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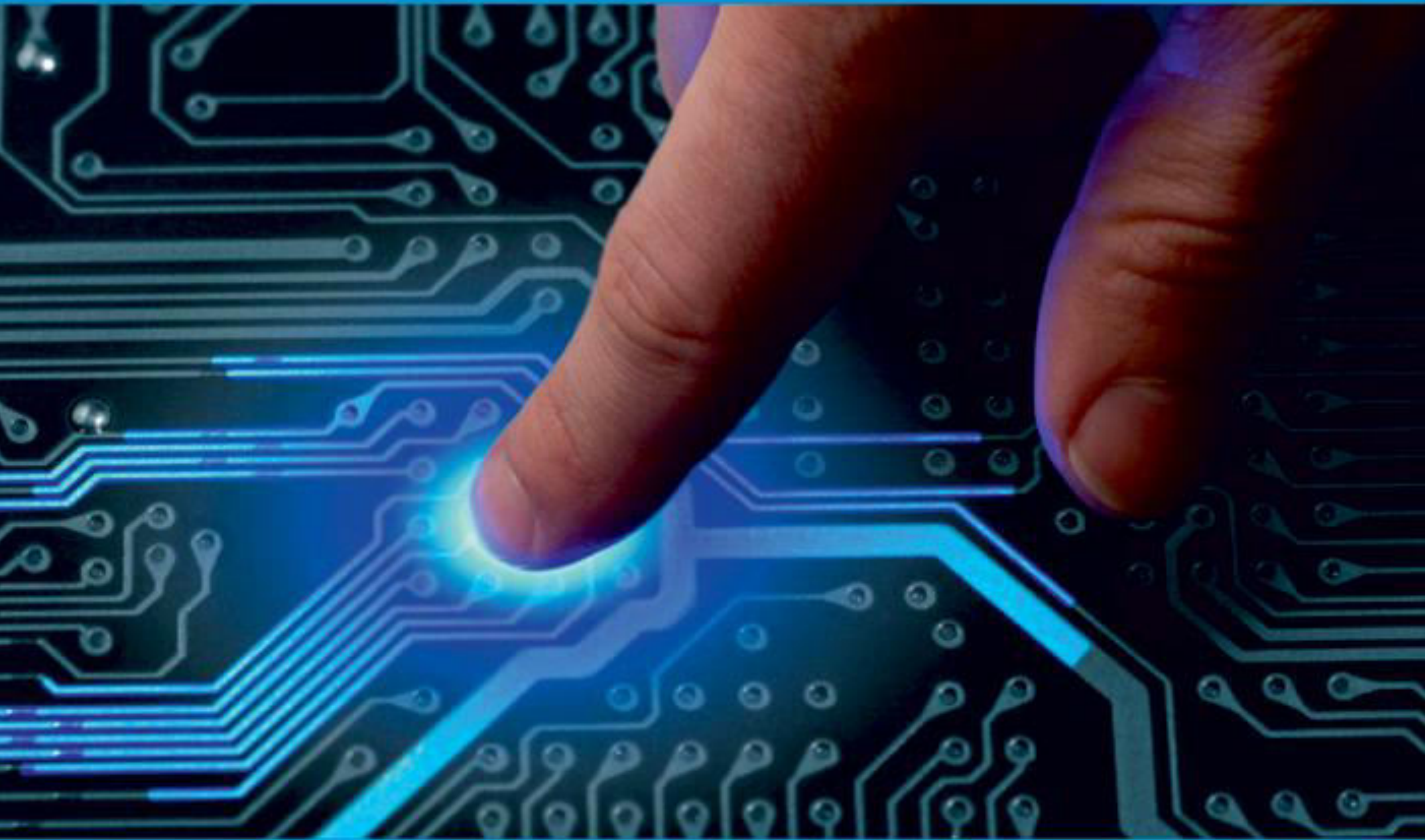

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Highly Isolated Compact 4-Port EL Patch Antenna Array Using Various Decoupling Structure

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ABSTRACT: The design and implementation of decoupling structures in MIMO (Multiple Input Multiple Output) antennas require careful consideration of various factors such as antenna spacing, operating frequency, and desired isolation levels. These structures can be integrated into the antenna system architecture to minimize the coupling effects and improve the overall performance of the MIMO system. The integration of decoupling structures in MIMO antennas has a significant impact on their performance. By reducing the mutual coupling, the overall isolation between antennas is improved, leading to enhanced channel capacity, better diversity gain, and improved system reliability. While decoupling structures offer numerous benefits, their design involves certain challenges and trade-offs. These include increased complexity of the antenna system, additional power consumption, and the need for careful impedance matching to maintain optimal antenna performance. By addressing the challenges and trade-offs involved, it is possible to effectively integrate these structures and realize the full potential of MIMO technology in modern wireless network. Thus here we design a highly isolated compact four port MIMO EL patch antenna array with decoupling structures like Electromagnetic Band Gap Structure (EBG), Complementary Split Ring Resonators (CSRRs), and Defected Ground Structure (DGS) which operates at a frequency range of 4.5GHz. The structures have been designed on the Ansys HFSS 15.0.3 software. The MIMO antenna consists of four identical patch antenna elements with various decoupling structure on ground plane and introduce EL slots into radiating element to improve the performance of radiation characteristics and impedance matching. The overall dimensions of the methods are 50mm x 50mm x 1.6mm. The proposed antenna design reduces the mutual coupling between the antenna elements and enhances isolation. Simulated have been analysed in terms of reflection coefficient, radiation pattern, return loss, gain. All the required result show that the proposed MIMO antenna have high isolation, high efficiency and also shows the best method of decoupling structure. MIMO is being used in a variety of new applications, such as virtual reality (VR), augmented reality (AR), and autonomous vehicles. These applications require high data rates and low latency, which MIMO can help to provide.

KEYWORDS: MIMO, EL slot, EBG, CSRR, DGS.

I. INTRODUCTION

MIMO (Multiple-Input Multiple-Output) antennas have seen significant advancements in recent years, driven by the ever-growing demand for faster data rates and increased capacity in wireless communication systems, especially with the advent of 5G technology. MIMO technology has emerged as a key solution to address the growing demand for high data rates and improved network capacity. This technology has the capability to significantly enhance the performance of wireless communication systems by using multiple antennas at both the transmitter and receiver. The use of Multiple Input Multiple Output antennas has become increasingly popular in modern wireless communication systems due to their ability to mitigate the effects of multipath fading, improve spectral efficiency, and enhance signal reliability. In MIMO systems, the antennas are closely spaced, which can lead to strong mutual coupling between them. This mutual coupling can significantly degrade the performance of the antennas and the overall MIMO system. To address this issue, decoupling structures are employed to minimize the coupling effects and ensure the independent operation of each antenna element.

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To design a highly isolating MIMO patch antenna array, we know the steps of process they are, 1. Understanding Mutual Coupling: Mutual coupling arises due to the close proximity of antenna elements. Currents flowing in one element induce unwanted currents in others, affecting their radiation patterns and impedance matching. The strength of coupling depends on factors like element spacing, frequency, and substrate properties. 2. Isolation Techniques: Several techniques can be employed to enhance isolation in MIMO patch antenna arrays: i) Spacing the elements: Increasing the distance between elements reduces coupling but may be impractical due to size constraints. ii) Modifying the feed network: Employing decoupling structures like microstrip lines with specific lengths and bends can manipulate the signal paths to reduce coupling. iii) Utilizing Metamaterials: These artificially engineered materials with negative permittivity or permeability can act as shields or waveguides, blocking unwanted signal interaction. iv) Optimizing the ground plane: Shaping the ground plane with slots, via, or defected ground structures (DGS) can introduce reactance, disrupting unwanted current paths and enhancing isolation 3. Design Considerations: i) Target isolation level: Define the desired isolation level based on system requirements. Higher isolation often comes at the expense of size, bandwidth, or gain. ii) Frequency band: Choose antenna elements and isolation techniques suitable for the operating frequency range. iii) Substrate selection: Low-loss dielectric substrates with minimal dispersion are preferred to minimize signal distortion and coupling. iv) Simulation and optimization: Utilize electromagnetic simulation software to model and optimize the antenna array, achieving the desired balance between isolation, impedance matching, radiation pattern, and size.

The coupling between antennas in an array causes performance degradation and interference. The goal is to mitigate these coupling effects to ensure optimal performance and the solution should be cost effective, compact size, simple design, lightweight, low profile, high isolation and good impedance matching. Hence we introduce a highly compact 4-port EL patch MIMO antenna array with the dimensions of 50mm x 50mm x 1.6mm with various decoupling structures. Its frequency range covers sub-6GHz (3.2-5.75 GHz) and also having the features of reliable connectivity, high speed data transfer, excellent antenna diversity and larger channel capacity. Decoupling structure of Electromagnetic Band Gap Structure (EBG), Complementary Split Ring Resonators (CSRRs), and Defected Ground Structure (DGS) to defects or modifications in the ground plane, which leads to reduce interference, enhance isolation and improve the overall performance of antenna systems.

II. ANTENNA DESIGN

The proposed antenna design is based on the concept of patch antenna with EL slots into the radiating element introduce EL slots into radiating element to improve the performance of radiation characteristics and impedance matching. The antenna is printed on FR-4 substrate of 4.4 dielectric constant. The center frequency of the designed antenna is 4.5 GHz. The antenna's bandwidth was set by the patch W's width. The resonant frequency is determined by the patch L's length. Higher permittivity results in an increase in the antenna's impedance. Patch antenna "shrinking" is permitted at higher permittivity values. Length L and Width W of the antenna are calculated from equation 1 &2, where c, f_o, ε_{eff}, ε_r be speed of light, center frequency, effective permittivity, relative permittivity.

$$W = \frac{c}{4f_0\sqrt{\frac{\varepsilon_{r+2}}{2}}} \quad (1)$$

$$L = \frac{c}{4f_0\sqrt{\varepsilon_{eff}}} \quad (2)$$

The microstrip line feeding technology is applied in this design. The dielectric material generates and reflects waves when a thin microstrip antenna is activated from a feeding network. A portion of the incident energy is radiated outward when the waves hit the metal patch's corners or edges. Decoupling structures are specialized techniques employed to mitigate mutual coupling and achieve high isolation between antenna elements.

The flow charts of EL patch antenna design show in figure1. Steps for designing a proposed antenna are Step1: Design four patch antennas on a FR4 dielectric substrate above the ground. Step2: Assign boundaries and excitation to each port. Step3: Then create isolation between the antenna elements using various decoupling structures between four antennas. Step4: Click validate check, then analyze and simulate it. Step5: Get the results by HFSS and create rectangular plot report and generate new reports.

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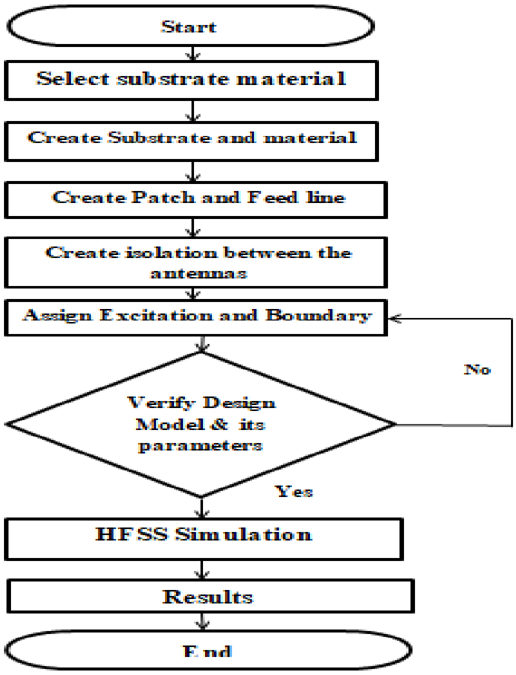

Fig1: Flow chart of EL patch antenna design

III. DECOUPLING STRUCTURE IN MIMO

The design and implementation of decoupling structures in MIMO antennas require careful consideration of various factors such as antenna spacing, operating frequency, and desired isolation levels. These structures can be integrated into the antenna system architecture to minimize the coupling effects and improve the overall performance of the MIMO system. There are several types of decoupling structures that can be utilized to isolate MIMO antennas. Here are some common types of decoupling structures for antennas.

i. DEFECTED GROUND STRUCTURE (DGS):

A Defected Ground Structure (DGS) involves introducing specific patterns or features into the ground plane of a PCB or other planar structure to create electromagnetic band gaps or alter the electromagnetic behavior of the circuit. This allows for various benefits, including improved performance, frequency filtering, and reduced interference. The proposed antenna is designed on FR-4 substrate with overall dimensions 50mm x 50mm x 1.6mm within the frequency range of 4.5 GHz and having DGS structure between the antennas. Figure 2 depicts the DGS structure. DGS is introduced to reduce mutual coupling. The dimensions of DGS structure are L_{DGS} = 45mm and W_{DGS} = 10mm. The isolation between the ports is greater than -62.5 dB (Fig.3). The gain of the 4 port antenna is 9.76 dB (Fig.4).

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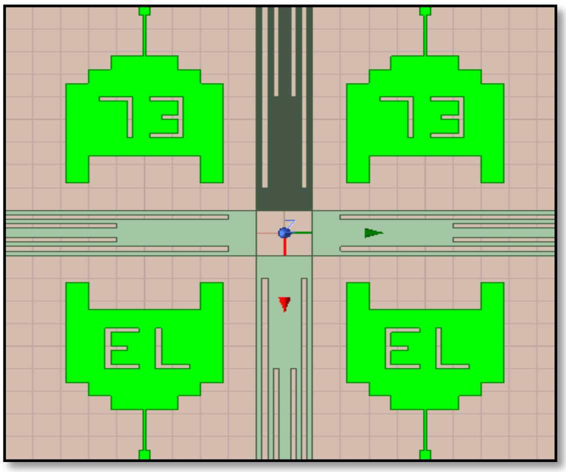
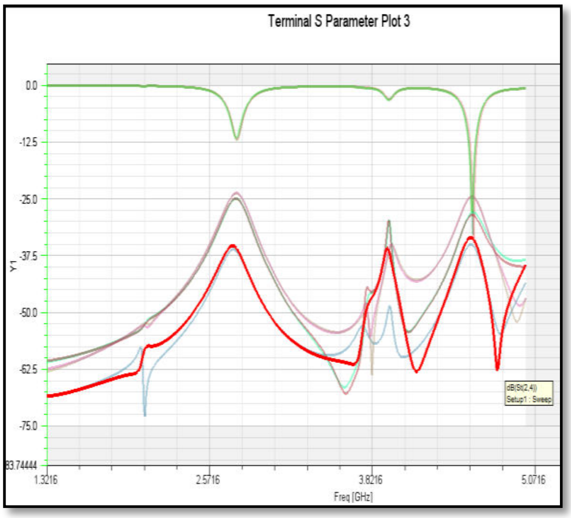


Fig 2: Front view of proposed antenna design using DGS method



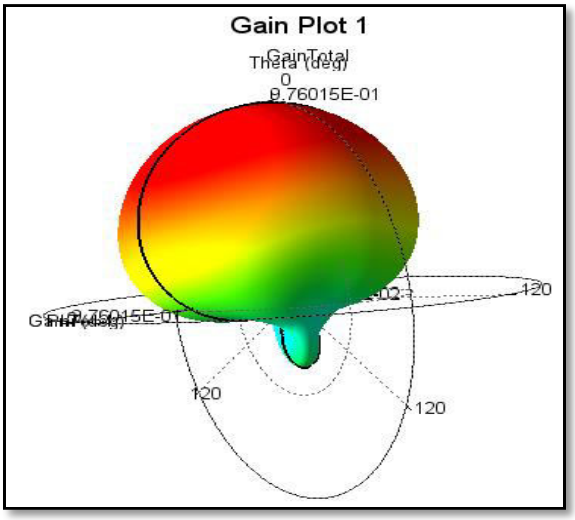


Fig 3: Isolation between the ports

Fig 4: Gain between the ports

ii. COMPLEMENTARY SPLIT RING RESONATORS (CSRR):

CSRR of a pair of split ring resonators arranged to complement one another. The divided space between the rings results in capacitance that aids in regulating the structure's resonance. Two identical SRRs placed near to one another so that their split gaps are aligned but facing different directions make up the CSRR structure. The interaction between the SRRs in this complimentary arrangement results in intriguing electromagnetic characteristics. The proposed antenna has overall dimensions of 50mm x 50mm x 1.6mm within the frequency range of 4.5 GHz is designed on FR-4 substrate and having CSRR structure between the antenna. The CSRR structure is shown in figure 5. The design and optimization of CSRRs depend on factors like the dimensions of the resonators, the substrate material, and the desired resonant frequency. The dimensions of CSRR structure are R_{CSRR1} = 7mm and R_{CSRR2} = 4mm, split gap of CSRR is 4mm. The isolation between the ports is greater than -34.5 dB (Fig.6). The gain of the 4 port antenna is 7.32 dB (Fig.7).

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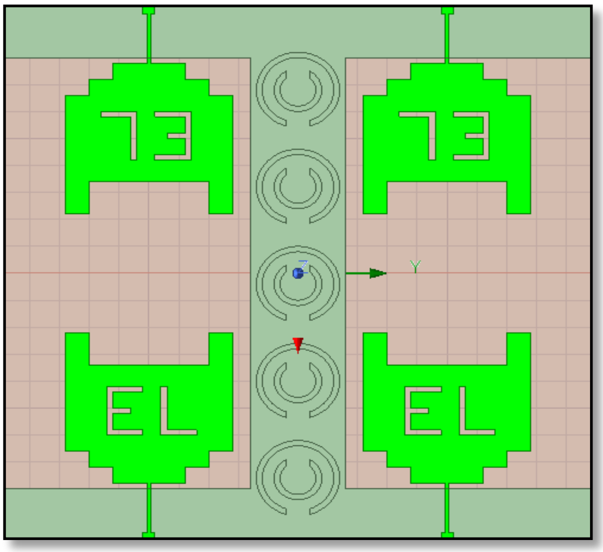
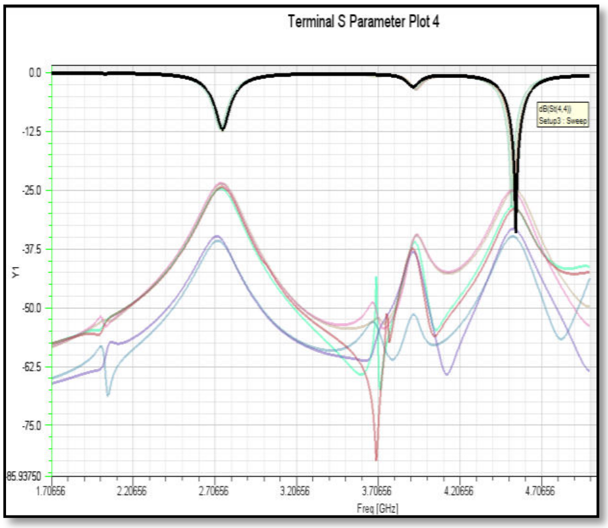


Fig5: Front view of proposed antenna design using CSRR method



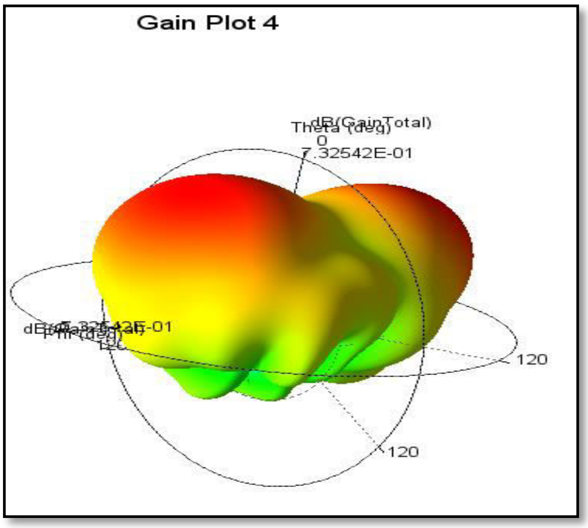


Fig 6: Isolation between the ports

Fig 7: Gain between the ports

iii. ELECTROMAGNETIC BAND GAP STRUCTURE (EBG):

An Electromagnetic Band Gap (EBG) structure is a periodic arrangement of materials or structures designed to control the propagation of electromagnetic waves in a specific frequency range. It acts as a frequency-selective filter for electromagnetic radiation, preventing certain frequencies from propagation through the structure while allowing others to pass. The proposed antenna is designed on FR-4 substrate with overall dimensions 50mm x 50mm x 1.6mm within the frequency range of 4.5 GHz and having EBG structure between the antennas. The EBG structure with TL slots is shown in figure 8. The dimensions of EBG structure are L_{EBG} = 6mm and W_{EBG} = 7.5mm. The isolation between the ports is greater than -29.3 dB (Fig.9). The gain of the 4 port antenna is 6.39 dB (Fig.10).The proposed EL patch antenna geometric parameters in millimeter are tabulated in table 1.

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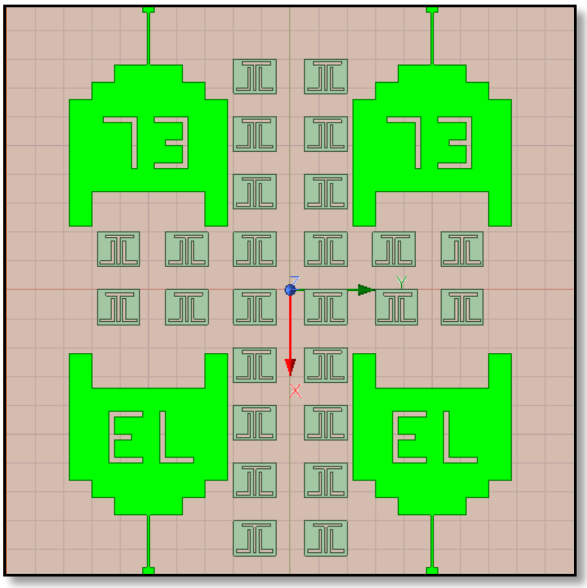
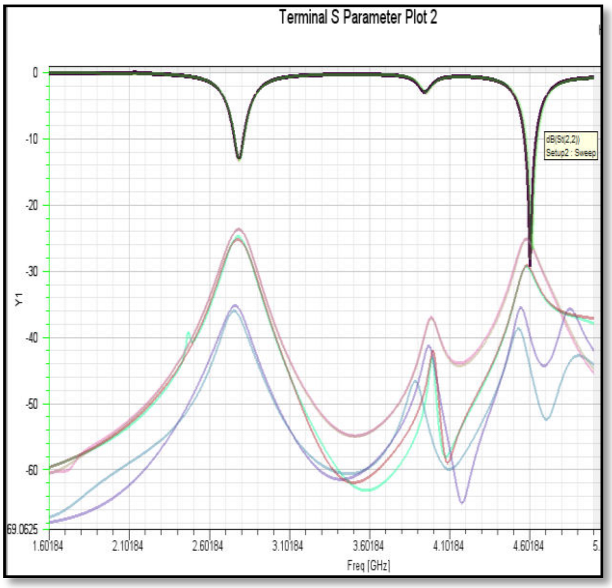


Fig8: Front view of proposed antenna design using EBG method



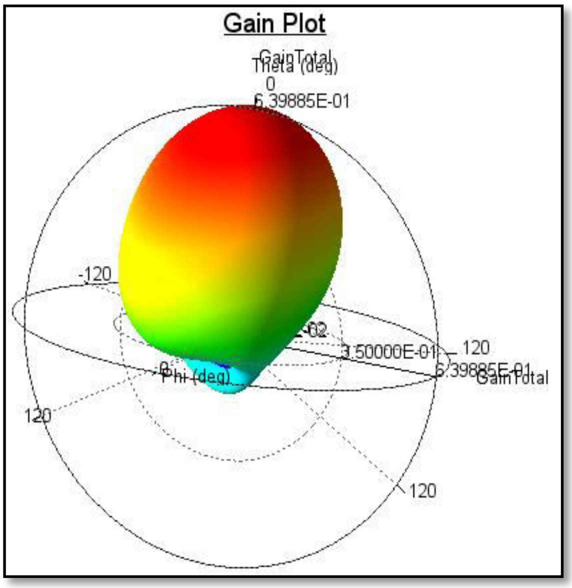


Fig 8: Isolation between the ports

Fig 10: Gain between the ports

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PARAMETERS	DIMENSIONS
Length of the substrate	50mm
Width of the substrate	50 mm
Height of the substrate	1.6 mm
Dielectric constant	4.4
Length of the patch	28 mm
Width of the patch	28 mm
Distance between two antennas	22 mm
Length of the DGS	45 mm
Width of the DGS	10 mm
Radius of circular CSRR 1	7 mm
Radius of circular CSRR 2	4 mm
Split gap of CSRR	4 mm
Length of the EBG	6 mm
Width of the EBG	7.5 mm

Table1: The proposed EL patch antenna geometric parameters

IV. COMPARISION BETWEEN MIMO ANTENNA USING DGS, CSRR AND EBG

Tables2 compares the result of the three methods using various decoupling structures like DGS, CSRR and EBG of reducing mutual coupling between antenna elements and enhancing isolation. All the methods achieve high isolation and gain between the ports. The DGS shows the best isolation reduction method among the three. In DGS method, the isolation is reaching -62.5 dB and gain approaches 9.76dB. However in CSRR method, the isolation reaching -34.5 dB and having gain between the ports is 7.32dB. However in EBG method, the isolation is reaching -29.3dB and gain approaches 6.39dB. Therefore the best method is EL patch antenna with DGS because it has high isolation also gain approaches 9.76dB.

Design of EL patch antenna using	Isolation loss (dB)	Gain (dB)
DGS	-62.5	9.76
CSRR	-34.5	7.32
EBG	-29.3	6.39

Table2: Comparison between DGS, CSRR and EGS in four port MIMO antenna array.

V. CONCLUSION

In this project, a four port EL patch MIMO antenna array with highly isolation between the ports introduced. Here, we introduce three methods of decoupling structure such as DGS, CSRR and EBG to reduce mutual coupling and enhancing isolation. Thus we compare the overall performances of each method. The proposed antenna array elements with appropriate dimensions have been simulated using the Ansys HFSS 15.0.33 software. The antenna arrays are designed on FR4 substrate with overall dimensions of 50mm x 50mm x 1.6mm with noticeable cost reduction. The three methods of decoupling structures are used here. The best method is DGS, because DGS has high isolation and gain of 9.76dBi. MIMO is being used in virtual reality (VR), augmented reality (AR), autonomous vehicles, etc.

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REFERENCES

[1] M.S.Khan,A.D. Capobianco, M.F.Shafique, B.Ijaz, A.Naqvi, and B.D.Braaten, "Isolation Enhancement Of A Wideband MIMO Antenna Using Floating Parasitic Elements", Microwave and optical technology letters, 7 July 2015.

[2] Jugul Kishore Amitkumar, Abdul Quaiyum Ansari, Binod Kumar Kanaujia, "A Review On Different Mutual Coupling Reduction Between Elements Of Any MIMO Antenna", Radio Science, 01 March, 2021

[3] Phalguni Mathur, Robin Augustine, M. Gopalakrishna And Sujith Raman, "Dual MIMO Antenna System For 5G Mobile Phones, 5.2Ghz WLAN, 5.5Ghz Wimax And 5.8/6 Ghz Wifi Application", IEEE Access, August 5,2021.

[4] G.F. Pedersen and S.Zhang , "Mutual coupling reduction for UWB MIMO antennas with wideband neutralization line", IEEE Antennas and Wireless Propagation Letters, 21 May 2015.

[5] A. Christina Josephine Malathi and D. Thiripurasundari, "Review On Isolation Techniques in Mimo Antenna Systems", Indian Journal of Science and Technology, September 2016.

[6] Hussein Attia, Oludayo Sokunbi, and Sharif I. Sheikh , "Microstrip Antenna Array with Reduced Mutual Coupling Using Slotted-Ring EBG Structure for 5G Applications", IEEE explore, 31 October 2019.

[7] Wonsang Choi, Hongmim Lee, "Isolation Enhancement Between Microstrip Patch Antennas Using Dual_band EBG Structure Without Common Ground Plane", IEEE transactions on Antennas and propagation, 2012.

[8] Michael A. Jensen, John W. Wallence, Brigham Young University, "A Review Of Antennas And Propagation for MIMO wireless communication", IEEE transactions on Antennas and propagation, 08 Nov 2004.

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