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A COMPACT G-SHAPED FOUR ELEMENTS MIMO ANTENNA FOR 5G

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Abstract

A novel multi-band MIMO antenna system is proposed for modern wireless applications by offering compactness and improved performance through polarization diversity techniques. The design consists of four G-shaped antennas connected effectively by eliminating mutual coupling. The G-shaped MIMO is designed using Fr-4 substrate with dimensions of15mm x15mm x1mm.The MIMO antenna operates across multiple frequency bands, ranging from 5.8743 to 74.61 GHz. Measured isolation exceeds 21dB between adjacent and diagonal ports, ensuring robust signal integrity. Peak gain of 3.8dbi is observed at 24.5 GHz. Additionally, diversity metrics including Gain, Efficiency, and Directivity are evaluated, demonstrating the antenna's efficacy in various performance parameters.

Keywords: MIMO antenna, G-Shape, 5G, Impedance bandwidth, CST Microwave Studio, Far-field pattern, Current distribution.

1.INTRODUCTION

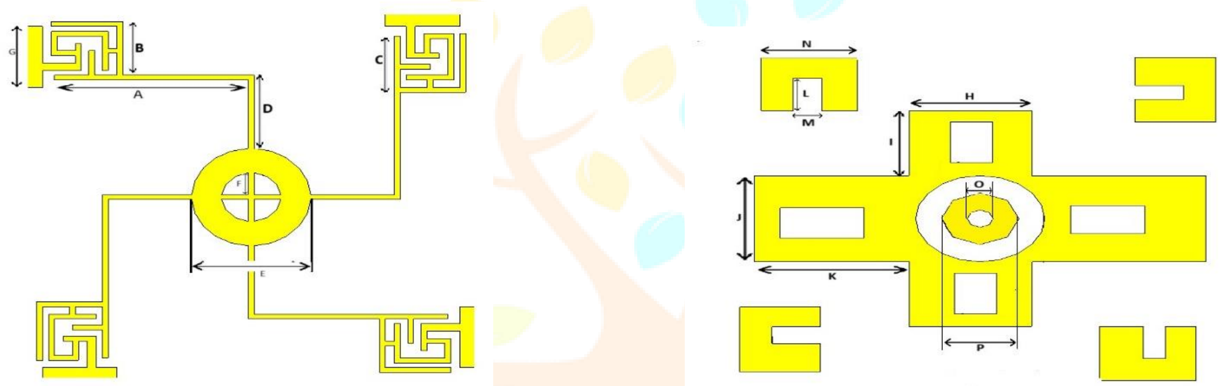
Mobile communication has evolved from analogue 1G to digital 2G (GSM), then to 3G, 3.5G, and 4G (LTE) systems with higher data rates. The demand for faster data rates has led to the development of 5G technology as the foundation for the 2020 generation. The 5G technology offers ultra-high data rates, low latency, increased capacity, and higher quality of service. The introduction of 5G technology will expand development opportunities beyond previousconstraints.
Wireless communication technology prioritises high bandwidth, data throughput, and dependability for both indoor and outdoor applications. MIMO technology's many radio channels provide great throughput in non-line-of-sight (NLOS) communications. Multiple antennas on the same substrate might have a significant impact due to their small size. Polarisation diversity is a technique that allows for both horizontal and vertical signal reception. The following studies explore design of four-port MIMO antenna that prioritise port isolation and compactness.

Many obstacles encountered the creators of the multiple-input multiple-output (MIMO) technology when trying to enhance its features for mobile applications, like element isolation, when it was heavily included into 5G technology. Various methods have been employed to enhance this isolation, including the use of parasitic elements between patch elements and defective ground structures. Modern smartphones have limited space, so mobile phones need broadband small-size MIMO antennas. A significant issue remains in designing a compact size MIMO antenna with reduced isolation. A 15*15 mm^2 four-port MIMO system operating in the 5–75 GHz frequency.
Modern wireless communication systems now depend heavily on the integration of Multiple Input Multiple Output (MIMO) antennas to meet demands for high data speeds, spectrum efficiency, and signal dependability. Research endeavours have concentrated on tackling issues such as compactness, polarisation diversity, and mutual coupling. Innovative ways to reduce mutual coupling in compact UWB MIMO antennas have been proposed in earlier works (Luo & Hong, 2015; Ren et al., 2014; Chen & Wang, 2015 [1][2][3]. Technological developments in metamaterial integration (Wang & Duan, 2018) have improved isolation performance without appreciably enlarging antenna size. Compact, effective, and adaptable MIMO antennas are are still required, though [4].

Additionally, UWB MIMO antennas with frequency reconfigurability were described by Gao and Chen (2020) for cognitive radio systems, providing a versatile approach to adjust to changing communication requirements [6]. Dual-band UWB MIMO antennas with adjustable filtering features were introduced by Zhang and Wang in 2021[8], showcasing flexible filtering capabilities for improved spectrum utilisation. A tiny UWB MIMO antenna with a faulty ground structure was proposed by Abbas and Allam (2022), providing effective operation in a small form factor appropriate for contemporary mobile communications [9].Various shapes of antenna models are designed by researchers [10]-[23].Even with these developments, MIMO antenna designs that are small, effective, and adaptable are still needed in order to meet the changing needs of contemporary wireless communication systems. To meet the needs of modern wireless applications, the current work suggests a novel 2x2 dual-band MIMO antenna with polarisation diversity approach. In order to efficiently utilise polarisation diversity, the suggested design combines radiating parts that are polarised both horizontally and vertically. Utilising ground structures and placing antenna elements orthogonally helps to reduce mutual coupling, which improves signal robustness and reliability. The novel aspect is the all-encompassing strategy for resolving pressing issues and maximising performance indicators including antenna size, bandwidth coverage, and isolation. The efficacy of the suggested antenna design across a range of frequency bands is shown by experimental measurements, underscoring its applicability for a variety of wireless communication applications. Moreover, a wide range of performance measures, including as Gain, Efficiency, and Directivity, are thoroughly assessed, demonstrating the enhanced performance and adaptability of the suggested design in contrast to current alternatives. In brief, the suggested 2x2 dual-band MIMO antenna is a noteworthy development in the industry, providing a small, effective, and adaptable way to satisfy the needs of contemporary wireless communication systems. The suggested antenna design raises the bar for MIMO antenna systems with its creative design techniques and thorough performance assessment, opening the door for improved connectivity and dependability in upcoming wireless networks.

2. DESIGN METHODOLOGY

To receive and transmit signals in both vertical and horizontal directions, the 2x2 MIMO antenna elements with 50ohm ports are stacked orthogonally. The antenna is made up of one vertical slot in each ground plane, G-shaped components. The suggested MIMO with two bands using a computer simulation tool, an antenna with polarisation diversity is constructed on a 15x15mm^2 FR4 substrate. (CST). The FR4 substrate is 1 mm thick and has a permittivity of 4.3. Fig. 2.1 displays the schematic views of the front view and back view of MIMO. Table 2.1 displays the dimensions of designed antenna.



Front View of MIMO Back View of MIMO

Fig.2.1Schematic views of MIMO

Table.2.1. Dimensions of the proposed antenna (dimensions in millimetre (mm))

Parameter	A	B	C	D	E	F	G	H
Value	6.5	2.2	2.4	3.0	3.36	0.89	2.5	3.8
Parameter	I	J	K	L	M	N	O	P
Value	3.0	4.0	5.40	1.50	0.9	3.0	0.92	3.0

2.1 Simulation and Measurement Results

Using four antenna radiators, the suggested MIMO antenna characteristics are tuned to achieve the lowest possible return loss and mutual coupling. To test return loss and isolation using a two-port MIMO antenna, link any two of the ports, with the remaining ports terminated by 50Ω.The CST MWS (CST microwave studio version 18) results agree well with the proposed 2×2 MIMO. The simulation and measurement of S parameters reveal that $S_{11} = S_{22} = S_{33} = S_{44}$, $S_{12} = S_{21} = S_{34} = S_{43}$, $S_{14} = S_{41} = S_{23} = S_{32}$, and $S_{13} = S_{31} = S_{24} = S_{42}$. To simplify the analysis, we only consider the S_{11}, S_{12}, and S_{13} scattering parameters for visualizing and measuring other parameters. Figures 2.1.1 and 2.1.2 illustrate the simulated S parameters of all ports and single port.The dual-band antenna has simulated −10dB impedance bandwidths that cover frequencies with SWR < 2. The measured −10dB impedance bandwidths range from 5.8743 to 6.6571 GHz, 12.076 to 12.877 GHZ, 24.533 to 30.276 GHz, 43.691 to 46.451 GHz, and 51.954 to 74.61GHz.

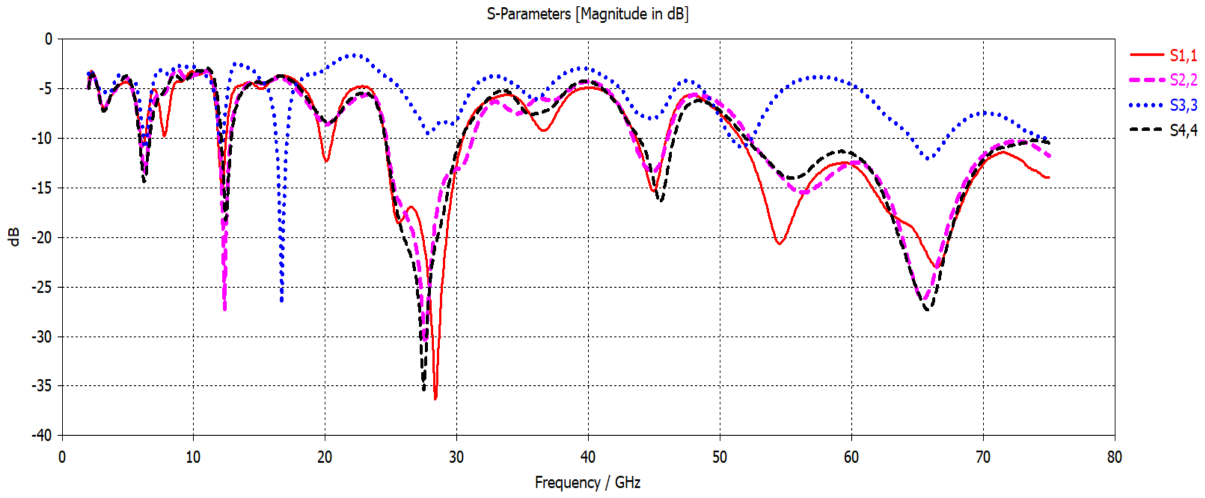


Fig.2.1.1 S-Parameters of MIMO

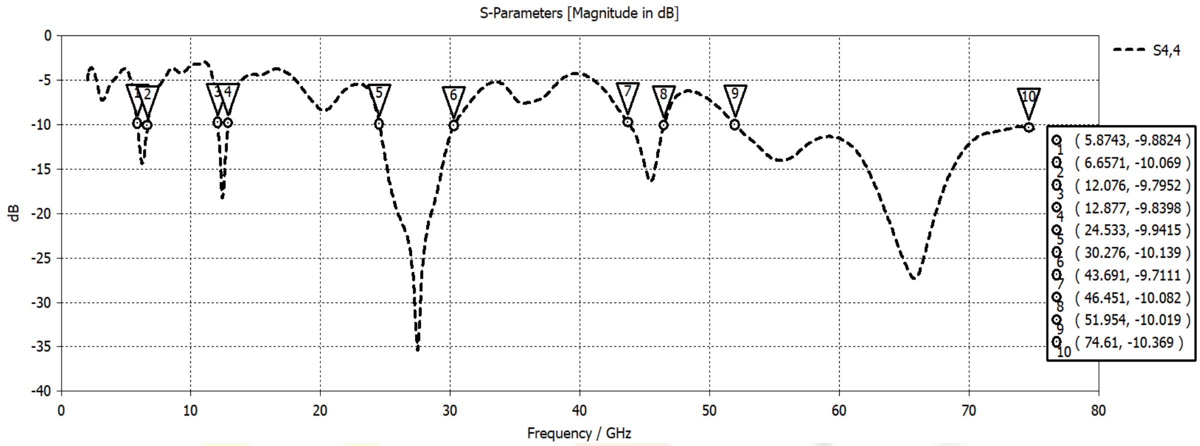


Fig.2.1.2 S_{44} of MIMO

To test the impact of surface current distribution on the proposed MIMO antenna, one of the ports is stimulated while the remaining ports are terminated by 50Ω. As shown in Fig. 2.1.3, at 45.3GHz resonant frequency, the simulated surface current distribution ranges from 0 to 110 Ampere/meter. As a result, the neighboring and diagonally arranged antenna elements get a very low quantity of current. This will produce more than 21dB of isolation.

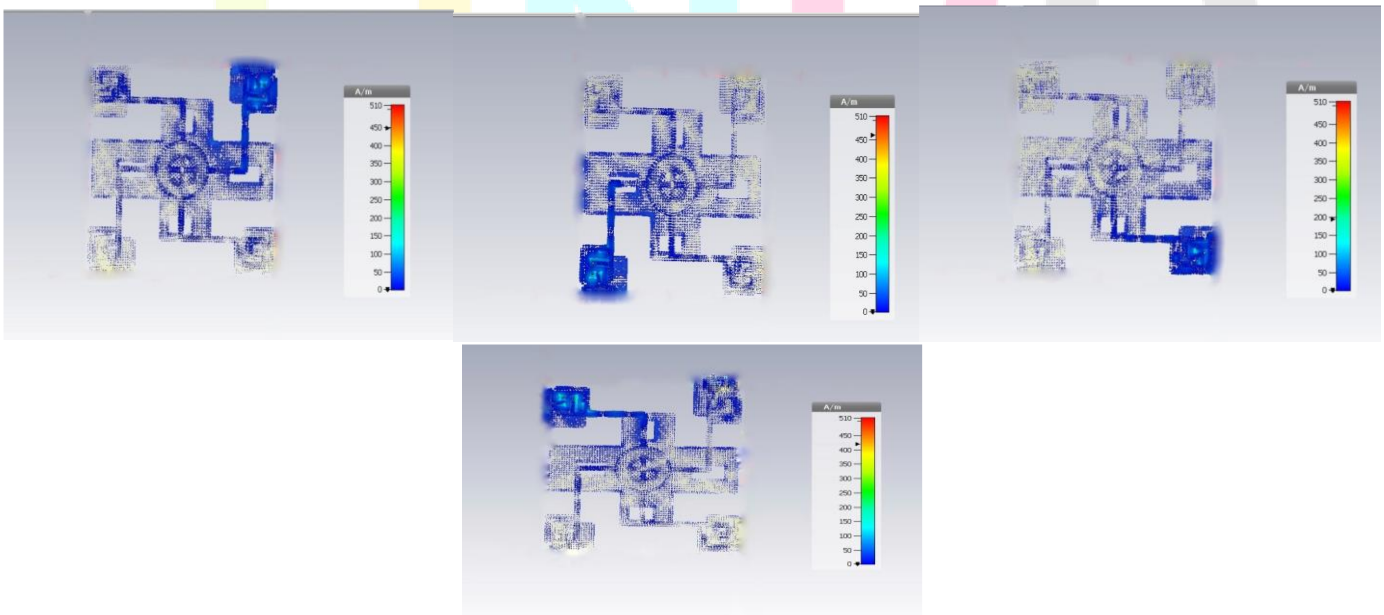


Fig.2.1.3 Surface Currents of MIMO at f=45.3GHZ

2.2 Diversity Performance

The proposed G-shaped MIMO antenna diversity performance explained in terms of gain, efficiency, and directivity. The simulated max gain for the proposed MIMO is 3.8dBi at the resonance frequency of 24.533 to 30.276 GHz. A plot of the gain simulation results as shown in the Fig.2.2.1.

Efficiency counts among the diversity parameters as well. The polarization diversity of G-shaped MIMO antenna is derived from CST simulations conducted at both lower and higher frequencies. At the resonance frequency of 24.533 to 30.276 GHz, the radiation efficiency is 75%. A plot of the Radiation Efficiency simulation results as shown in the Fig.2.2.2.

The diversity gain parameter is the next diversity parameter, and it may be found using Equation (1) in terms of maximal theoretical directivity (10 dB) and correlation coefficient. Better isolation is associated with higher directivity values and vice versa.
The measured directivity increases at frequencies ranging from 24.533 to 30.276 GHz are 7dB.

$$G_{DG} = 10 * \sqrt{1 - |\rho|^2} \quad (1)$$

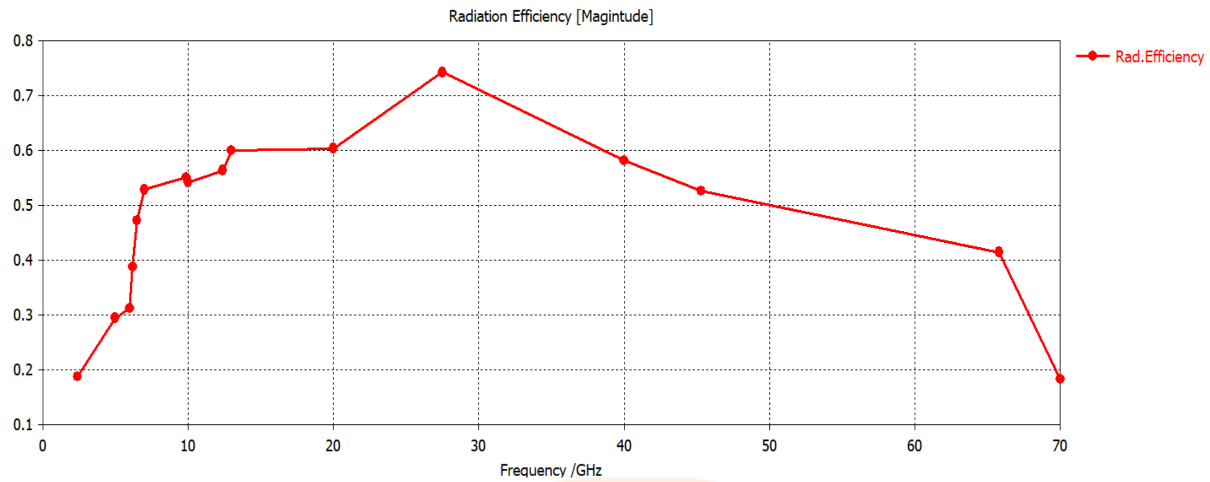


Fig.2.2.1 Gain

Fig.2.2.2 Radiation Efficiency

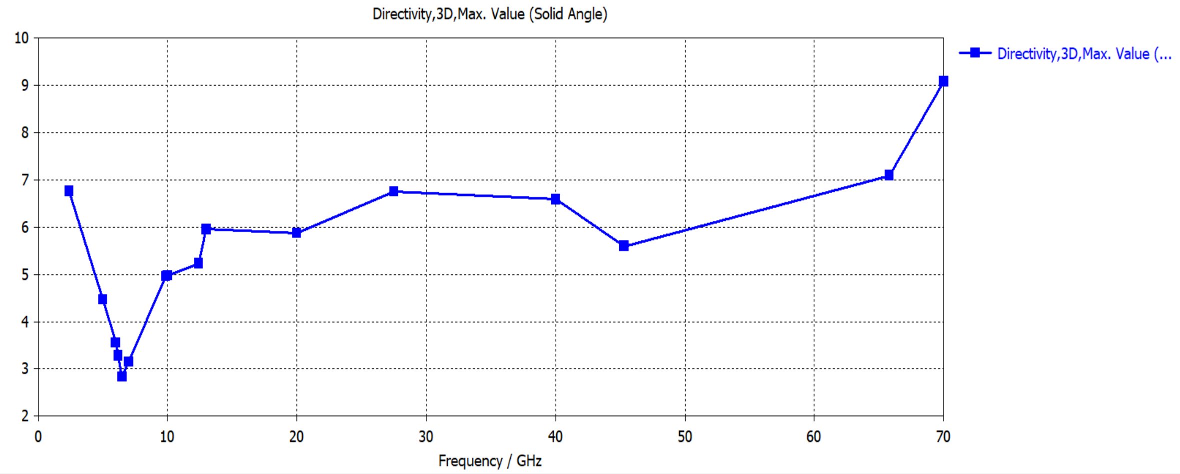


Fig.2.2.3 Directivity

2.3 Far Field Radiation Patterns

When the distance from the source is much greater than the antenna's size, the way electromagnetic waves propagate from an antenna or radiating source is depicted by a far-field radiation pattern. It offers vital information about aspects of signal propagation as polarization, gain, and directionality. In order to improve antenna designs and boost the effectiveness of signal transmission and reception in applications ranging from wireless networks to radar systems and telecommunications, engineers thoroughly examine far-field radiation patterns. Engineers can adjust antenna layouts to reach desired coverage areas and reduce interference by knowing how signals propagate in different directions. This helps to ensure dependable communication and data transfer in a variety of settings.

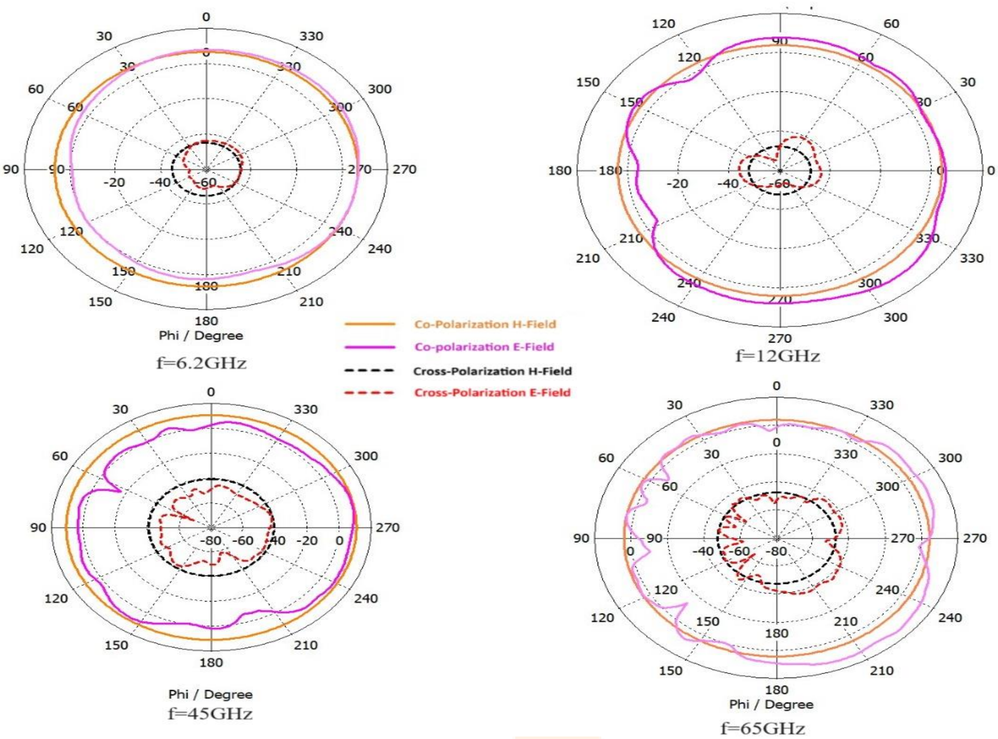


Fig.2.3 Farfield Radiation Patterns

2.4 Antenna Fabrication:

Photolithography is used to create the antenna prototypes on microwave substrates. When high dimensional accuracy is required, this approach is used. A laser printer prints the antenna geometry's first negative mask onto butter paper. Acetone is used to clean copper clad sheets of the appropriate size in order to eliminate any oxide layer from their surface. A thin layer of photoresist material is placed and cured on copper clad using a high-speed spinner. After that, copper clad is exposed to UV light on a substrate with a prepared negative mask on it. Whereas the unexposed area is unaffected and can be erased by dipping in developer solution, the exposed section of the photo resist material layer hardens. Next, water is used to rinse it. Now, the undesirable copper is etched utilizing.

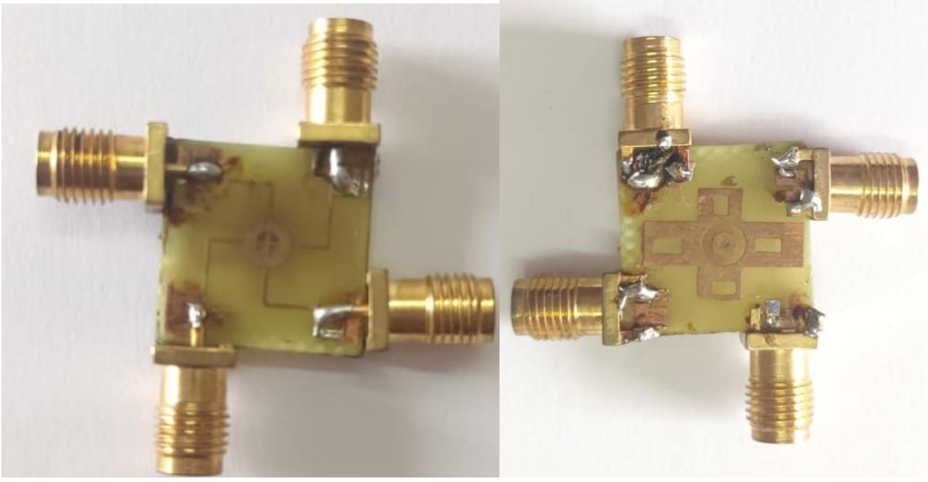


Fig 2.4.1: Hardware implementation of the proposed MIMO antenna

Fig 2.4.2: Length and width of the proposed MIMO antenna design

2.5 Fabrication results:

S-Parameters:

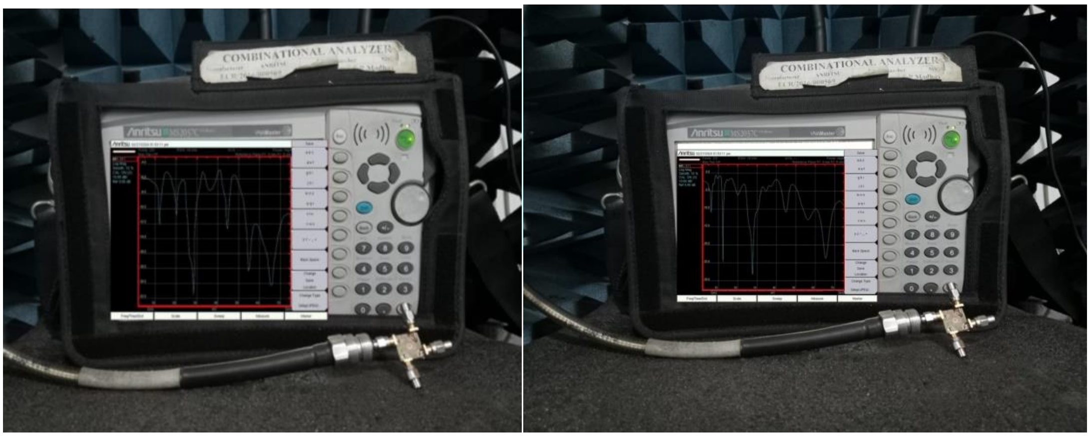


Fig 2.5.1: S_{11} and S_{22} results of Fabricated MIMO antenna

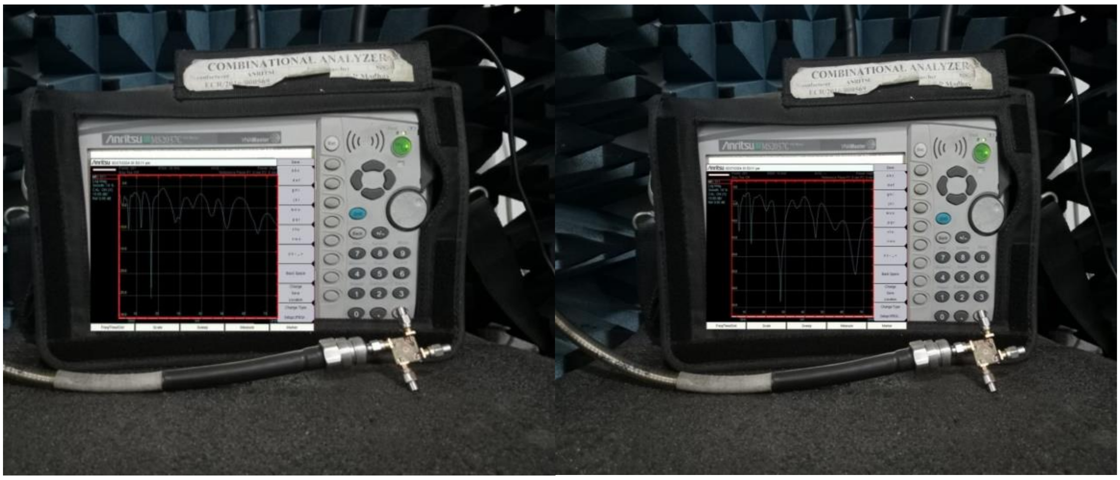


Fig2.5.2: S_{33} and S_{44} results of fabricated MIMO antenna

2.6 Comparison Table

Reference	Author(s)	Size (mm^2)	Substrate	Gain (dBi)	Operating Frequency (GHz)
[1]	C.-M. Luo, J.-S. Hong	22 × 26	FR4	3.8	3.1 - 10.6
[2]	Y. J. Ren, F. S. Zhang, J. H. Liu	22 × 26	FR4	6.5	3.1 - 10.6
[3]	K. Chen, Y. Z. Wang	35 × 16	FR4	6	3.1 - 5
[4]	F. Wang, Z. Duan	48 × 80	FR4	4.7	3.1 - 10.6
[5]	X. Huang, J. Wu	13.5 × 34	FR4 epoxy	4	3 - 12
[6]	S. Khan, S. Asif	25 × 27	Rogers TMM4	5.7	3 - 11
[7]	X. Zhao, S. Riaz	120 × 60	FR4	2.6	1 - 4.5
[8]	J. Zhang, C. Du, R. Wang	65 × 65	Liquid Crystal Polymer	6.9	2.9 - 10.86
[9]	M. M. Abbas, A. N. Allam	33 × 33 × 0.233	RO4003C	5.3	25 - 50
[10]	Cheng and Wang	90 × 90	Silicon Dioxide	8.4	2.4 - >10
[11]	Proposed Antenna	15 × 15	FR4	3.8	2 - 75

3.Conclusion:

For modern wireless applications, the proposed G-shaped 2x2 multi-band MIMO antenna with polarization diversity offers a potential solution. CST software was used to design the antenna. The antenna demonstrated remarkable performance attributes, such as a broad bandwidth, favourable radiation pattern, and elevated gain. By comparing with conventional designs the proposed MIMO antenna exhibits good performance across several frequency bands can be attributed to its novel design, which includes the integration of both horizontally and vertically polarized radiating elements and the use of orthogonal arrangement to mitigate mutual coupling. Its adaptability for various communication scenarios is highlighted by the observed frequency ranges, which range from 5.8743 to 6.6571 GHz, 12.076 to 12.877 GHz, 24.533 to 30.276 GHz, 43.691 to 46.451 GHz, and 51.954 to 74.61 GHz. With a peak gain of 3.8 dBi and observed isolation between diagonal and neighbouring ports surpassing 21 dB, our antenna performs admirably in terms of diversity. Furthermore, indicators like Directivity, Gain, and Efficiency confirm its efficacy in real-world wireless settings. Subsequent efforts may entail practical experimentation and assimilation into industry-standard systems to verify its efficacy in many settings and implementation situations. All things considered, the proposed antenna design advances the field of MIMO antenna technology and provides improved connection, dependability, and flexibility for next-generation wireless networks.

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