transmission capacity by allowing data to be transmitted over multiple signal paths simultaneously. Creating multiple versions of the same signal provides more opportunities for data to reach the receiving antenna without being affected by attenuation, increasing the signal-to-noise ratio and error rate.

In this paper, a MIMO antenna is designed with size optimization considering the operating frequency at 2.4 GHz. The required mathematical calculation has been performed. The antenna is designed using ANSYS High Frequency Structure Simulator (HFSS) software. Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages, and printed circuit boards. The antenna would be fabricated and the results would be measured after the simulation. We introduce Defected Ground Structure (DGS) in the proposed antenna design. The result of this proposed compact MIMO antenna system shows wide bandwidth, high data rate and good amount of physical and virtual size reduction, which are promising proposed compact MIMO antennas suitable for next generation wireless application systems.

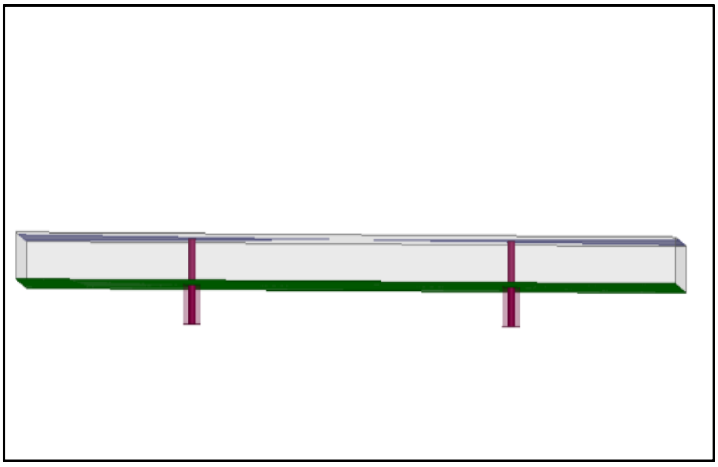
CHAPTER 2: THEORY

An initial design of a two-antenna array was determined using conventional microstrip theory. The design procedure began with determining the length, width and the type of dielectric substance for the given operating frequency. Then, using the measurements obtained below simulation has been setup for the basic triangular microstrip patch antenna and the parameters are optimized for the best impedance matching. A dielectric substrate Rogers RO3003 with ε_r = 3 and thickness of 6mm is introduced such that it increases the bandwidth. Coaxial feeding technique is introduced. A 'Swastik' shaped defected ground structure (DGS), is introduced at 116mm x 116mm ground of MIMO antenna to enhance gain and bandwidth. At last performance is evaluated by simulation parameter check.

Defected Ground Structure (DGS): A defected ground structure (DGS), is a purposefully created defect on the ground plane of a printed microstrip board. It is typically created in the form of an etched-out pattern on the ground plane. DGS is a simplified form of Electromagnetic Band Gap (EBG) structure. We have designed a 'swastik' shaped DGS for better performance. In the designed antenna, DGS in the shape of a 'swastik' is used for a specific purpose.



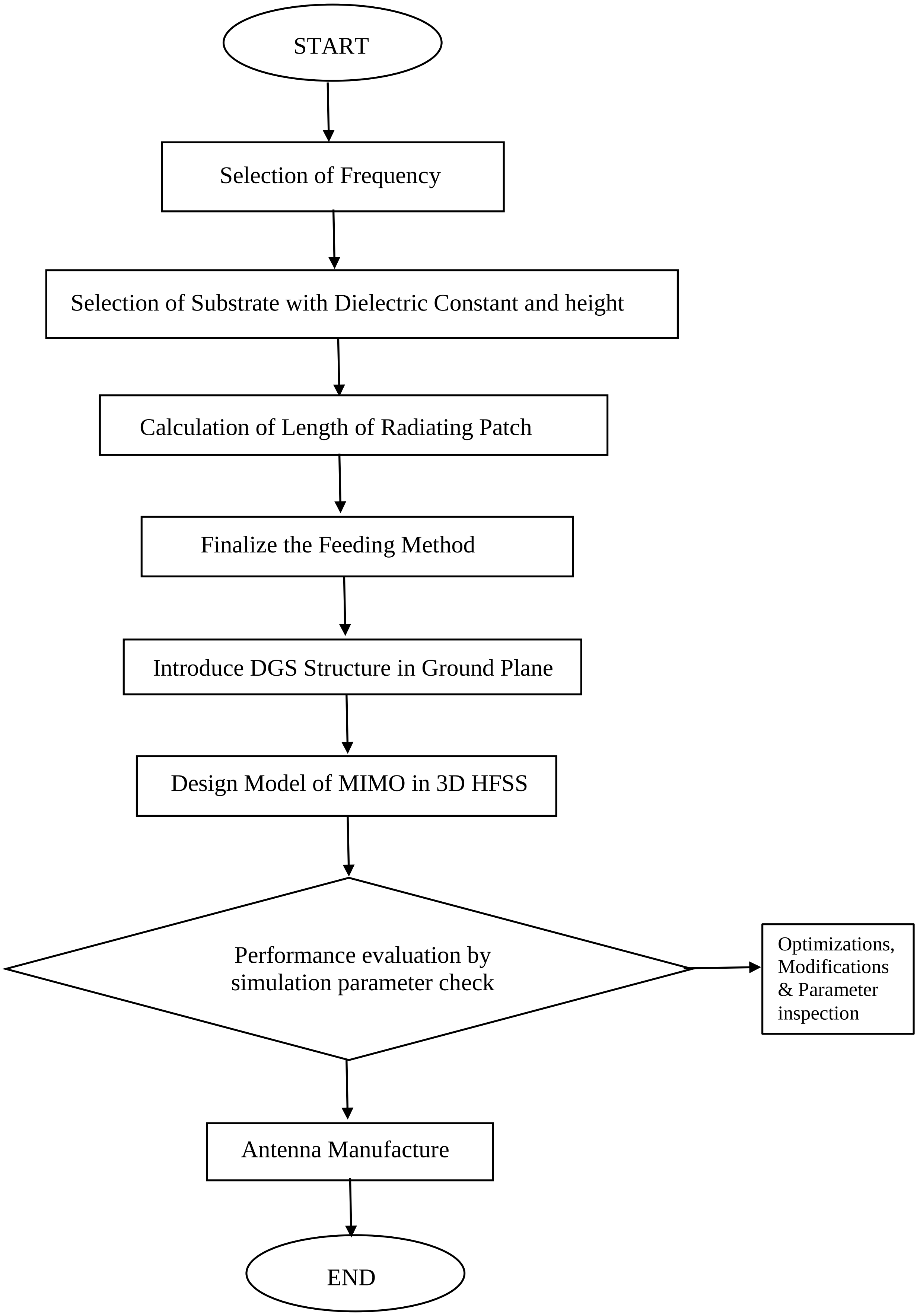
(i) Top View



(ii) Side View

Fig 1: Antenna Design in ANSYS HFSS

2.1 <u>FLOWCHART</u>:-



2.2 Mathematical Formulation:-

In order to demonstrate the design of proposed antenna with a frequency range of 2.4GHz, Rogers RO3003 substrate with relative permittivity $\varepsilon_r = 3$, and thickness (h) = 6mm.

- **Resonant Frequency**:-

Resonant frequency determines the dimension of the microstrip antenna. Therefore the corresponding resonance frequency is determine by reference

$$f_r = \frac{ck_{mn}}{2\pi\sqrt{\varepsilon_r}} = \frac{2c}{3a\sqrt{\varepsilon_r}}(m^2 + mn + n^2) \qquad \text{———} \quad (1)$$

Where c is velocity of light in free space and Kmn is wave number. The wave number can be determined by reference

$$K_{mn} = \frac{4\pi}{3}\sqrt{m^2 + mn + n^2}$$

Therefore, from the above equation for lowest order resonance frequency, is given

$$f_r = \frac{2c}{3a\sqrt{\varepsilon_r}} \qquad \text{———} \quad (2)$$

Where :

f_r = Operating frequency

ε_r = Permittivity of the dielectric

a = length of the side triangular patch

- **Triangular Patch Dimension:-**

The triangular patch has three sides with a length, as shown in Fig 2

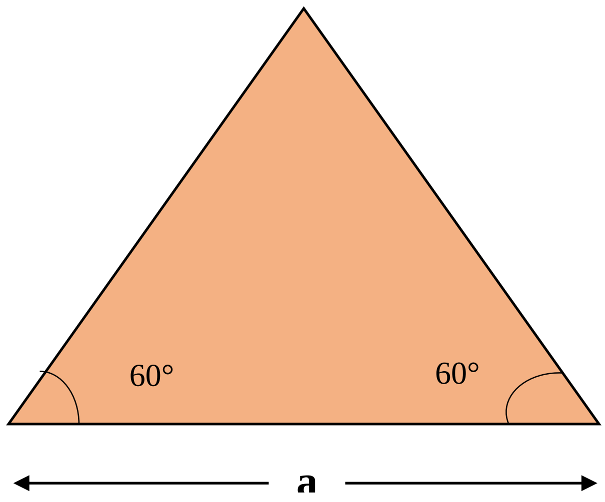


Fig 2: Triangular Patch Microstrip Antenna

After substituting the above equation with the given value for fr = 2.4 GHz, velocity of light, c = 33 × $10^8\ ms^{-1}$, and ε_r = 3, the length of patch can be calculated. In order to determine length of triangle patch, a, the Eq. 2 is utilized which give the result

$$\boldsymbol{a = \frac{2c}{3f_r\sqrt{\varepsilon_r}}} \qquad (3)$$

Finally,

$$\boldsymbol{a = \frac{2*3*10^8}{3*2.4*10^9\sqrt{3}} \approx 48\ mm}$$

In this project, we have used Patch's length (a) = 37.9 mm as we get good result using this value.

- **Coaxial Feed Location Measurement:-**

  The antenna is designed using RO3003 dielectric of thickness 6mm with dimensions of 116x 116 x 6mm^3 and feed by a Co- axial feed of 50Ω. Equations (4-9) are used for the proposal of rectangular micro strip patch antenna. Feed points location inside the patch are X=10mm and Y=13.6mm from the centre.

$$\boldsymbol{W = \frac{c}{2f_r\sqrt{\frac{(\varepsilon_r+1)}{2}}} = \frac{3*10^8}{2*2.4*10^9\sqrt{\frac{(3+1)}{2}}}\ mm} \qquad (4)$$

$$\boldsymbol{\approx 44\ mm}$$

$$\boldsymbol{\Delta L = 0.412h\frac{(\varepsilon_r+0.3)\left(\left(\frac{W}{h}\right)+0.264\right)}{(\varepsilon_r+0.258)\left(\left(\frac{W}{h}\right)+0.8\right)}\ mm} \qquad (5)$$

$$\boldsymbol{= 0.412*6*\frac{(3+0.3)\left(\left(\frac{44}{6}\right)+0.264\right)}{(3+0.258)\left(\left(\frac{44}{6}\right)+0.8\right)}\ mm} \approx 2.33\ mm$$

$$\boldsymbol{L = \frac{c}{2f\sqrt{\varepsilon_r}} - 2\Delta L} \qquad (6)$$

$$\boldsymbol{= \frac{3*10^8}{2*2.4*10^9\sqrt{3}} - 2*2.33\ mm \qquad \approx 33\ mm}$$

Effective dielectric constant (ε_{reff})

$$\boldsymbol{\varepsilon_{reff}} = \frac{\varepsilon_r+1}{2} + \left[\frac{\varepsilon_r-1}{2\sqrt{1+12\left(\frac{h}{W}\right)}}\right] \qquad \text{———} \quad (7)$$

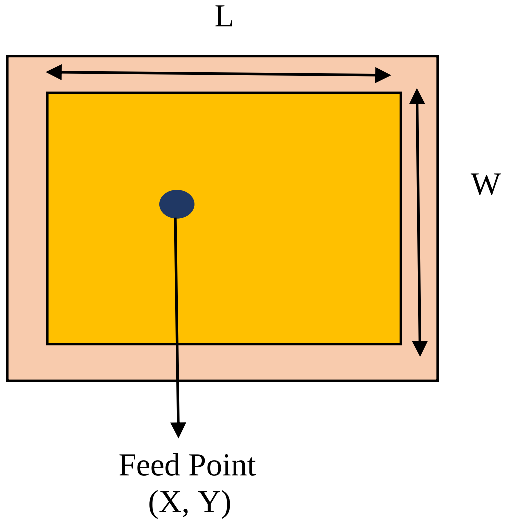
$$= 2.62 \text{ mm}$$

Distance of feed point from L (X):

$$\mathbf{X} = \frac{\mathbf{L}}{2\sqrt{\boldsymbol{\varepsilon}_{\mathbf{reff}}}} = \mathbf{10}\boldsymbol{mm} \qquad \text{———} \quad (8)$$

Distance of feed point from W (Y):

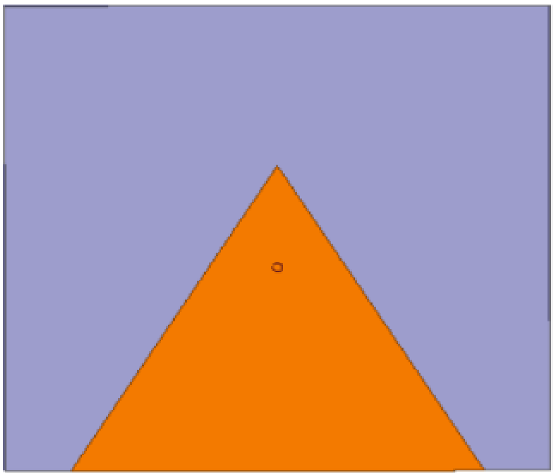
$$\mathbf{Y} = \frac{\mathbf{W}}{2\sqrt{\boldsymbol{\varepsilon}_{\mathbf{reff}}}} = \mathbf{13.6}\ \boldsymbol{mm} \qquad \text{———} \quad (9)$$



But we have used triangular patches because interference between rectangular patches is higher than triangular patches in this project.

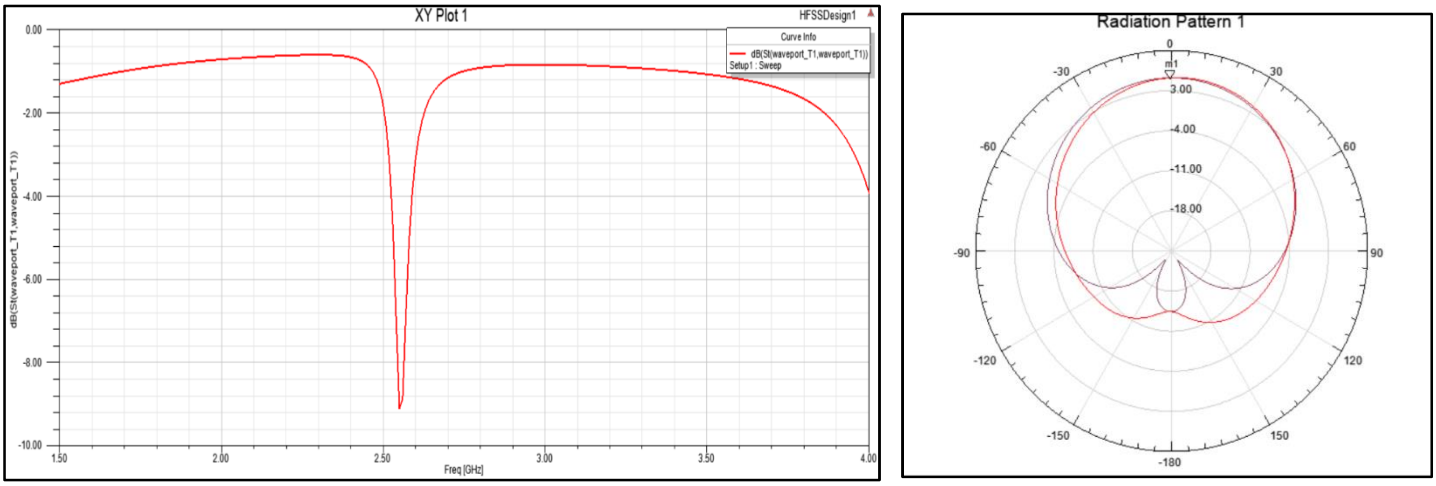
<u>**CHAPTER 3: DESIGN OF PROPOSED SYSTEM**</u>

- **Design of Single Patch Antenna:** The Microstrip Patch Antenna is a single-layer design which consists generally of four parts (patch, ground plane, substrate, and the feeding part). Patch antenna can be classified as single – element resonant antenna. A triangular resonator antennas are placed on top of a 6 mm thick Rogers RO3003 substrate with a length of 80 mm and a relative permittivity of 3, and the ground plane is designed on the bottom of the substrate. The Operating frequency is 2.4 GHz.



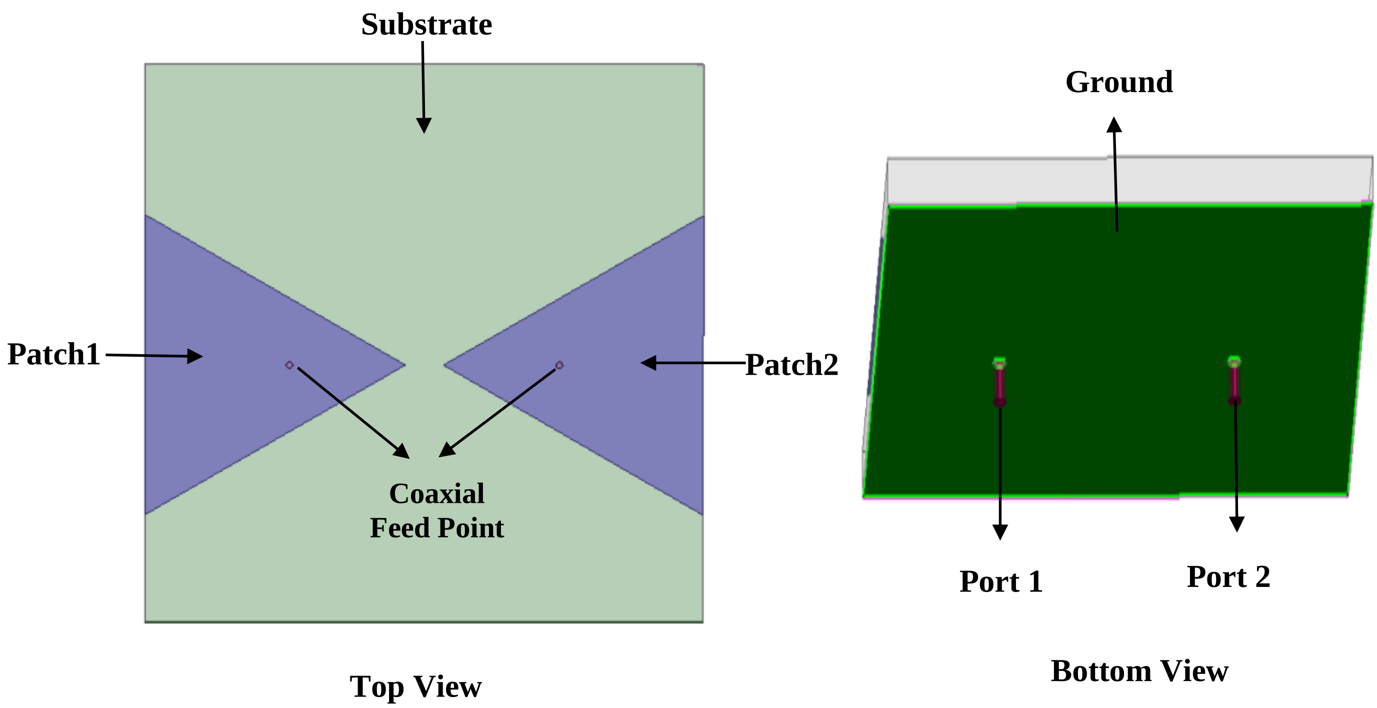
<u>Fig 3: Single Patch Antenna</u>

- **Result:-**



<u>Fig 4: Result of S-Parameter & Radiation Pattern of gain</u>

- **Design of MIMO Antenna:** The geometry and layout of the given MIMO antenna are shown in Fig. 5. Two triangular resonator antennas are placed on top of a 6 mm thick Rogers RO3003 substrate with a length of 116 mm and a relative permittivity of 3, and the ground plane is designed on the bottom of the substrate. The radiating element is moved by the coaxial feeding technique. Coaxial feed technique consists of pin, probe and coax. The height of the probe is 6mm from the base plane to the patch and similarly the height of the pin is 5mm below the base plane in the opposite direction to the probe, the length of the coaxial cable being the same as the pin and also in the same direction, but the only difference is the radius, we took the radius of the coax according to the ground cutter 1 mm, and the radius of 0.7 mm is placed under the power point port. One thing to note first is that we need to cut the ground according to the coaxial feed radius means the radius of the coaxial.



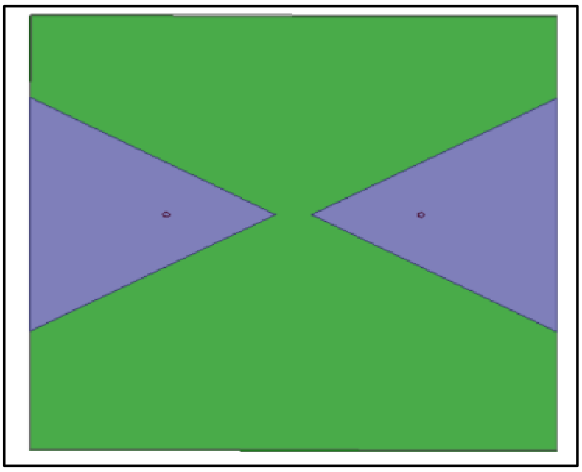
<u>Fig 5: Proposed MIMO Antenna</u>

However, the proposed design is only related to the isolation of the antenna array. Furthermore, the proposed antenna also provides the desired gain, reliable efficiency, which are important parameters for any antenna array. Table 1 lists the advanced parameters of a given MIMO antenna.

Parameters	**Values**	**Parameters**	**Values**
Substrate Length(L)	116 mm	Coaxial-1 height	5 mm
Substrate Width(W)	116 mm	Patch 2 length	37.9 mm
Height(h)	6 mm	Pin-2 radius	0.7 mm
Permittivity(ϵ_r)	3	Pin-2 height	5 mm
Ground Length	116 mm	Probe-2 radius	0.7 mm
Ground Width	116 mm	Probe-2 height	6 mm
Patch 1 length	37.9 mm	Coaxial-2 radius	1.6 mm
Pin-1 radius	0.7 mm	Coaxial-2 height	5 mm
Pin-1 height	5 mm	Port-1 radius	1.6 mm
Probe-1 radius	0.7 mm	Port-2 radius	1.6 mm
Probe-1 height	6 mm		
Coaxial-1 radius	1.6 mm		

Table 1: Dimensions of Proposed MIMO Antenna

A second patch of the same shape and size is placed close to the first as shown in Fig. 6. One has a common base plane. Each antenna element in the MIMO system is powered by a 50 Ω microstrip feed line to achieve perfect impedance matching.



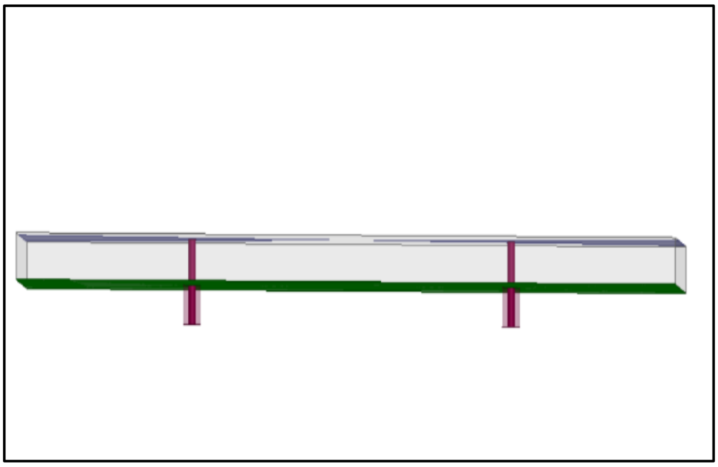


Fig 6: Top View & Side View of Proposed Antenna

- **Result:-**

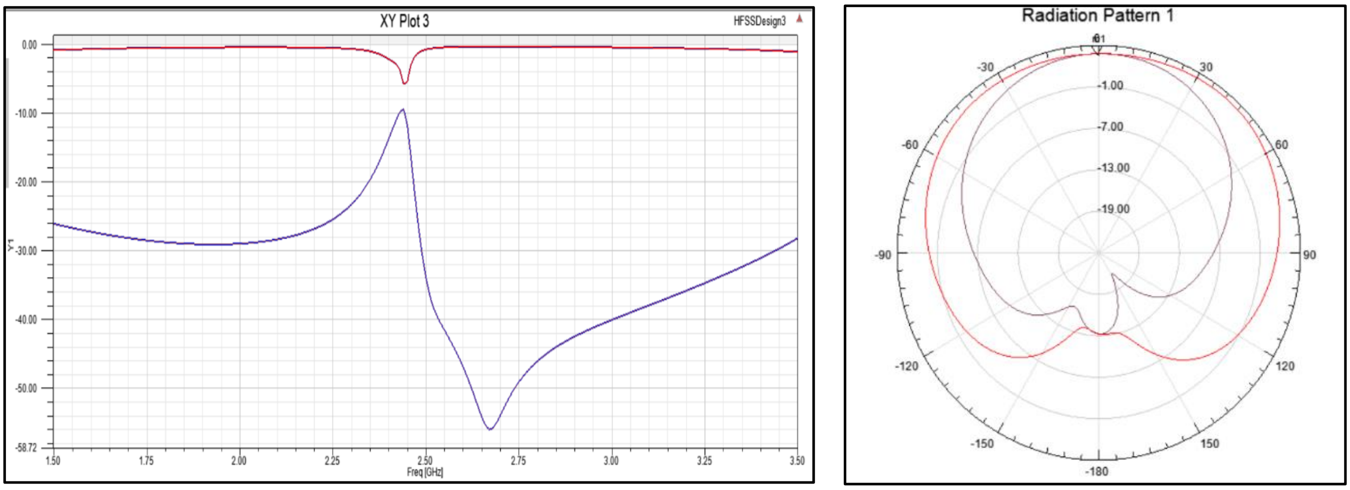
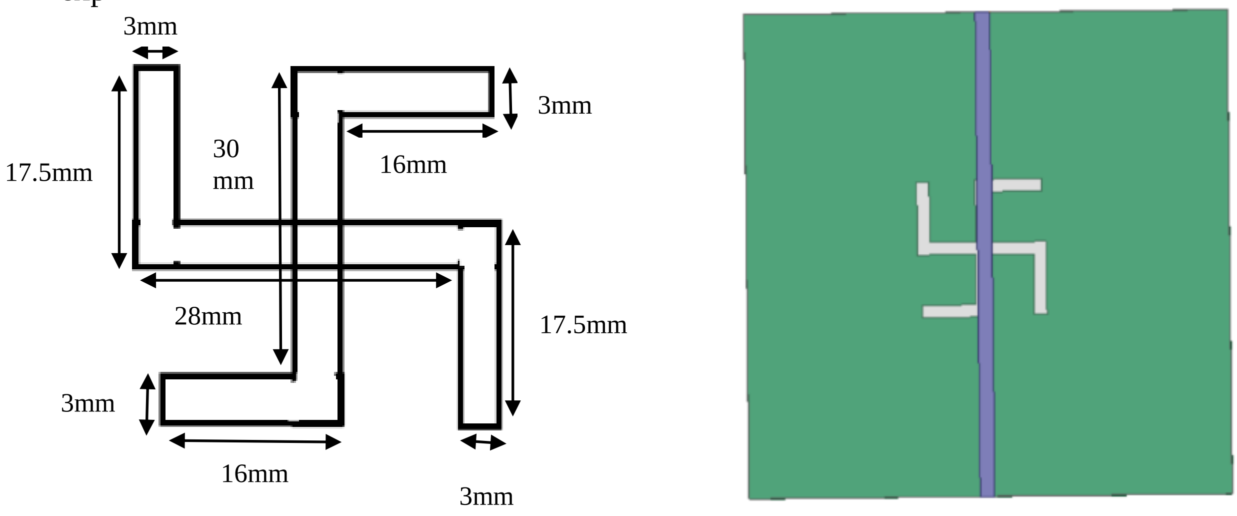
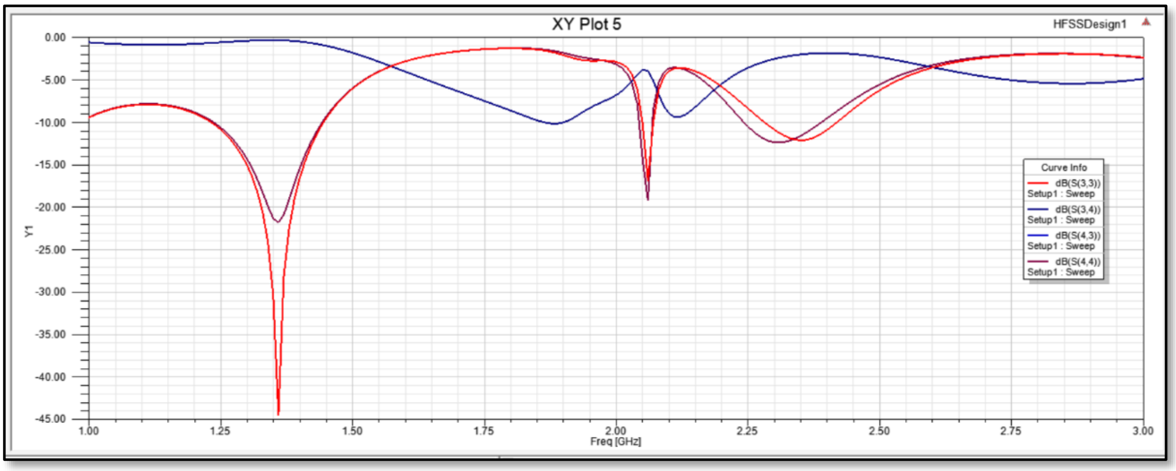


Fig 7: Result of S-Parameter & Radiation Pattern of gain

- **Design of DGS:** DGS (Defected Ground Structure) is a popular technique used in antenna design to achieve various antenna properties, such as miniaturization, bandwidth enhancement, and radiation pattern control. In this Paper, experimental investigations were carried out on a microstrip antenna that was embedded with a Swastik-shaped DGS. We find that the unwanted cross-polarization is reduced while the impedance bandwidth is expanded.



(a)



(b)

Fig 8: (a) Swastik Shaped DGS Structure & (b) Result

- **MIMO antenna design with DGS:** In microstrip antennas, DGS is used to increase gain and bandwidth. It is also used to suppress harmonic higher modes, mutual coupling between elements and to improve the radiation characteristics of a microstrip antenna. Here triangular patches on the upper plane of the antenna and etched meander shape structure on the ground plane. We have designed a 'swastik' shaped DGS for better performance. In the designed antenna, DGS in the shape of a 'swastik' is used for a specific purpose. Increases isolation between antenna arrays by acting as reactors to distinguish array radiation. The dimension of swastika shaped DGS are 30mm, 16mm, 3mm, 28mm and 17.5mm.

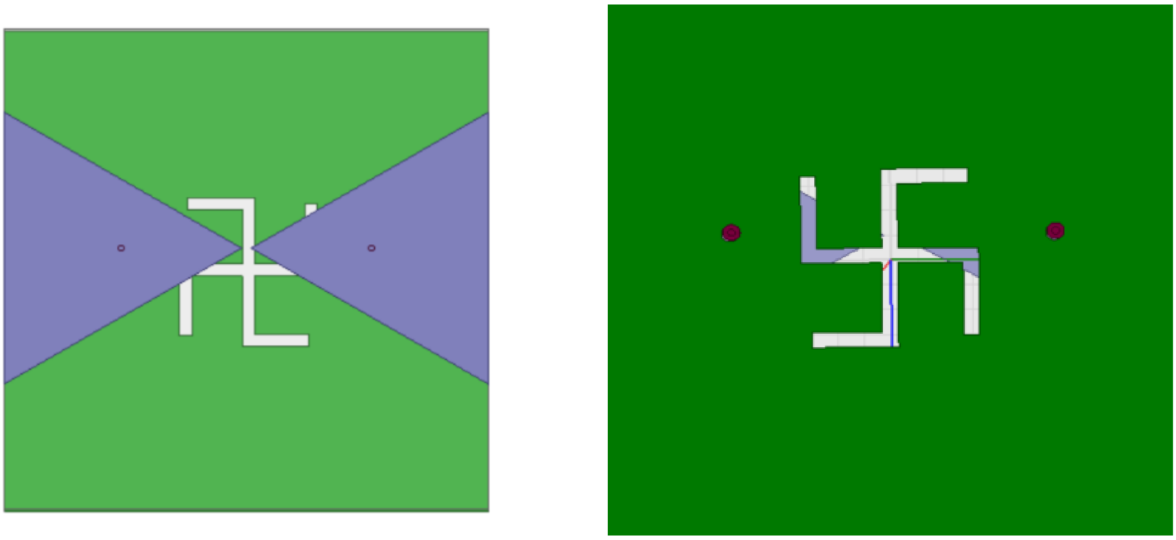
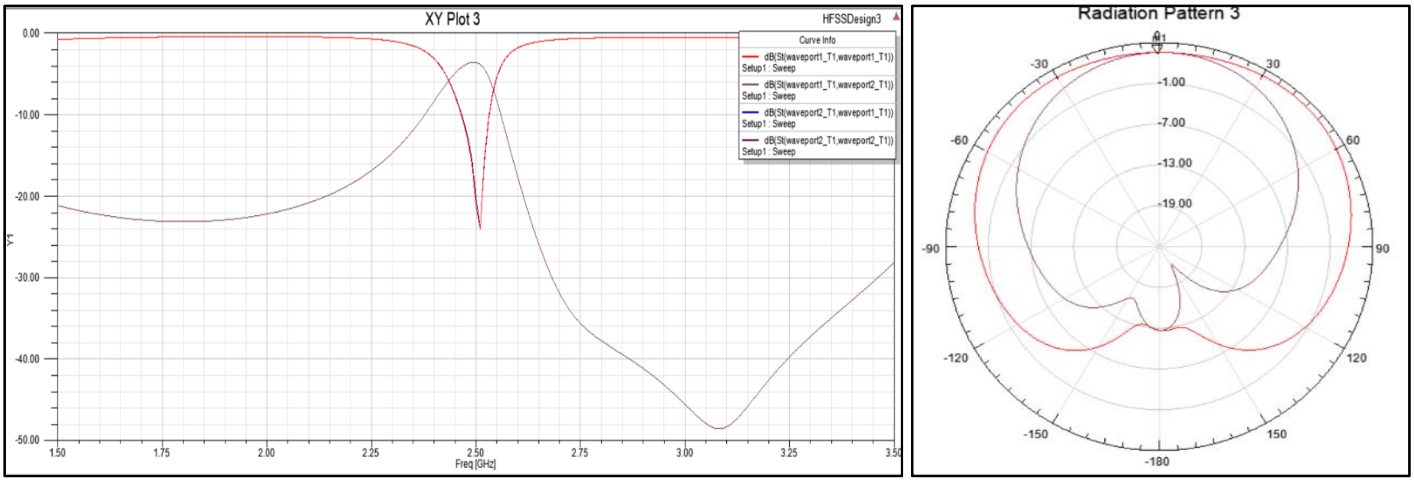


Fig 9: Top view & Bottom view MIMO Antenna with DGS

- **Result:-**



<u>Fig 10: Result of S-Parameter & Radiation Pattern of gain</u>

CHAPTER 4: RESULTS & DISCUSSION

Parametric Study:-

The results of the proposed antenna have been simulated in a finite element method-based solver high-frequency structure simulator (HFSS).

- **S-Parameter:-**

Two triangular patches are placed on a commercially available Rogers RO3003 substrate with a dielectric constant of three and a height of 6 mm. Return Loss S11 is (represents the amount of radiation reflected back from the antenna), also known as the reflection coefficient. S21 is insert attenuation or isolation before separation.

In fig 11, the simulated S11 result of the given MIMO antenna while using Swastik-shaped DGS in the ground at 2.4 GHz is −24.05 dB & without using DGS at ground at 2.4 GHz is -5.97 dB.

In fig 12, the simulated S21 result of the given MIMO antenna while using Swastik-shaped DGS in the ground at 2.4 GHz is −53 dB & without using DGS at ground at 2.4 GHz is -48 dB.

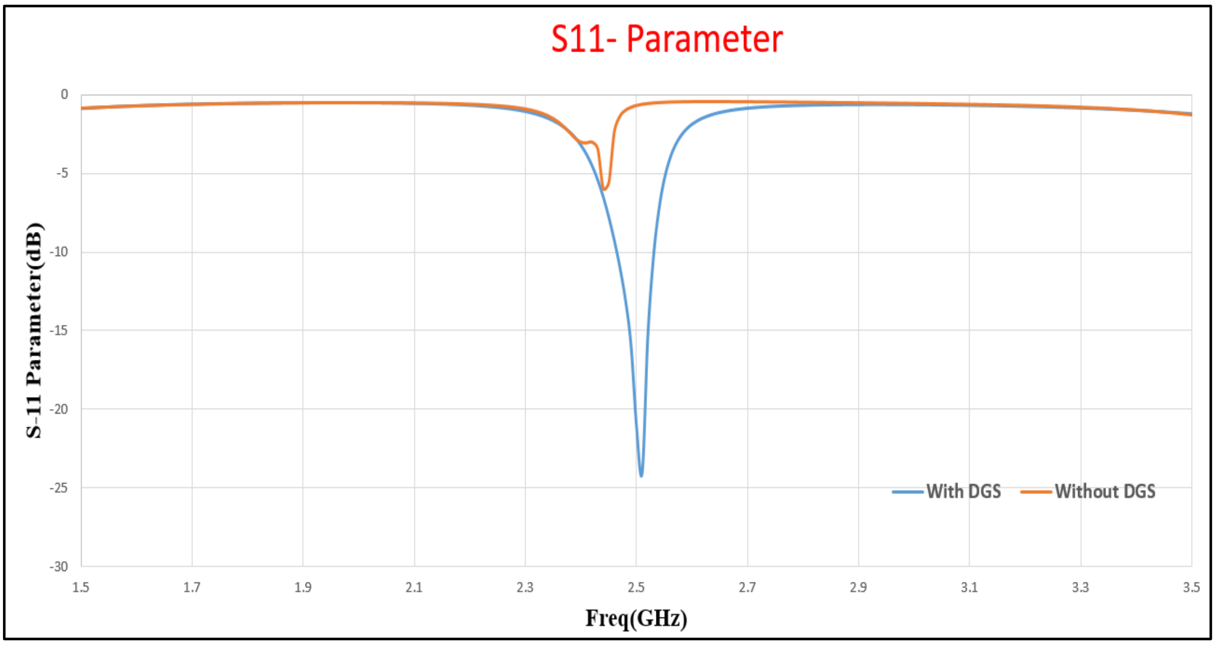


Fig 11: S11 Parameter with DGS & without DGS

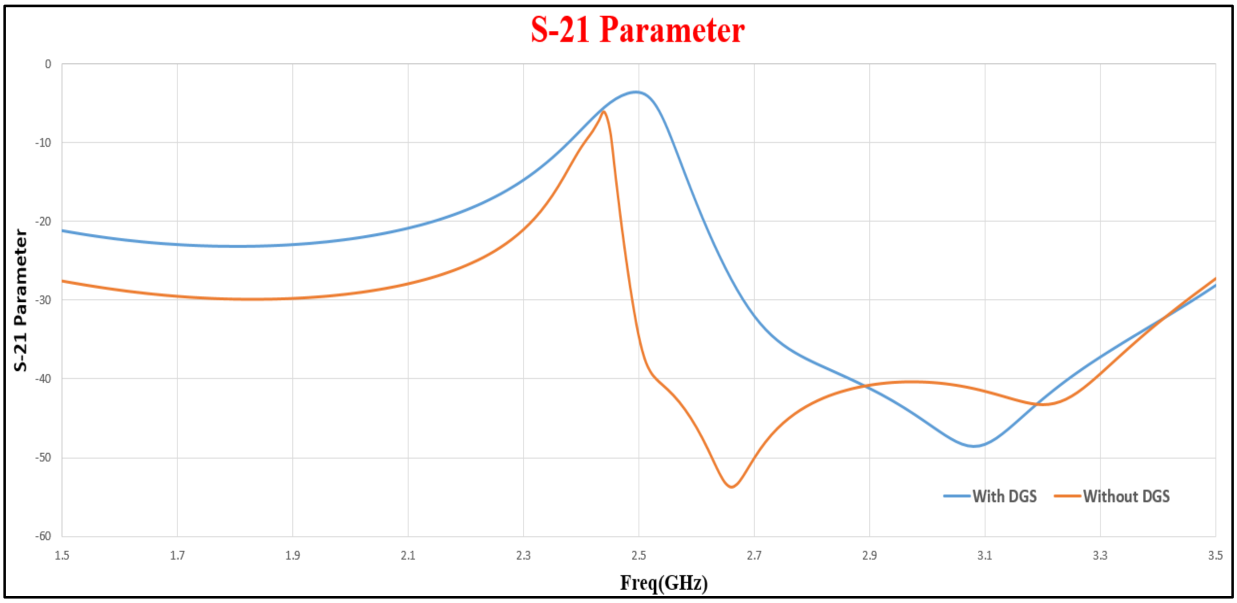


Fig 12: S21 Parameter with DGS & without DGS

- **VSWR:-**

Voltage Standing Wave Ratio (VSWR) is the amount of line mismatch and is an important part of the S11 parameter in an antenna system, a suitable VSWR value for an antenna is between one and two. In Fig. 13, the VSWR value using DGS is 1.13, which is ideal for communication.

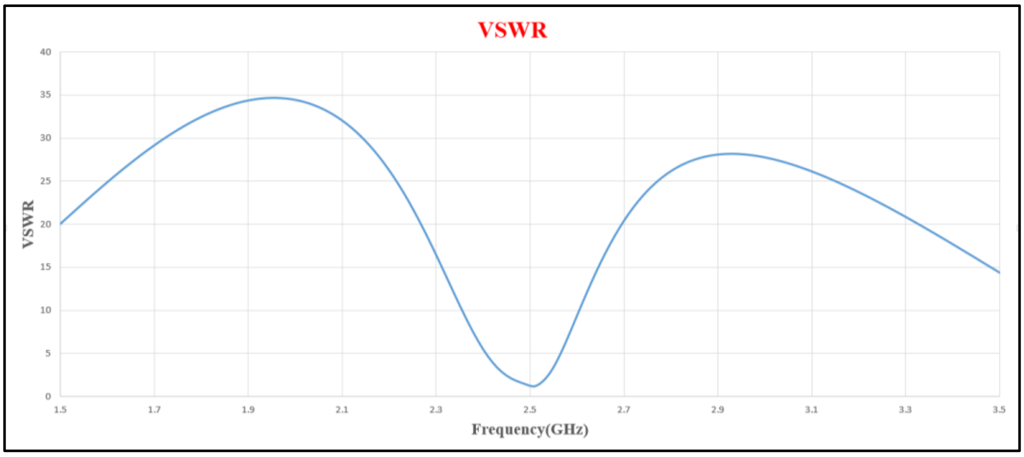


Fig 13: VSWR of Proposed

- **<u>Antenna Gain</u>:-**

Antenna gain is a main parameter that links antenna directivity and efficiency. It is the directivity of the antenna; if the antenna gain is high in a certain direction, it means that the antenna is working properly.

In fig 14, the total gain of antenna using DGS is 3.53 dB & without using DGS 3.23 dB at 2.4 GHz.

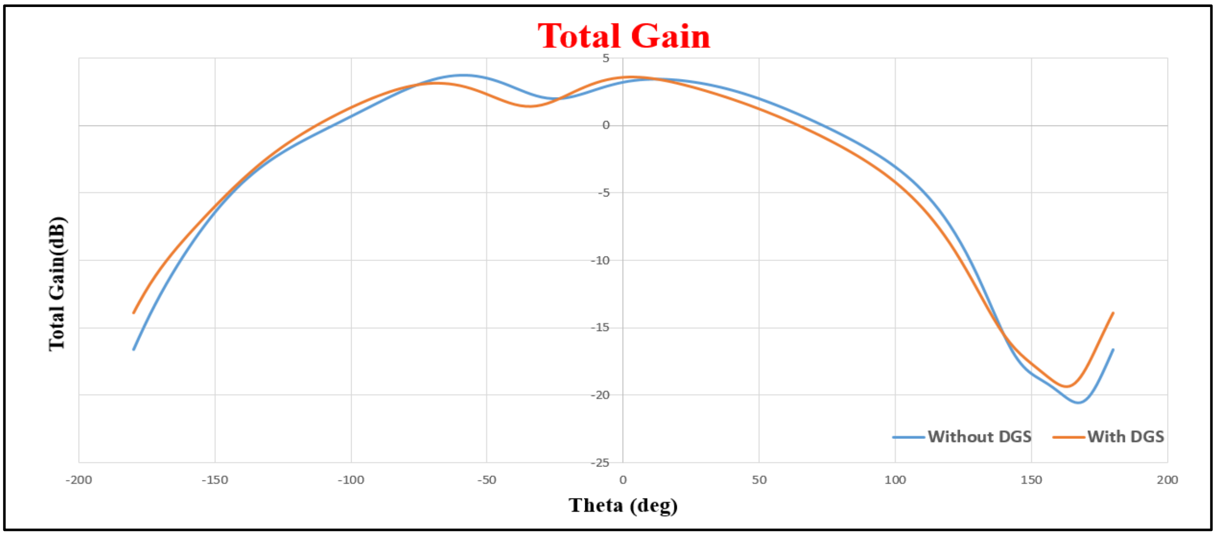


Fig 14: Total Gain with DGS & without DGS

- **<u>Directivity</u>:-**

Directivity is also another parameter of the antenna and is defined as the magnitude of the radiation intensity in the proposed direction to its average in the total directions, it is also similar to gain means that if the directivity is high, the antenna will work properly.

In fig 15, the total directivity of antenna using DGS is 3.73 dB & without using DGS 3.46 dB at 2.4 GHz.

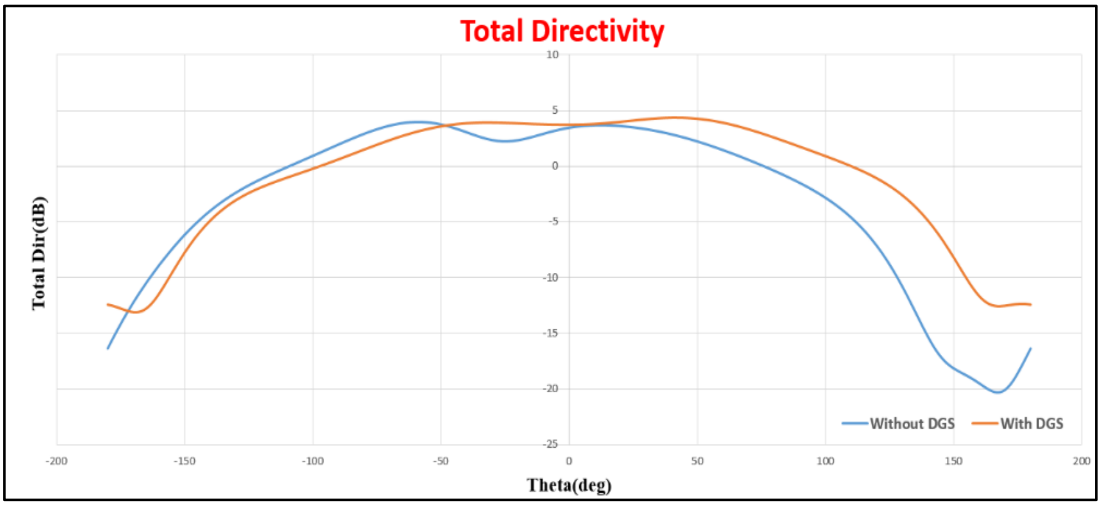


Fig 15: Total Directivity with DGS & without DGS

- **3-D Polar Plot:-**

In fig 16, the total gain of antenna using DGS is 4.16 dB at 2.4 GHz in 3-D Polar Plot.

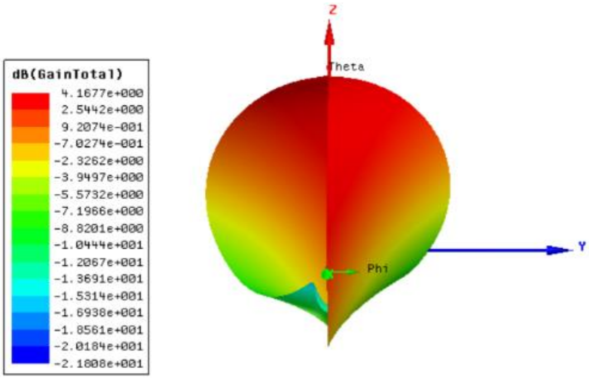


Fig 16: 3-D Polar Plot

- **Radiation Pattern:-**

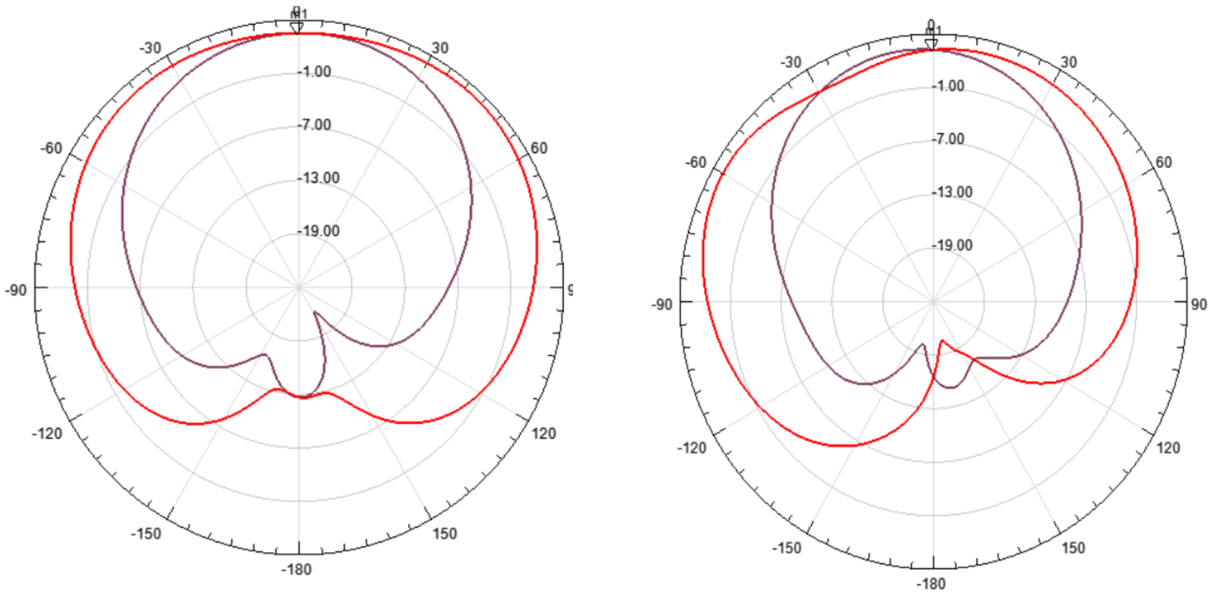


Fig 17: Radiation Pattern (a) with DGS & (b) without DGS

- **Current Distribution**:-

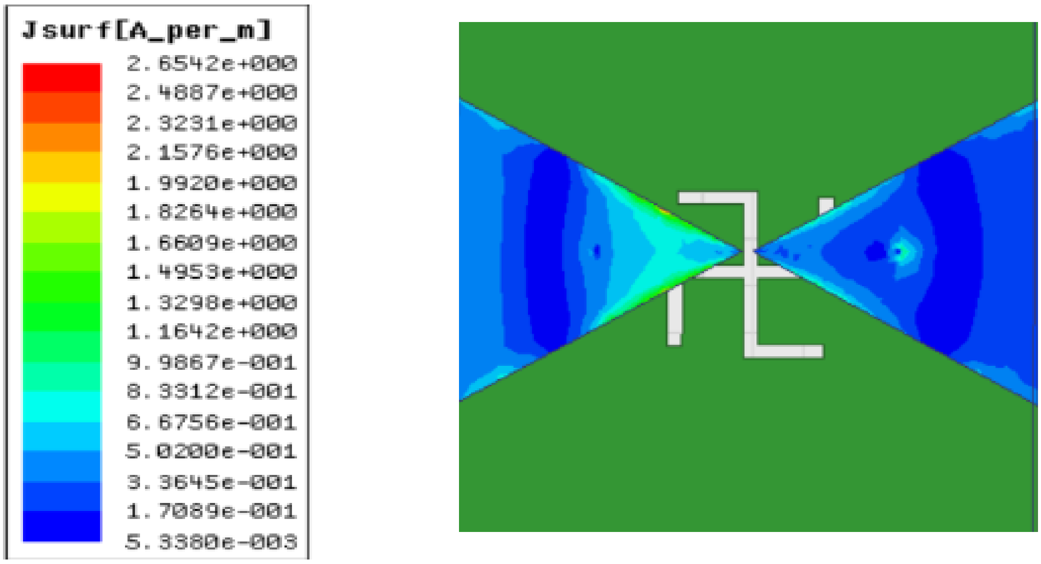


Fig 18: Simulated Current Distribution

DISCUSSIONS:-

In this project, the proposed MIMO antenna arrays with advanced isolation has been designed using HFSS Software. The proposed antenna is designed to operate at 2.4 GHz frequency band which is used for wireless communication in IoT devices, particularly for Wi-Fi and Bluetooth connectivity. Two triangular patch antennas are placed close to each other on a RO3003 substrate with a thickness of 6 mm, and DGS is used for isolation in the ground layer. The main purpose of DGS of different shapes is to obtain high cross-coupling reduction. In this paper, -53 dB was obtained using H-shaped DGS. Describes S11 parameters, S21 parameters, VSWR, total gain, directivity, radiation pattern. The obtained results are -24.05 dB, -53 dB, 1.13, 3.53 dB, 3.73 dB respectively for the above parameters at 2.4 GHz frequency. Projected antennas are valuable for MIMO antenna systems that require a high degree of cross-coupling reduction. The proposed MIMO antenna is applicable for IoT applications and also in other practical scenarios.

CHAPTER 5: FUTURE PLAN

Future plans for this project include publishing a research paper and, if necessary, further we will improve the results through ongoing experiments and simulations. Test this MIMO antenna with IoT devices. The 2.4 GHz band is widely used for wireless communication in IoT devices, particularly for Wi-Fi and Bluetooth connectivity. This band offers high data rates but has limited range and can be subject to interference from other devices operating in the same band. Common wireless technologies used in IoT applications include Wi-Fi, Bluetooth, WLAN, and ZigBee, which operate in the 2.4 GHz frequency band. Some IoT components like DHT11 Sensor, BMP180 Sensor, Rain Sensor, ESP8266 Nodemcu Wi-Fi Module also work on 2.4GHz frequency band.

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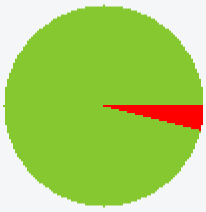

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ABSTRACT

The present and future wireless communication systems, WiFi, fourth generation (4G), fifth generation (5G), Beyond5G and sixth generation (6G), are a mixture of many frequency spectrums. Therefore, multifunctional antenna modules with a common or shared aperture that operate on multi-band frequency spectra are highly desirable. This project presents the design and analysis of a compact MIMO (Multiple Input Multiple Output) antenna for wireless communication. The MIMO antenna is designed with size optimization considering the operating frequency at 2.4 GHz. The required mathematical calculation has been performed. The antenna is designed and simulated using ANSYS High Frequency Structure Simulator (HFSS) software. The designed antennas were simulated. The antenna would be fabricated and the results would be measured after the simulation. The results of this proposed compact MIMO antenna system show wide bandwidth, high data rate and significant reduction in physical and virtual size, which makes it promising as a suitable proposed compact MIMO antenna for next-generation wireless application systems.

In IoT applications, MIMO can be particularly useful in environments with a large number of wireless devices, such as smart homes, industrial automation, and transportation systems. MIMO can improve the reliability and quality of wireless connections by mitigating the effects of interference and signal attenuation caused by obstacles such as walls, buildings, and other devices. MIMO also enables multiple antennas to transmit data simultaneously, which can increase the overall data throughput and reduce latency. This is especially important in IoT applications where real-time data transmission is critical, such as in remote monitoring, security and surveillance, and emergency response systems. Some of the popular wireless technologies used in IoT applications are Wi-Fi, Bluetooth, WLAN, and ZigBee, which operate in the 2.4 GHz to 5 GHz frequency band. These wireless standards are capable of handling high transmission rates over short distances.

CHAPTER 1: INTRODUCTION

MIMO (multiple input, multiple output) is an key technology used in modern wireless communication. As the name suggests, MIMO uses multiple antennas to transmit and receive. Combining multiple transmission sources increases data transmission speed and system efficiency. Smart devices with 802.11n wireless standard support MIMO technology.

MIMO (Multiple Input, Multiple Output) is an antenna technology for wireless communication in which multiple antennas are used at both the source (transmitter) and the destination (receiver). Antennas are combined at both ends of a communication circuit to minimize errors, optimize data rates, and improve radio transmission capacity by allowing data to be transmitted simultaneously over multiple signal paths.

This antenna is designed using ANSYS high frequency structure simulator (HFSS) software. Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed connectors, filters, connectors, IC packages, and printed circuit boards. We introduce Defected Ground Structure (DGS) in the proposed antenna design. The result of this proposed compact MIMO antenna system shows wide bandwidth, high data rate and good amount of physical and virtual size reduction, which are promising proposed compact MIMO antennas suitable for next generation wireless application systems.

CHAPTER 2: THEORY

An initial design of a two-antenna array was determined using conventional microstrip theory. The design procedure began with determining the length, width and the type of dielectric substance for the given operating frequency. Then, using the measurements obtained below simulation has been setup for the basic triangular microstrip patch antenna and the parameters are optimized for the best impedance matching. A dielectric substrate Rogers RO3003 with $\varepsilon_r = 3$ and thickness of 6mm is introduced such that it increases the bandwidth. Coaxial feeding technique is introduced. A ‘Swastik’ shaped defected ground structure (DGS), is introduced at 116mm x 116mm ground of MIMO antenna to enhance gain and bandwidth. At last performance is evaluated by simulation parameter check.

CHAPTER 3: PROPOSED SYSTEM

Designing of MIMO Antenna: The geometry and layout of the given MIMO antenna are shown in Fig. 1. Two triangular resonator antennas are placed on top of a 6 mm thick Rogers RO3003 substrate with a length of 58 mm and a relative permittivity of 3, and the ground plane is designed on the bottom of the substrate. The radiating element is moved by the coaxial feeding technique. Coaxial feed technique consists of pin, probe and coax. The height of the probe is 6mm from the base plane to the patch and similarly the height of the pin is 5mm below the base plane in the opposite direction to the probe, the length of the coaxial cable being the same as the pin and also in the same direction, but the only difference is the radius, we took the radius of the coax according to the ground cutter 1 mm, and the radius of 0. 7 mm is placed under the power point port. One thing to note first is that we need to cut the ground according to the coaxial feed radius means the radius of the coaxial.

Designing of DGS: DGS (Defected Ground Structure) is a popular technique used in antenna design to achieve various antenna properties, such as miniaturization, bandwidth enhancement, and radiation pattern control. In this Paper, experimental investigations were carried out on a microstrip antenna that was embedded with a Swastik-shaped DGS. We find that the unwanted cross-polarization is reduced while the impedance bandwidth is expanded.

MIMO antenna design with DGS: Here triangular patches on the upper plane of the antenna and etched meander shape structure on the ground plane. We have designed a ‘swastik’ shaped DGS for better performance. In the designed antenna, DGS in the shape of a ‘swastik’ is used for a specific purpose. Increases isolation between antenna arrays by acting as reactors to distinguish array radiation. The dimension of swastika shaped DGS are 30mm, 16mm, 3mm, 28mm and 17.5mm.

CHAPTER 5: RESULTS & DISCUSSION

Parametric Study:-

• S-Parameter:-

Two triangular patches are placed on a commercially available Rogers RO3003 substrate with a dielectric constant of three and a height of 6 mm. Return Loss S11 is (represents the amount of radiation reflected back from the antenna), also known as the reflection coefficient. S21 is insert attenuation or isolation before separation.

In fig 4, the simulated S11 result of the given MIMO antenna while using Swastik-shaped DGS in the ground at 2.4 GHz is −24.05 dB & without using DGS at ground at 2.4 GHz is -5.97 dB.

In fig 5, the simulated S21 result of the given MIMO antenna while using Swastik-shaped DGS in the ground at 2.4 GHz is −53 dB & without using DGS at ground at 2.4 GHz is -48 dB.

• VSWR:-

Voltage Standing Wave Ratio (VSWR) is the amount of line mismatch and is an important part of the S11 parameter in an antenna system, a suitable VSWR value for an antenna is between one and two. In Fig. 6, the VSWR value using DGS is 1.13, which is ideal for communication.

• Antenna Gain:-

Antenna gain is a main parameter that links antenna directivity and efficiency. It is the directivity of the antenna; if the antenna gain is high in a certain direction, it means that the antenna is working properly.

In fig 7, the total gain of antenna using DGS is 3.53 dB & without using DGS 3.23 dB at 2.4 GHz.

DISCUSSIONS:-

In this project, the proposed MIMO antenna arrays with advanced isolation has been designed using HFSS Software. The proposed antenna is designed to operate at 2.4 GHz frequency band which is used for wireless communication in IoT devices, particularly for Wi-Fi and Bluetooth connectivity. Two triangular patch antennas are placed close to each other on a RO3003 substrate with a thickness of 6 mm, and DGS is used for isolation in the ground layer. The main purpose of DGS of different shapes is to obtain high cross-coupling reduction. In this paper, -53 dB was obtained using H-shaped DGS. Describes S11 parameters, S21 parameters, VSWR, total gain, directivity, radiation pattern. The obtained results are -24.05 dB, -53 dB, 1.13, 3.53 dB, 3.73 dB respectively for the above parameters at 2.4 GHz frequency. Projected antennas are valuable for MIMO antenna systems that require a high degree of cross-coupling reduction. The proposed MIMO antenna is applicable for IoT applications and also in other practical scenarios.

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Future plans for this project include publishing a research paper and, if necessary, further we will improve the results through ongoing experiments and simulations. Test this MIMO antenna with IoT devices. The 2.4 GHz band is widely used for wireless communication in IoT devices, particularly for Wi-Fi and Bluetooth connectivity. This band offers high data rates but has limited range and can be subject to interference from other devices operating in the same band. Common wireless technologies used in IoT applications include Wi-Fi, Bluetooth, WLAN, and ZigBee, which operate in the 2.4 GHz frequency band. Some IoT components like DHT11 Sensor, BMP180 Sensor, Rain Sensor, ESP8266 Nodemcu Wi-Fi Module also work on 2.4GHz frequency band.

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