# Performance Analysis of 4 Port MIMO Antenna Array for 5G Application

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**Abstract: -**
In this paper, performance of 4 port MIMO rectangular microstrip patch antenna is analysed for a 5G application that operates between 2.07 and 2.15 GHz. The development and use of microstrip patch structures is becoming more important due to the growth of wireless communication and multimedia services. An advantage of a patch antenna is that it is inexpensive, compact, simple to make, and adaptable to any 5G application. Gain, Reflection Coefficient, VSWR, Impedance, and Bandwidth of Antenna are some of the parameters used to analyse antenna performance.
**Keywords**: - MIMO, DG, Reflection Coefficient, VSWR, FBR, MEG, ECC.
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## 1. Introduction

Microstrip printed circuit boards radiate effectively thanks to their microstrip antenna parts. Figure 1 explains the rectangular microstrip patch antenna structural layout. [1].

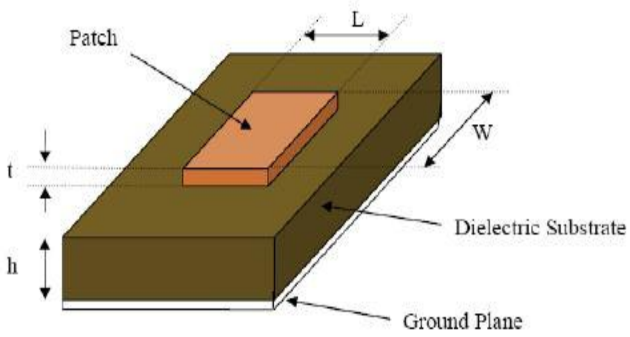


Fig.1:Sample Rectangular Microstrip Patch Antenna structure

A continuous metal layer is attached to the substrate's other side to form the ground plane in a microstrip patch antenna, which has a radiating patch on one side. The patch can take any form and is typically constructed of conductive materials like copper or gold. An antenna with a narrowband and wide-beam is called a patch antenna and is made by photo-etching the metal trace pattern of the antenna elements. [2]. It is necessary to use substrates with higher dielectric constants, which are less effective and have a narrower bandwidth, in order to create a compact Microstrip patch antenna. As a result, a trade-off between the antenna size and performance must be made [3]. Using coaxial feeding as the antenna feed and finite element-based HFSS software, we si mulate a four port MIMO antenna operating at a frequency range of 2.07 to 2.15 GHz in this article.

## 2. Related Work

A strip line fed antenna is presented in [4], which works at a frequency of 2.4 GHz. Another antenna made of the same substrate material can be found in [5], where the antenna operates at a frequency of 2.36 GHz and the substrate is 3.2 mm tall. Different bandwidth enhancement technique presented in [6] [7]. In [8], it describes the development of a microstrip patch antenna for a 2.4 GHz wireless communication application. In this study, an antenna with a substrate made of Styrofoam (εr =1.03) and a 12 mm height is built. Using this approach, an outside gain of 11 dB is attained. An antenna for use in the S band is designed in [9], where the substrate is made of FR4 (εr =4.4) and measures 1.6 mm in height. 2.25 GHz is the operating frequency for this design.[10] presents a design for a probe feed antenna that operates at frequencies of 2.21 GHz and 4.45 GHz. The substrate is made of RT Duroid (εr=2.2) and has a 1.6 mm height.

Yasin Kabiri et al. [11] have presented 4 element, IFA, MIMO antennaat 2.11 GHz with bandwidth set to 100 MHz for 5G system. Joni Kurvinen et al. [12] have presented Conventional 1x4 Vivaldi antennadesign with microstrip to slot-line transition is used in a linear four-elementarray enclosed inside a plastic. The substrate used for fabrication is Rogers RO4350B substrate. Specifications of antenna are 25–30 GHz,supports beamsteering angles of at least ±25 deg with peak gain of 7 dBifor 4G LTE and 5G wireless communication applications.



## 3.Design of Antenna

The designedantenna shape is shown in Fig. 2. The substrate of thickness 1 .6 mm and measures 38 mm by 27.3 mm in size is used. The patch is 33 mm by 2.8 mm and has a rectangular shape with modified edges. The substrate is made of FR4, which has a loss tangent of 0.02 and a dielectric constant of 4.4. Coaxial feeding is the method used by the antenna. The feed point is located on the substrate's YZ plain

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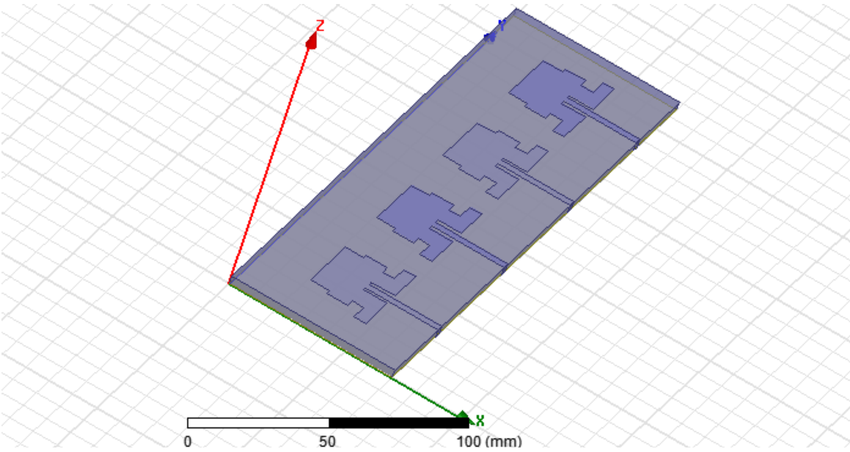


Fig.2: Geometry of 4 port MIMO antenna

## 4. Simulation Results

Utilizing HFSS software, the above design is being simulated. This substrate, FR4, has a dielectric constant of 4.4. The structure is simulated using the dimensions mentioned above. This design's operational frequency ranges from 2.07 to 2.15 GHz, and the return loss measured is -26.26 dB. At this frequency, a gain of 21.71dB is attained. The reflection coefficient (S11, S22, S33, and S44) versus frequency plot in Figure 3 shows that the port 1 antenna begins to operate at a frequency of

2.04 GHz (marker m5) and ceases to operate at a frequency of 2.10 GHz (marker m6). The antenna's centre frequency (marker m1) is 2.07 GHz, and its bandwidth is 60 MHz. Similarly, the port 2 antenna should begin operating at 2.08 GHz (marking m7) and cease operating at 2.14 GHz (marker m8).

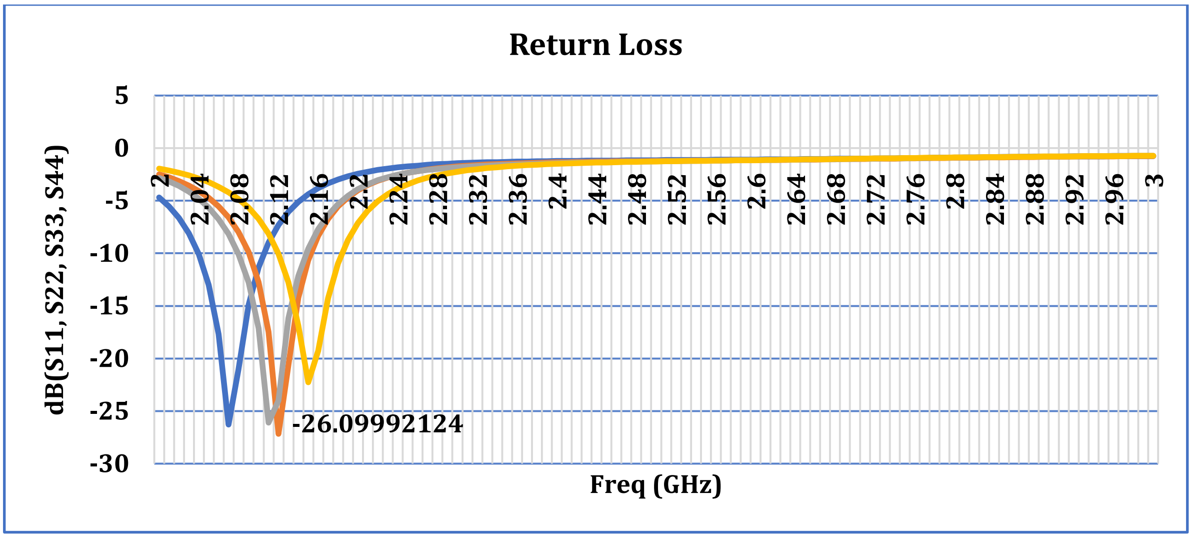


Fig.3: Return Loss (S11, S22, S33, S44) of 4 port MIMO antenna using FR4 material

The antenna's centre frequency is 2.11 GHz (marker m2), and its bandwidth is 60 MHz. The port 3 antenna begins operating at 2.09 GHz (marker m9) and ceases operation at 2.15 GHz (marker m10). The antenna's centre frequency is 2.12 GHz (marker m3), its bandwidth is 60 MHz, and its port 4 antenna begins operating at 2.12 GHz (marker m11) and ceases operation at 2.18 GHz (marker m12). The antenna's centre frequency (marker m4) is 2.15 GHz, and its bandwidth is 60 MHz.Figure 4 shows an antenna's 3D radiation pattern, which also shows the antenna's overall gain. The gain of the antenna as a whole when utilising FR4 as the substrate material is 21.71dB, as shown in the figure below.

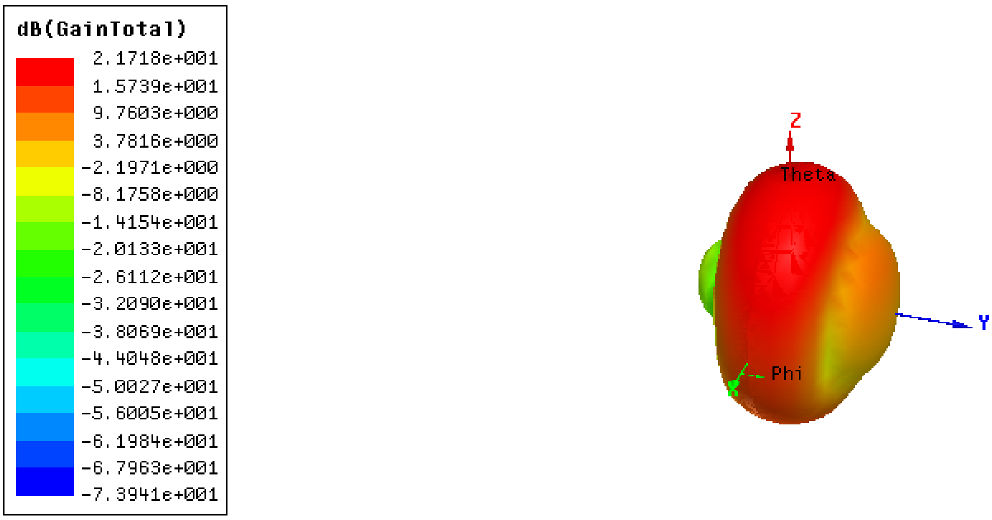


Fig.4: Total Gain of 4 port MIMO antenna using FR4 material

The current distribution for 4 port MIMO antenna is shown in fig.5, which has 5.9 A/m, maximum value of current at given frequency.

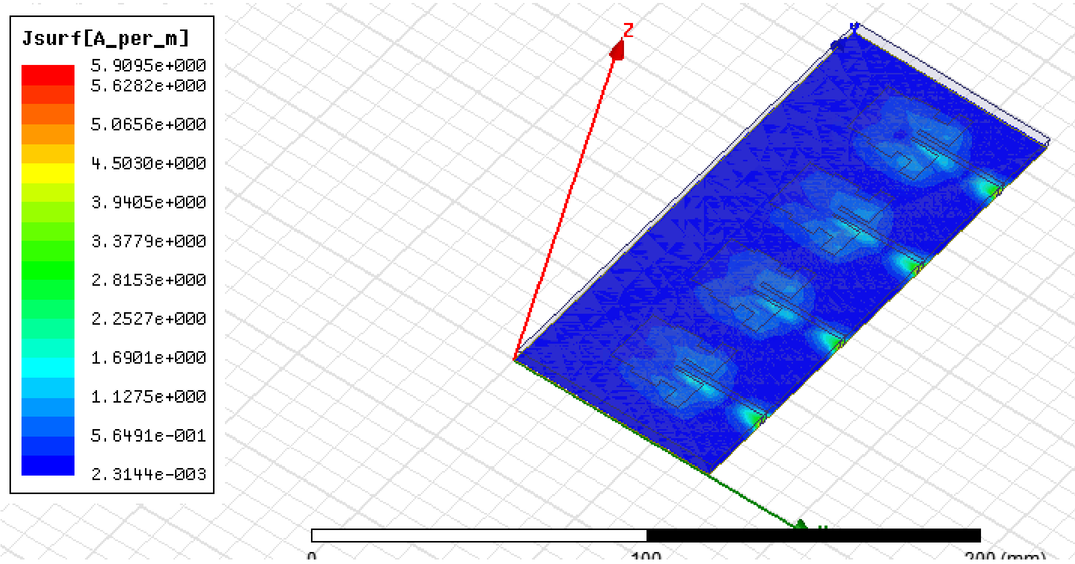


Fig.5: Distribution of current for 4 port MIMO antenna

As we move farther from the antenna, the gain of the antenna increases. Figure 6 depicts an antenna with a 2D radiation pattern that exhibits a unidirectional radiation pattern and has a major lobe and a back lobe. At an angle (θ) of 0 degrees, the maximum gain is 21.71dB, as shown by marker m1.

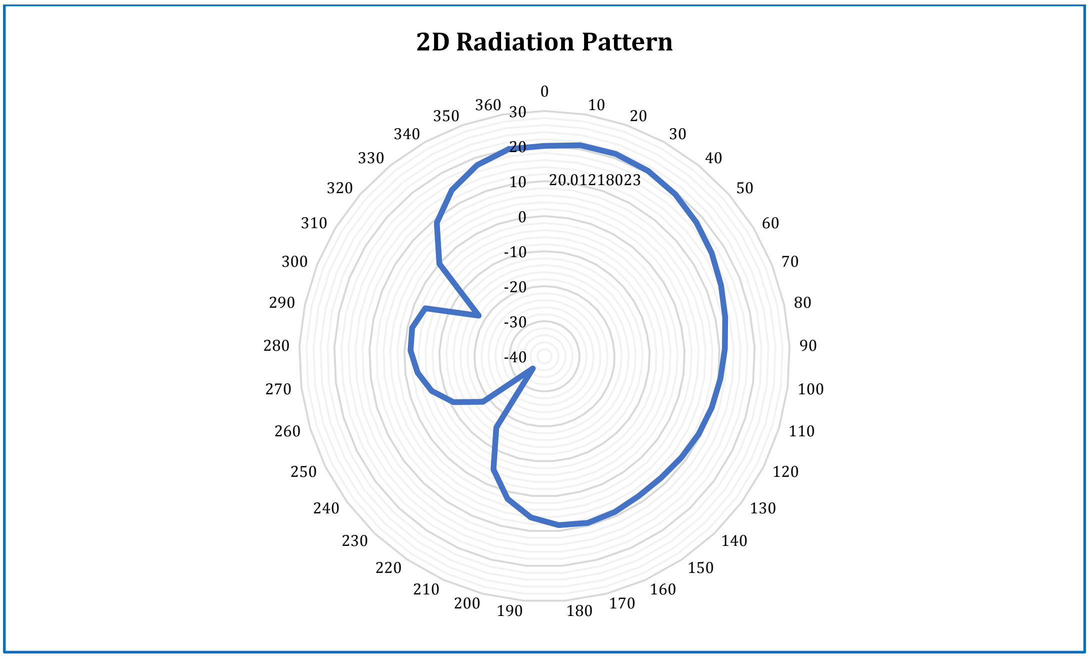


Fig.6: 2D radiation pattern of 4 port MIMO antenna

The fig.7 showsgraph of VSWR vs frequency.

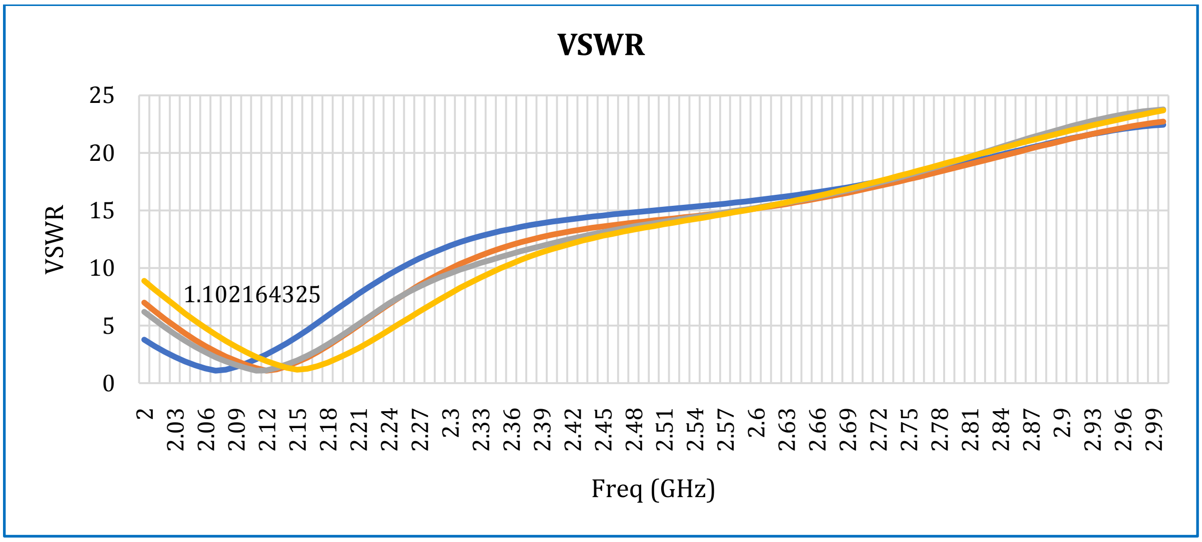


Fig.7: VSWR vs Frequency graph for 4 port MIMO antenna

At frequency of 2.07 GHz, as shown in fig. 8of impedance vs frequency for 4 port MIMO antennatheimpedance of antenna is 47.08Ω, making it simple to connect this antenna to a 50 Ω transmission line.

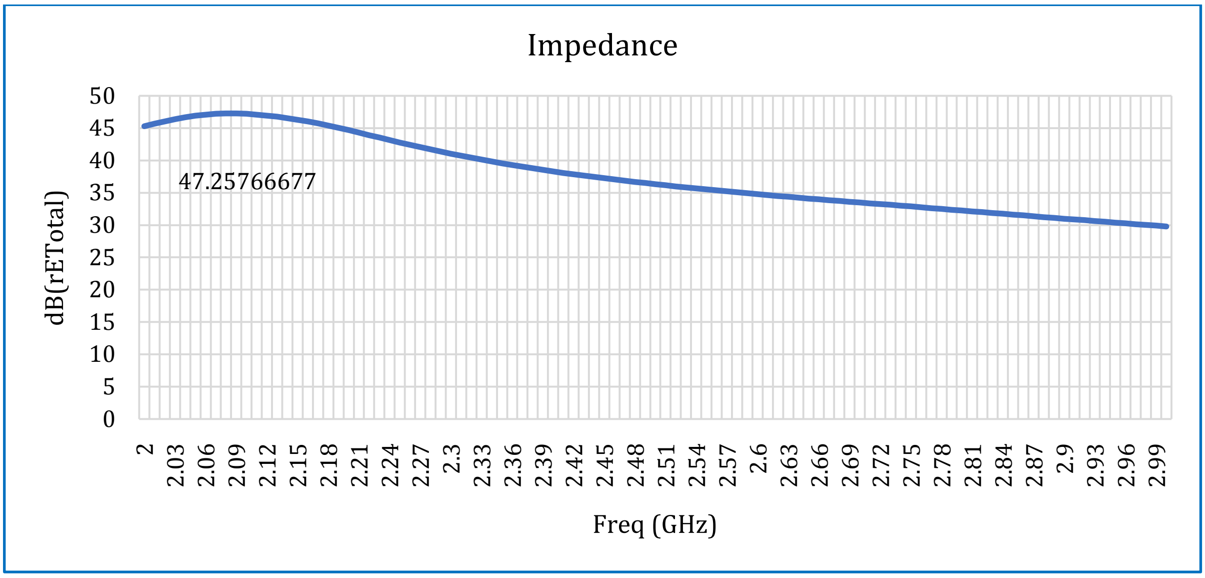


Fig.8: Impedance Vs frequency

For a 4 port MIMO system, the incident power is 1W per port, and the antenna's radiation efficiency is 52.17 %. The port isolations and cross-polarization radiations realised performance is excellent. The FBRs under each port excitation, on the other hand, are over 11.66 dB in the interest frequency region and exhibit little backward radiation. FBR is calculated by subtracting gain in dB at ϕ= 0deg, θ= 0deg (shown by marker m1) and ϕ= 0deg, θ= 180deg (shown by marker m2).

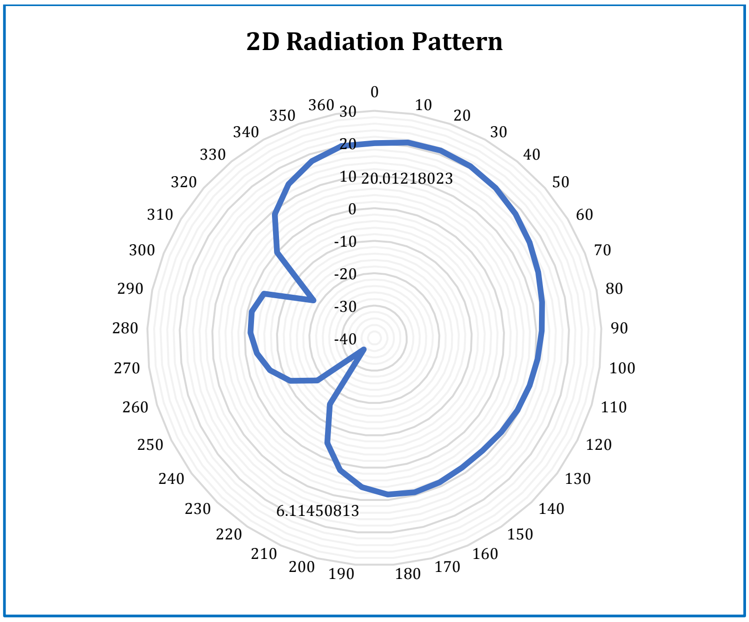


Fig.9:FBR calculation using 2D radiation pattern

The Mean Effective Gain, Correlation Coefficient, and Diversity Gain are used to assess the MIMO antenna's diversity performance. The average power received at the antenna divided by the total average power of the vertically and horizontally polarised waves received by an isotropic antenna is known as mean effective gain. Equation 3 can be used to measure MEG for each port using S-parameters.

$$MEG_i = 0.5\eta_{i,rad} = 0.5\left[1 - \sum_{j=1}^{M}\left[S_{ij}\right]^2\right] \quad (1)$$

Mean effective gain (MEG) values determined MIMO antenna system and given in Table 1.

Table 1: Mean effective gain (MEG) values determined

| Mean effective gain | Value | Centre Frequency |
|---|---|---|
| MEG1 | -3.06dB | 2.07 GHz |
| MEG2 | -2.94dB | 2.117 GHz |
| MEG3 | -3.39dB | 2.12 GHz |
| MEG4 | -2.90dB | 2.15 GHz |

The equality condition for the four antennas is satisfied because the MEG values are less than 3 dB. The estimated MEG for each antenna is displayed in Figure 10. The nearly identical MEG waveforms show independent and identical polarisation diversity. The symmetrical conformal design is responsible for these successful results.

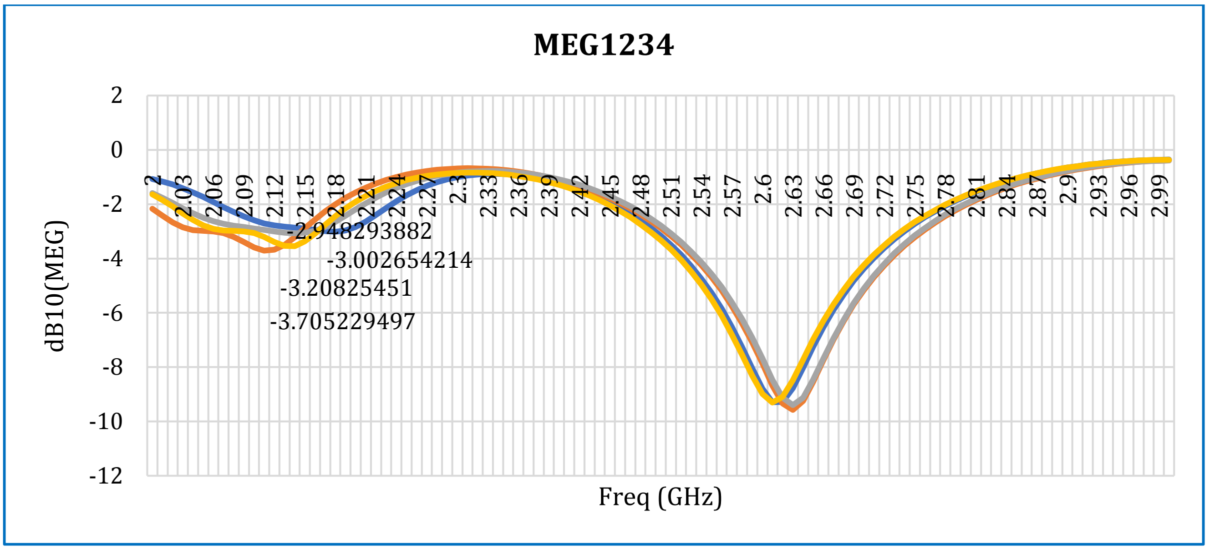


Fig.10: Computed MEG for all Antenna.

Fig. 11 shows that all the ECC ($\rho_e$) parameters are less than 0.03, which mean there is nearly no coupling energy between the neighbouring antenna elements.

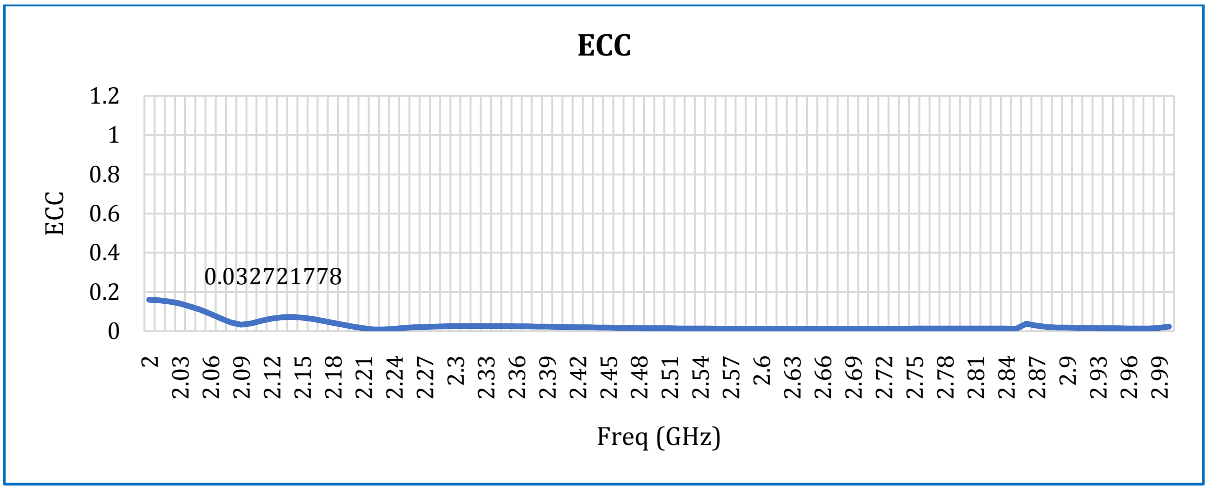


Fig.11: Graph of ECC Vs frequency

Diversity gain (DG) is another import parameter which assures good diversity and MIMO performance. In this work, DG is calculated using Equation(1).

$$DG = 10e_\rho \quad (2)$$

Where $e_\rho = \sqrt{(|1 - |0.99\rho_e|^2)}$ (3)

Figure10 shows the simulated diversity gain of the proposed MIMO antenna.

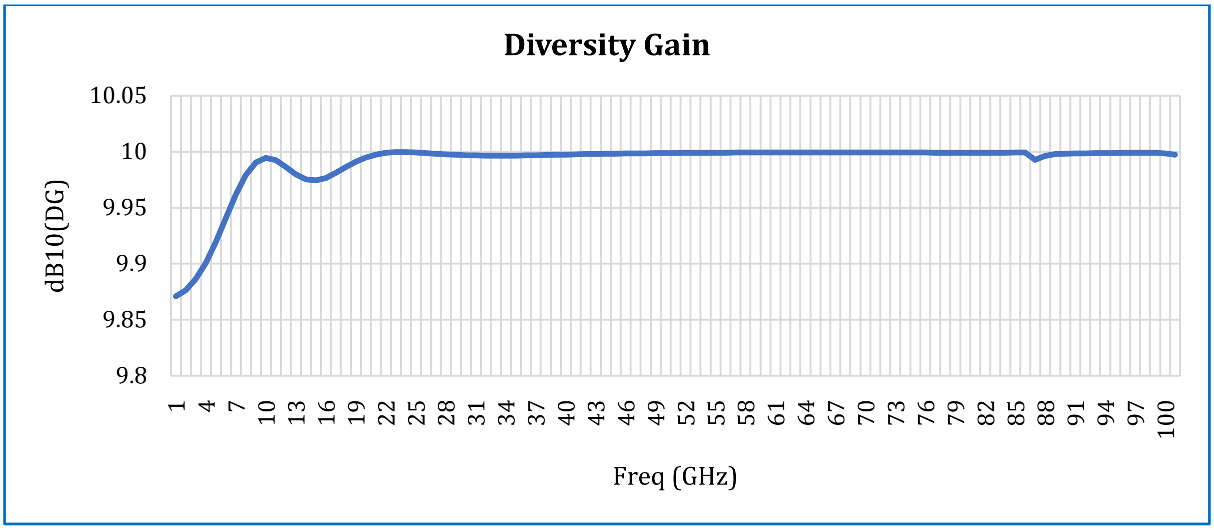


Fig.12. Graph of Diversity Gain Vs frequency

The state-of-the-art comparison of research variable for 4 port MIMO antenna for 5G application is shown in table 2.

Table 2: State of the art comparison

| Survey of Research Variable for 4 port MIMO antenna 5G Antenna | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Reference No** | **Frequency (GHz)** | **Gain (dBi)** | **Bandwidth (%)** | **Isolation (dB)** | **Radiation Efficiency** | **Front to Back Ratio (FBR) (dB)** | **Mean Efficient gain (MEG)** |
| [6] | 4.3 GHz | 9.36 dBi | 3.05% | > 17 dB | -- | 19 dB | -- |
| [8] | 3.3-4.2 GHz | 9.03 dBi | 55% | -- | -- | 20.4 dB | -- |
| [11] | 28 GHz | 12.61dBi | 26% | -- | 95.80% | 36.6-dB | -- |
| [12] | 3.5 GHz | 7.2 dBi | 22.60% | 30.84 dB | varies from 81% to 93%, | varies from 24 dB to 9 dB | Identical to all 6 Port |
| **This Work** | 2.0 – 2.1 GHz | 21.71dB | 45% | > 18dB | 52.17% | 11.66dB | Identical to all 4 Port |

**5. Conclusion**

In this study, a rectangular microstrip patch antenna with four ports for MIMO is suggested and designed using HFSS software. It has been noted that the antenna has a 60MHz bandwidth, a radiation efficiency of 52.17 %, and a total gain of 21.71 dB at this frequency. The antenna's VSWR is 1.1. Due to the antenna's 47.08 Ω impedance, it is simple to connect a 50 Ω transmission line to the antenna without creating impedance mismatch losses. In the appropriate frequency bands, ECC values are much below 0.5, ensuring good diversity performance.In the frequency bands, the diversity gain is almost 10 dB. The nearly identical MEG waveforms show independent and identical polarisation diversity. The proposed antenna is thought to be a good option for use in cutting-edge 5G wireless communication networks.

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