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Wide Bandwidth Tri-Band MIMO Antenna Design for 5G Communication

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ABSTRACT- Wireless communication research is currently focused on 5G. On an FR4 substrate, a building-like structure with two slot-based planar multiple input multiple output (MIMO) antenna has been designed. dielectric constant is 4.3, and the substrate thickness is 1.6mm. The proposed antenna is designed and simulated for 5G applications using CST microwave studio and HFSS at 24.25GHz, 29.25GHz, and 32.40GHz. According to the simulated results, the VSWR is lower than 3:1 and the return loss at both ports is -43.27dB, -60.55dB, and –42.61dB at 29.25GHz, 34.20GHz, and 34.075GHz resonating frequencies respectively. Isolation between both ports is better. At 24.25GHz, 29.25GHz, and 32.40GHz the proposed design achieves a gain of 5.1dBi, 5.5dBi, and 3.5dBi respectively. The structure is fabricated and measurement is carried out. The simulated and the measured results shows good agreement.

Keywords: 5G, High Gain, MIMO, Wide bandwidth.

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1. INTRODUCTION

With the latest advancements in communication, many crucial factors to consider for the upcoming fifth-generation (5G) communication system (wireless) [1]. The primary difference between this and the 4G system is that the 5G system will use a higher frequency—beyond 24 GHz—for wireless communication [2-3]. Since multi-gigabit data can be delivered per second using the millimetre frequency band, which offers greater bandwidth than the 3G and 4G frequency bands [4-5]. The hypothetical millimetre-wave frequency range of 24–84 GHz was made public in 2015 during a global radio communication meeting by the International Telecommunications Union. The frequencies are 59.3–71 GHz, 50.4–52.6 GHz, 47–50.2 GHz, 42–45 GHz, 37–40.5 GHz, 33.4–36 GHz, and 27.5–29.5 GHz [6].

The Federal Communication Commission, located in the United States, has suggested the 5G wireless communication technology for frequencies of 28, 38, 39, and 64–71 GHz. Of these, 38 GHz and 28 GHz are strong bands as they allow lower latency and higher data rates due to the low air attenuation. The research aims to develop a smaller, broader bandwidth antenna for each of these frequencies. Dual-band microstrip patch antennas, or MPAs, are a common configuration for high-speed data transmission due to their easy design, small size, low profile, and ease of integration with other system components. Rather than merging two separate frequency band antennas to enhance bandwidth, this is the most effective method of constructing a dual-band antenna. Reducing the number of antennas to one will lower the system's necessary area and cost [8].

Due to its improved efficiency and dependability, MIMO antenna utilization in wireless communication systems is now growing in popularity. However, because of the small distance between the pieces, mutual coupling is a significant issue. The correlation coefficient rises because of the interaction effect of the MIMO antenna, it worsens system performance by lowering gain and changing the radio-activity diagram [17].

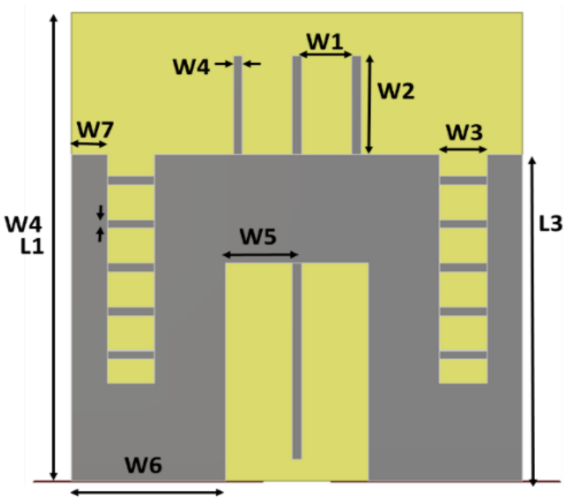
The Rogers substrate is used to build an elliptical slot microstrip patch antenna that operates at 28 GHz and 45 GHz, respectively, with a gain of 7.6 dB and 7.21 dB and a bandwidth of 1.3 GHz and 1 GHz [8]. In the paper [9], it has been achieved to create a dual-band PIFA antenna of 28 GHz and 38 GHz with very less bandwidth and gain of 3.75dBi at 3.34 GHz and 5.06dBi at 1.395 GHz. In reference [10], there's a triangle-shaped MPA constructed. It has the bandwidth with 4.86 GHz and 3.60 and gain of 5.75dBi and 7.23dBi at 28 GHz and 38 GHz, respectively despite its immense size. A 4dBi gain and 6dBi bandwidth antenna have been designed for 1.02 GHz and 3.49 GHz, respectively for 28 and 38 GHz frequencies in the paper [11].

The author of the paper [12] designed an SIW antenna; its size is not given clearly, and its gain and bandwidth at frequencies of 2.2 GHz and 28 GHz and 5.2dBi and 5.9dBi, respectively, are reported.

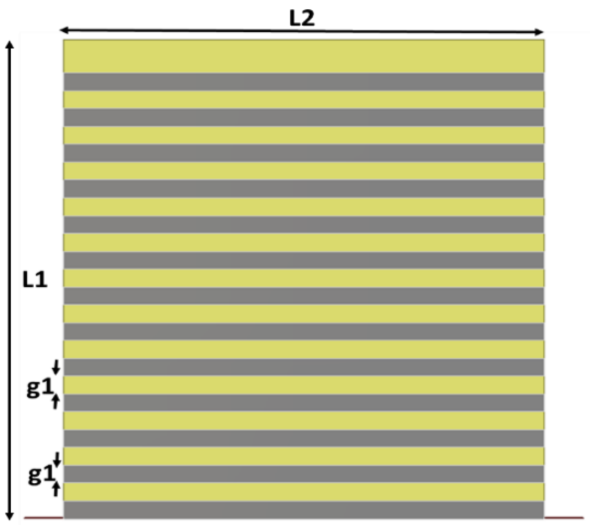
The reference [13] has constructed a spiral planar monopole antenna with dual bands operating at 38 GHz and 28 GHz, albeit with subpar gain. The reference [13] uses a tiny antenna that is driven by a co-planar waveguide (CPW) feed to achieve the maximum gain of 6.6 dB at a frequency of 28GHz. A Roger RT5880 substrate measuring 5×5 mm^2 and 0.254 mm in height has been used. According to all the research, a dual-band antenna is strongly advised in place of two single-band antennas to save costs and increase overall bandwidth [8–15][16].

Using an FR4 substrate, this work proposes a building-like arrangement structure MIMO antenna that operates in the 24.25GHz, 29.25GHz, and 32.40GHz frequency bands. This allows for the achievement of multi-band functionality, high gain, and high efficiency. The top of the proposed design is a building-like structure while the bottom is designed like strip lines.

2. PROPOSED 5G MIMO ANTENNA DESIGN METHODOLOGY



(a)



(b)

Figure 1. Proposed MIMO antenna (a) Front design, (b) Back design

The proposed MIMO antenna is designed on a FR-4 substrate with a building-shaped design in each port. The substrate thickness is 1.6mm, and the dielectric constant is 4.3. The design is compact, single-layer and easy to fabricate therefore such a simple structure is considered. Using CST-Microwave Studio, the proposed antenna for 5G broadband applications has been designed and simulated. The ground layer of copper is formed on a 20×19mm^2 substrate and has a thickness of 35µm. *Figure 1(a)* and *figure 1(b)* depicts the front and back design of proposed 5G MIMO antenna, and *table 1* below shows the dimensions of the proposed antenna.

Table 1. Dimensions of proposed antenna

Parameter	Dimension (in mm)	Parameter	Dimension (in mm)
W1	2.10	W4	0.40
W2	4.50	W5	2.80
W3	2.00	W6	6.50
L1	21.50	Ts	1.6
L2	19.00	W7	1.50
L3	15.00	g1	0.80

3. RETRIEVED RESULTS

3.1. VSWR and Return Loss

The proportion of radio waves that are rejected and received at the antenna's input is known as the S_{11} parameter or antenna returns loss. It is measured in dB, and an antenna must be less than -10 dB to function properly. The return-loss Vs frequency graph of the suggested antenna is shown in *figure 2*.

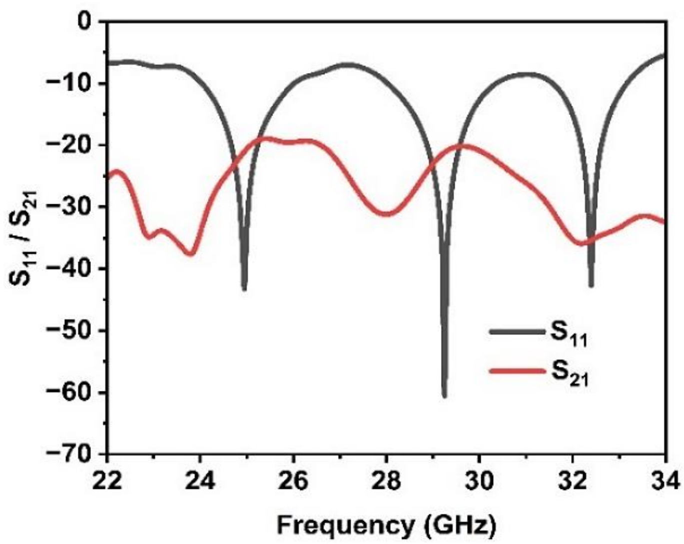


Figure 2. S-parameters for proposed MIMO antenna

The S_{11} parameter values for the frequencies of 24.95GHz,29.25GHz, and 32.40GHz are -43.27dB, -60.55dB, and –42.61dBrespectively, indicating that relatively little input radio waves at those frequencies are being rejected. S11 characteristics can also be represented alternatively using the Voltage Standing Wave Ratio (VSWR) as depicted in *figure 3.*

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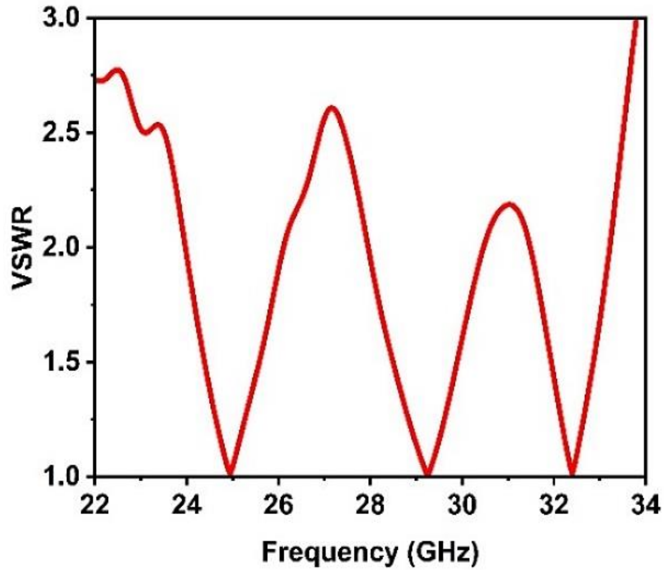

Figure 3. VSWR of proposed antenna

3.2. Envelope Correlation Coefficient (ECC)

The envelope correlation coefficient, or ECC, indicates how well the antenna understands the varied performance of the suggested work. The simulated ECC as shown in *figure 4* result for the proposed design shows that over the complete frequency range, the ECC values are less than 10^{-35}.

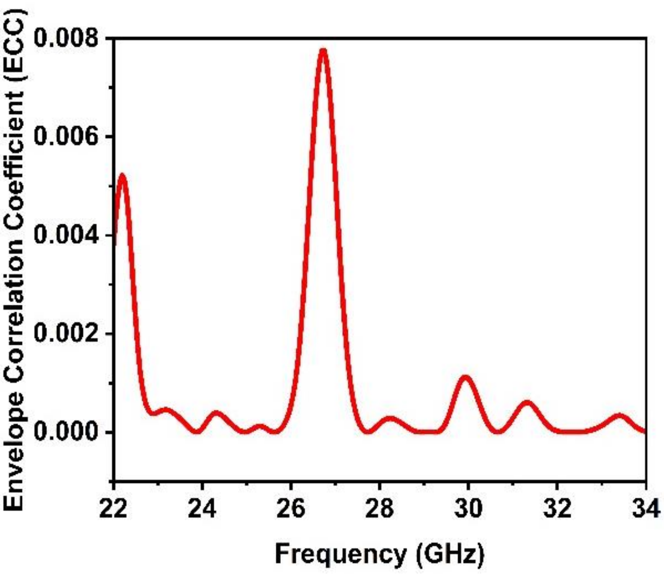

Figure 4. Envelope Correlation Coefficient for the proposed antenna

3.3. Antenna Gain

Achieving the intended direction of radiation from an antenna is determined by its antenna gain. *Figure 5* shows the gain values in the suggested simulation design for the MIMO antenna, which is above 5.1dBi, 5.5dBi, and 3.5dBi in the frequency band.

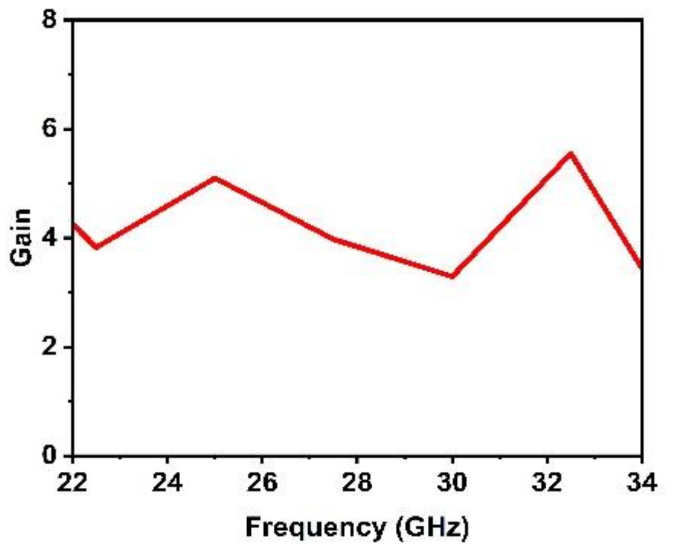

Figure 5. Gain of proposed Antenna

3.4. Antenna Efficiency

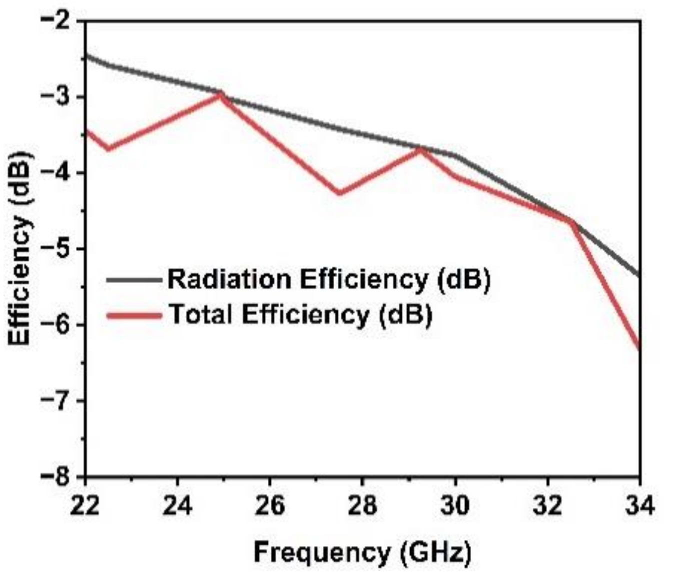

Figure 6. Antenna Efficiencies for the proposed antenna

Figure 6 presents the combined efficiency of the proposed MIMO antenna and the simulated radiation. According to the results, the radiation efficiency is better than 97% throughout the whole bandwidth, and the overall efficiency is more than 89%.

3.5. Radiation Patterns

3.5.1. E-field

At the frequencies of 24.95GHz, 29.25GHz, and 32.40GHz, the main lobe magnitude is 18dB, the angular width (3dB) is 40.6°, and the side lobe level is -3.4dB, at phi=90°displayed in *figure 7 (a), (b), and (c)* respectively.

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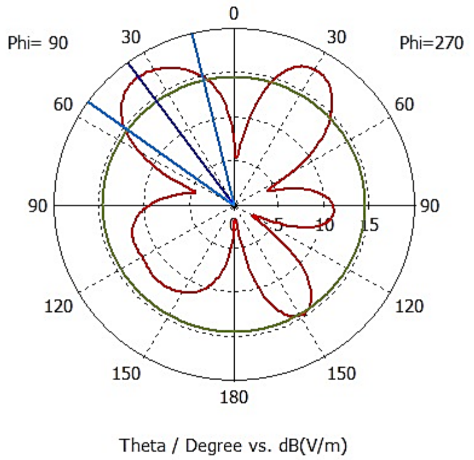
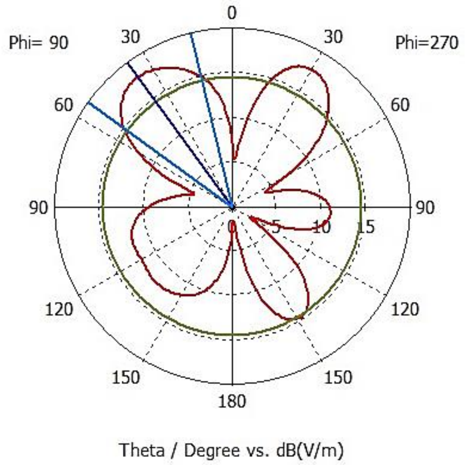
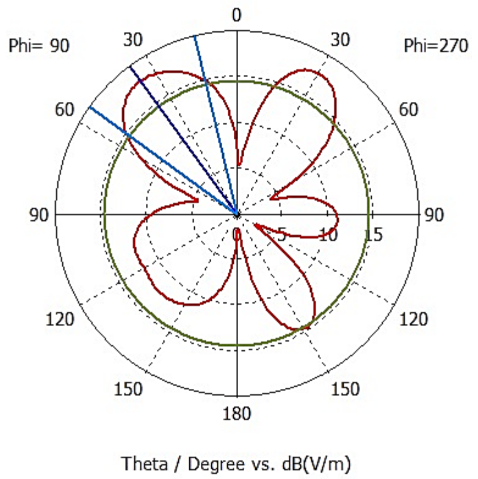


(a)



(b)

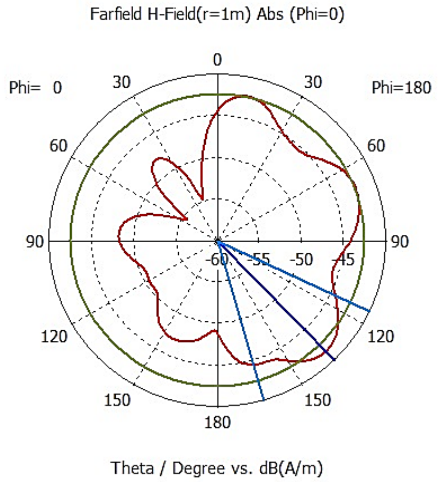


(c)

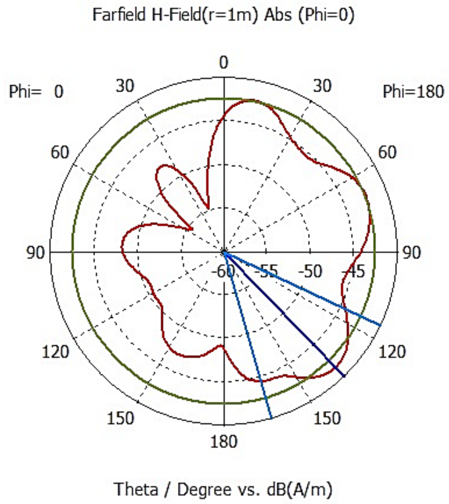
Figure 7. E-field pattern for the proposed antenna at (a). f= 29.25GHz, (b). f= 34.20GHz and (c). f= 34.075GHz

3.5.2. H-field

Figure 8(a), (b), and (c) displays that, the main lobe magnitude is -41.5dBi, angular width (3dB) is 49.0° and the side lob level is -0.9dB at phi=0° at 24.95GHz, 29.25GHz, and 32.40GHz frequencies respectively.



(a)



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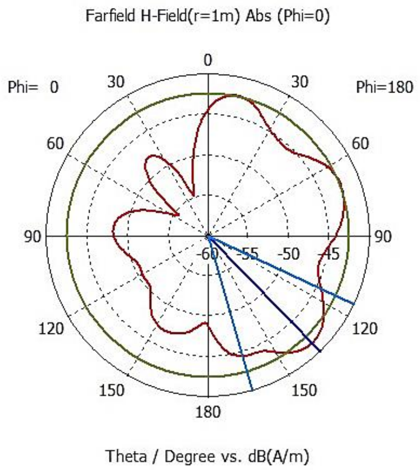


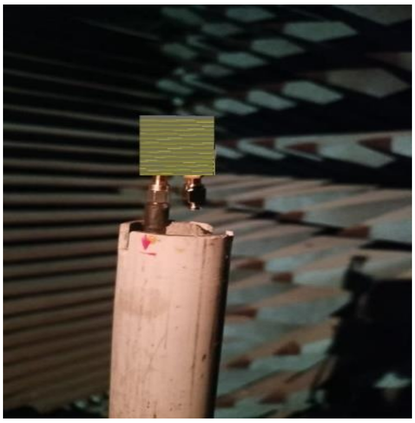
(c)

Figure 8. H-field pattern for the proposed antenna at (a). f= 29.25GHz, (b). f= 34.20GHz, (c). f= 34.075GHz

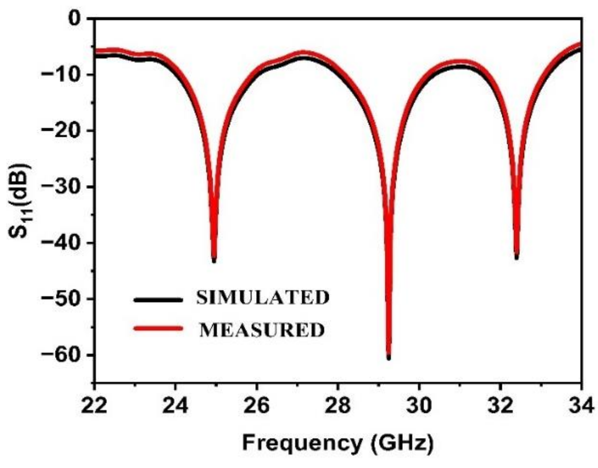
3. VALIDATION

The proposed structure is fabricated on FR-4 substrate using PCB printing and etching process. *Figure 9(a)* and *figure 9(b)* shows the front and back of the fabricated antenna placed inside the anechoic chamber. The measurement is done using vector network analyser. The comparison of simulated and the fabricated structure is show in *figure 9(c)*. Simulation and measurement results are in good agreement to each other.

(a)



(b)



(c)

Figure 9. Fabricated proposed antenna (a) Front, (b) Back, (c) Comparison between simulated and measured result

Table 1 shows a comparison of the designed structure with the style of artwork. All the compared work are on triple band antenna, the designed antenna is also a triple band antenna but compact in size and wider band bandwidth in comparison to others.

REF	**Number of bands**	**Size (mm^2)**	**Frequency range (GHz)**
[18]	3	32 x 26	2.35-2.5, 3.25-3.8, 4.4-6.2
[19]	3	50 x 50	2.3-2.75, 3.4-3.75, 4.8-6
[20]	3	14 x 12	5.2-5.7, 11.8-17.3, 23.4-37.3
Present Work	**3**	**21.5 x 19**	**24-26, 28-30.3, 31.6-33.1**

4. CONCLUSION

A building-like shape MIMO antenna has been designed on an FR4 substrate including strip-structured ground elements. A broader bandwidth, high efficiency, and high realized gain are obtained by the proposed multi-band MIMO antenna that operates at the 29.25GHz, 34.20GHz, and 34.075GHz frequency bands, where return-loss is -43.27dB, -60.55dB and –42.61dB respectively. In frequency band, more than97% of the radiation efficiency is observed. The antenna produced a gain of 5.1dBi, 5.5dBi, and 3.5dBi at 24.95GHz, 29.25GHz, and 34.20GHz respectively.

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