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# Design of inverted L shaped MIMO antenna for 5G applications

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## Abstract

The design of an inverted L-shaped multiple-input multiple-output (MIMO) antenna for fifth-generation (5G) applications is presented in this research article. High isolation and outstanding MIMO diversity performance in a compact structure are the primary objectives of the design. The design's benefits are its affordability, symmetric and compact shape, and simplicity. The proposed MIMO antenna system has excellent performance and accessibility, which makes it an ideal selection for a variety of applications. The design strategy, construction, and measurement of the antenna are all included in the study. The suggested design is appropriate for 5G applications and is simple to integrate into devices for communication. According to the paper's conclusion, the suggested MIMO antenna system is a viable option for 5G applications.

## 1. Introduction

The most recent version of cellular technology, known as 5G, is designed to substantially speed up and improve the responsiveness of wireless networks. With 5G, wireless broadband connections can transmit data at multigigabit speeds, with peak rates that might reach 20 gigabits per second (Gbps) and average data rates that are higher than 100 Mbps[2]. As the technology is implemented, a wide range of fresh applications, usages, and business scenarios are anticipated[1].

A wide range of industries, including healthcare, transportation, and manufacturing, stand to be revolutionized by 5G's enhanced speed, reduced latency, and higher dependability. Data can be transmitted from one location to another with a considerably shorter period between transmission and reception because of 5G's significantly more secure and robust connectivity than its predecessors[3]. A prominent field of study is the design and fabrication of an inverted L-shaped multiple-input multiple-output (MIMO) antenna for 5G applications. High isolation and exemplary MIMO diversity performance in a compact structure are the goals of the design. The design's benefits are cost-effectiveness, symmetrical structure, and simplicity of design. A wide range of applications is expected to benefit from the proposed MIMO antenna system's high performance and portability[1].

According to one source[1], an inverted-L wideband MIMO antenna with high impedance matching and compact size is suitable for millimeter-wave 5G applications. Another source[4] suggests a MIMO antenna for 5G NR that is small in size and has high isolation between the two antenna parts. This antenna features a double L-shaped construction. A tiny wideband inverted L-shaped flexible antenna with a flexible polyimide substrate and a modest dimension is presented by a third source[5] for sub-6 GHz 5G applications. The antenna exhibits good isolation and ECC, according to the same source, making it a great option for creating 5G MIMO antennas that operate in the sub-6 GHz range.

The inverted-L antenna and its derivatives, such as the inverted-F antenna, are another low-profile antenna design utilised in wireless applications, according to a fourth source[6]. The suggested inverted-L wideband MIMO antenna is said to be less efficient than previous designs, according to one source[1], however the authors don't specify which other designs they compare it to. All things considered, the inverted L-shaped antenna has been suggested in a number of designs for 5G applications, and some of these designs have demonstrated strong performance in terms of compact size, impedance matching, isolation, and flexibility.

An antenna's impedance matching to the transmitter or transmission line it is attached to is gauged by the reflection coefficient. The total amount of power available at the antenna for transmission is influenced by the reflection coefficient; if the reflection coefficient is very high, the power available at the antenna for transmission will be lower than that available without reflections[8].

An excessive quantity of power is likely to be reflected back to the source due to a high reflection coefficient, which could potentially damage the transmitter and lower the system's overall efficiency. A good impedance match, on the other hand, means that most of the power is delivered to the antenna and very little is reflected back to the source, which can be determined by a low reflection coefficient. To maximize power transmission and enhance system efficiency, attaining a low reflection coefficient is of the utmost importance in antenna design[9,10].

In antenna design, there are numerous ways to minimize the reflection coefficient. Utilizing matching networks, which are created to match the impedance of the antenna to that of the transmission line or source, is one method. Utilizing optimization methods, matching networks may be created to reduce the reflection coefficient in the passband[13]. Utilizing absorbent components or buildings is another method for lowering the power reflected. To lessen reflections and boost system effectiveness[12], absorbent components or buildings can be put close to the antenna or transmission line.

Utilizing a transmission line with a characteristic impedance that matches the antenna's impedance is another method. This can be done by choosing a transmission line with a characteristic impedance that matches the antenna's impedance or by employing a matching network to align the antenna's impedance with the transmission line's characteristic impedance[14].

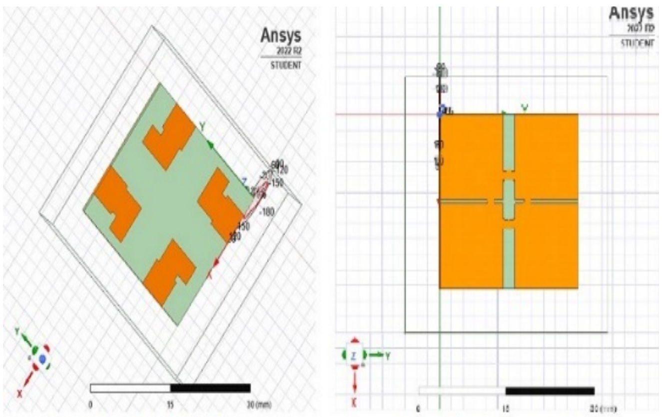
## 2. Proposed MIMO Antenna Design

The millimetre wave (mm-wave) spectrum is used by the 5G network, which is anticipated to greatly speed up wireless communication. The maximum supported throughput is a hundred times more than that of a 4G network. This poses tough problems for antenna designers who are attempting to fulfil system requirements. The mobile industry is using the mm-wave bands allocated for 5G connections (24.25-27.5, 27.5-29.5, 37-40, and 64-71GHz) to get the required outcomes.

The 27.5-29.5 GHz band has been designated by the FCC as the key frequency range for 5G networks. This is the reason that the 28 GHz range has been chosen by advanced technical nations like Japan, the Republic of Korea, the United States, etc. for their 5G networks. In comparison to other frequency bands, the 28 GHz frequency spectrum offers a substantial advantage in reducing data transmission losses. Research on 5G antennas' miniaturization, high gain, and narrow -3dB rays beam width has already started because they will be mounted externally on spacecraft and high-performance objects like aircraft, satellites, missiles, cars, military equipment, and practical communications systems.
Finding solutions to minimize size and increase gain for 5G applications employing microstrip patch antennas operating at 28GHz bands (Ka-band) was the primary driving force behind this study.

## Simulated Design

For 5G antenna simulation, there are a variety of software solutions available, such as the ANSYS simulation application, which offers a full solution from system and MIMO antenna design to performance assessment in realistic situations. Eight distinct 5G patch antenna array designs with various structural dimensions were designed in our research. Each design's outputs were simulated, and the one that performed the best was ultimately selected to be fabricated and put through real-time analysis. This method facilitates a more effective and economical approach to designing and testing 5G antennas, ultimately resulting in improved performance and a quicker rollout of 5G networks.




Proposed Design (Top View)    Proposed Design (Bottom View)

Fig. 1. Proposed 4xU Design

The proposed layout for a 5G patch antenna array is shown in Figure 1. HFSS software was utilised to model the design, and Rogers RT5880 material was used in the simulation and antenna fabrication. Faster deployment of 5G networks and improved performance are anticipated benefits of the suggested architecture. The design and placement of various antenna systems that fulfil 5G requirements, don't interact with one another, and are resistant to interference from other on-board devices may be done with the use of electromagnetic simulation tools. This method enables a more effective and economical method of designing and testing 5G antennas.

The designed antenna's length, breadth, and height are shown in the table 1 along with other physical characteristics of the antenna design. The measurements are given in millimeters. The antenna was designed, simulated, and fabricated using these dimensions. In order to obtain improved gain and bandwidth for 5G mm-wave applications, the antenna's dimensions were optimized.

| # | Name | Type | POS X | POS Y | POS Z | Size X | Size Y | Size Z | Radius |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Patch 2 Rect(1+2+3) | Rectangle 1 | 0 | 15.014 | 0 | 4.214 | 4.93 | 0 | NA |
| | | Rectangle 2 | 4.214 | 15.514 | 0 | 4 | 3.93 | 0 | NA |
| | | Rectangle 3 | 5.214 | 19.444 | 0 | 3 | 2.12 | 0 | NA |
| 2 | Patch 3 Rect(1+2+3) | Rectangle 1 | 14.534 | 19.786 | 0 | 4.93 | 4.214 | 0 | NA |
| | | Rectangle 2 | 15.034 | 15.786 | 0 | 3.93 | 4 | 0 | NA |
| | | Rectangle 3 | 18.964 | 15.786 | 0 | 2.12 | 3 | 0 | NA |
| 3 | Patch 4 Rect(1+2+3) | Rectangle 1 | 18.286 | 4.056 | 0 | 4.214 | 4.93 | 0 | NA |
| | | Rectangle 2 | 14.286 | 4.556 | 0 | 4 | 3.93 | 0 | NA |
| | | Rectangle 3 | 14.286 | 2.436 | 0 | 3 | 2.12 | 0 | NA |
| 4 | Patch 1 Rect(1+2+3) | Rectangle 1 | 3.036 | 0 | 0 | 4.93 | 4.214 | 0 | NA |
| | | Rectangle 2 | 3.536 | 4.214 | 0 | 3.93 | 4 | 0 | NA |
| | | Rectangle 3 | 1.416 | 5.214 | 0 | 2.12 | 3 | 0 | NA |
| 5 | Substrate | Box 1 | 0 | 0 | 0 | 22.5 | 24 | 1.6 | NA |
| 6 | Radiation Box | Box 1 | -5 | -6 | -7.5 | 33 | 35 | 15 | NA |
| 7 | Port 1 | Box 1 | 3.036 | 0 | 0 | 4.93 | 0 | 1.6 | NA |
| 8 | Port 2 | Box 1 | 0 | 15.014 | 0 | 4.93 | 0 | 1.6 | NA |
| 9 | Port 3 | Box 1 | 14.534 | 24 | 0 | 4.93 | 0 | 1.6 | NA |
| 10 | Port 4 | Box 1 | 22.5 | 8.986 | 0 | -4.93 | 0 | 1.6 | NA |
| 11 | Ground (Rect(1+2+3+4)+ Circle (1-2) | Rectangle 1 | 22.5 | 0 | 1.6 | -11 | 11 | 0 | NA |
| | | Rectangle 2 | 0 | 0 | 1.6 | 11 | 11 | 0 | NA |
| | | Rectangle 3 | 0 | 24 | 1.6 | 11 | -11 | 0 | NA |
| | | Rectangle 4 | 11.5 | 24 | 1.6 | 11 | -11 | 0 | NA |
| | | Circle 1 | 11 | 12 | 1.6 | 0 | 0 | 0 | 3.79 |
| | | Circle 2 | 11 | 12 | 1.6 | 0 | 0 | 0 | 2.59 |

Table 1. Proposed 4xU Design Dimensions

In this design RT Duroid material was used. In terms of designing antennas, RT Duroid material offers a variety of benefits, including a low dielectric constant, good thermal stability, and low loss tangent. The strong thermal stability of RT Duroid material, such RT/duroid 5880, allows it to sustain performance across a wide temperature range, while the low dielectric constant of RT Duroid material makes it appropriate for high-frequency applications.

Furthermore, the low loss tangent of RT Duroid material contributes to great efficiency and minimal signal attenuation in antenna designs. Due of these benefits, antenna designers frequently choose RT Duroid material for use in wireless communication and radio frequency applications[17].

The performance of various antenna designs may be compared using the figures, which each represent a certain parameter.

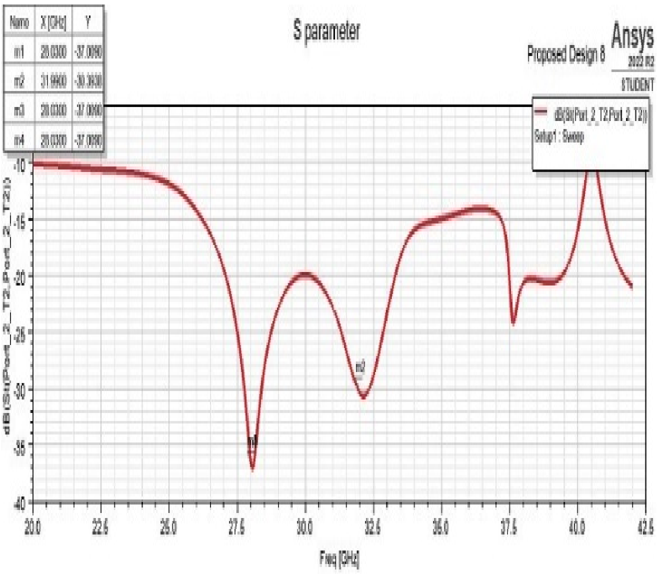



Fig. 2. Proposed 4xU Design Reflection Co-efficient

Figure 2 shows that the S parameter, also known as the reflection coefficient, is at its lowest between 28.03 GHz and 31.99 GHz, with values of -37.00 dB and -30.39 dB, respectively. This is seen to be quite great performance range. Figures 3 and 4 show the 2D radiation patterns for the E-Plane and H-Plane, respectively.

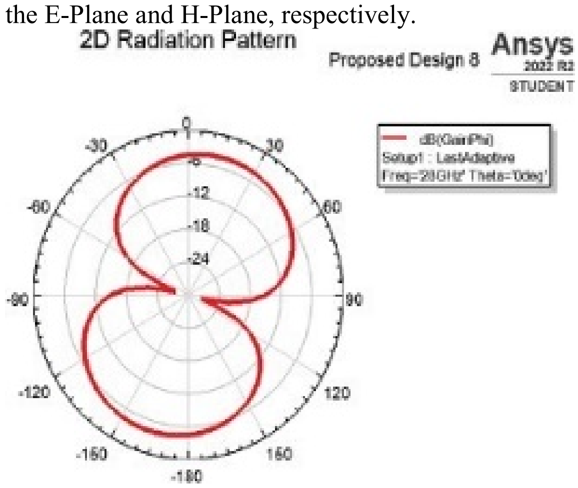



Fig. 3. Proposed 4xU Design Radiation Plot E-Plane

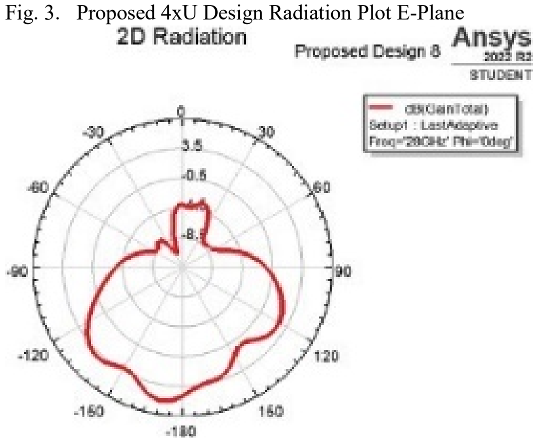
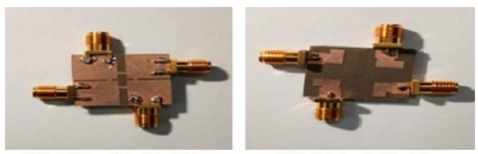



Fig. 4. Proposed 4xU Design Radiation Plot H-Plane

## Fabricated MIMO Antenna Design



Fabricated Antenna Bottom View 4xU    Fabricated Antenna Top View 4xU

Fig. 5. Fabricated Antenna Design 4xU

Figure 5 depicts the fabricated antenna for a 4 port 5G patch antenna array. The reflection coefficient, also known as the S parameter, is at its lowest between 24.253 GHz and 31.507 GHz, with values of -24.70 dB and -28.15 dB, respectively, according to Figure 6. This performance range is thought to be fairly excellent. The lowest VSWR values at 32 GHz, which is 1.06 and is regarded as being at a good level of performance.

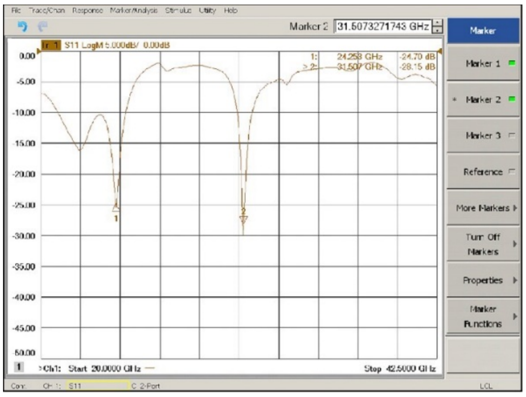



Fig. 6. Fabricated Antenna Return Loss

## 3. Conclusion

In conclusion, the antenna's performance was great, with a VSWR of 1.02 and a gain of 9.13 and reflection co-efficient of -37 dB. The usage of the RT Duroid material, which has a low dielectric constant, good thermal stability, and low loss tangent, was one of several strategies used to optimize the design. The antenna's dimensions were all carefully chosen design criteria in order to achieve the intended performance. The outcomes show how the design strategy works and how crucial rigorous optimization is for producing high-performance antenna designs. By taking into account other elements, the design may be enhanced further. The design may be used in a variety of applications, including wireless communication and radio frequency applications, and makes a helpful contribution to the field of antenna design.

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