5 × 5 MIMO Antennas for Future 5G mm-Wave Communication

Samad, A., Zahid, M., Sultan, A., Amin, Y., Shoaib, S

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Abdul Samad
TED, UET
Taxila, Pakistan
samad8602@gmail.com

Muhammad Zahid
TED, UET
Taxila, Pakistan
muhammad.zahid@uettaxila.edu.pk

Ayesha Sultan
TED, UET
Taxila, Pakistan
ayeshasultan1703@gmail.com

Yasar Amin
TED, UET
Taxila, Pakistan
yasar.amin@uettaxila.edu.pk

Sultan Shoaib
School of Applied Science Computing & Engineering
Wrexham Glyndwr University
Wales, United Kingdom
sultan.shoaib@glyndwr.ac.uk

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Abstract— **A suggested MIMO antenna's goal is to function in one of the Federal Communication Commission's designated 5G spectral bands (FCC). Due to its propensity to handle both many inputs and numerous outputs, MIMO technology may effectively address issues with large amounts of transportation and high data rates. The overall dimension of a single-element antenna is 10 x 10 mm^2. The proposed MIMO antenna design consists of twenty-five elements and the resonance frequency of each antenna element is 37 GHz. The maximum gain and directivity of an antenna are greater than 6 dB. For the designing and simulation of the proposed twenty-five element MIMO antennas is CST Studio Suite software. The proposed antenna will be a candidate for future mm-Wave communication applications in terms of compactness.**

Keywords— MIMO, FCC, spectral bands, 5G, CST

I. Introduction

Due to rising data rates and increased traffic, 5G will eventually appear. The prior technologies do not meet the band allocation standards. There is a need for new frequency bands to handle the high internet traffic. The Federal Communication Commission (FCC) designates specific spectral bands as 5G communication-only zones. The major elements to propel the next 5G technology in the last several years have been wireless communication for a variety of services that enable high data rates, and fast speed systems with IoT devices [1]-[4]. Additionally, this led to fundamental problems with transmission capacity and slower data speeds [5].

The International Telecommunication Union (ITU) has certified a several millimeter wave (mm-wave) frequency bands for 5G applications [6]. Designing an antenna for mm-wave frequencies is very difficult. Researchers' efforts to provide the groundwork for 5G (mm-wave) connectivity have expanded. Broader bandwidth requirements should be taken into consideration for 5G applications. The usage of MIMO technology for mm-wave frequency bands can improve both spectral efficiency and bandwidth. MIMO technique is widely employed for high transmission rates. By increasing the number of elements on both the transmitter and receiver sides, it is possible to enhance channel capacity and data rates [7].

Due to the rising number of components in MIMO technology, researchers in the antenna business must deal with various challenges. Currently, MIMO antennas of 2x2 and 4x4 dimensions are used. For future 5G communication to be successful, we most likely require an 8x8 MIMO antenna [8]. Numerous antenna designs for 5G (mm-Wave) communication are discussed in literature in [9]-[11].

With only one antenna element, it has been reported that it is difficult to achieve high gain values and channel capacity. There are numerous different array designs as well, and these array antennas are fed by a single excitation, giving them virtually equal channel capacity. Data rates will decrease since bandwidths are very low and frequency channels are occupied to accommodate many users. To address the bandwidth, channel capacity, and spectral band allocation difficulties, MIMO technology must be used. The outputs will be very productive as a result, guaranteeing maximum throughput. Due to MIMO technology, in addition to the many benefits, some drawbacks are also taken into consideration. As a result, certain parameters must be optimized for greater performance reliability to increase the performance of these MIMO antennas [12]-[15].

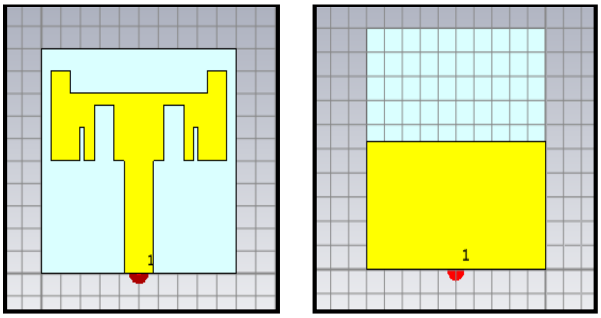
In this study, a single band antenna is offered to support 5G (mm-wave) communication. The antenna operates at a frequency of 37GHz. The twenty-five element MIMO design is produced using the antenna's single unit cell configuration and is afterwards simulated using the MWS CST program. The study's next section discusses and mentions the MIMO antenna's optimization and performance characteristics.

II. Dimensions and Antenna Design

This section discusses the parameters and the overall MIMO antenna design. The substrate used to build the suggested antenna has a thickness of 0.51 mm. Rogers RT5880 is the name of the substrate's substance (lossy). The substrate is maintained at 10x10 mm^2. The ground is 10x5.3 mm^2 and is made of annealed copper. The next subsections describe additional antenna design.

A. Single Unit Cell of Antenna

The creation of a single antenna element is the initial step. With a microstrip supplied line that is 1.5 mm wide, a rectangular patch of 9x4 mm^2 is intended to resonate at a frequency of 37 GHz. The partial ground is made of copper and has a 0.035 mm thickness. The antenna configuration for single units is depicted in Fig. 1. A single-element antenna with the planned primary dimensions listed in table I can be constructed using the geometry in Fig. 2.



(a) Front view (b) back view

Fig. 1. Single element of a proposed antennas

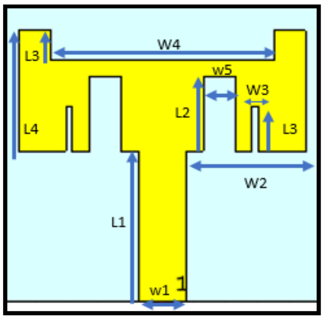


Fig. 2. Single antenna element dimensions

TABLE I. DIMENSIONS OF ANTENNA

Length	Values (mm)	Length	Values (mm)
W1	1.505	W2	4.5
W3	0.3	W4	7
W5	1	L1	5
L2	2.5	L3	1.5
L4	4		

B. *Design of MIMO Antenna*

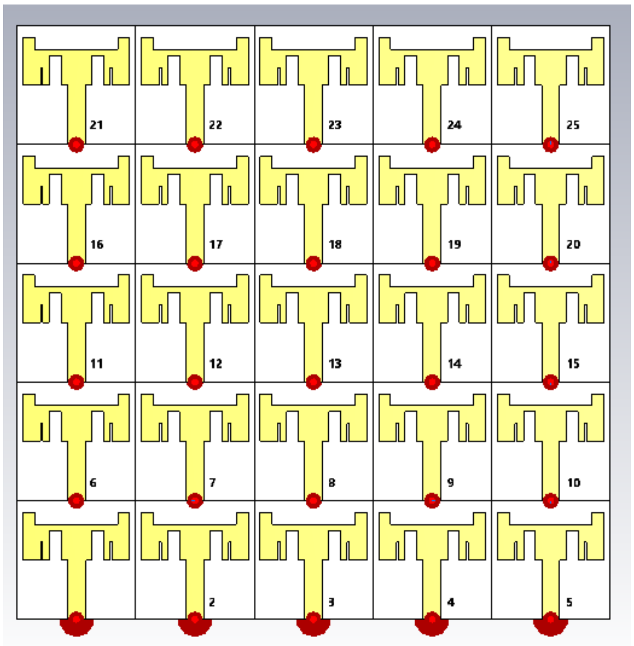
A 5x5 element MIMO antenna is created using the single-unit cell antenna architecture. The overall dimension of the proposed MIMO antenna is 50x50 mm^2. The patch and ground share the same remaining dimensions as the single element. Fig. 3 depicts the MIMO antenna's design. There are twenty-five discrete ports altogether because each MIMO element has its own discrete port. Because the discrete port uses less energy, it is used. This will result in an identical reference impedance of 50 ohms. To prevent mutual coupling between the MIMO elements, isolation between them should be kept to a minimum.

III. SIMULATED RESULTS

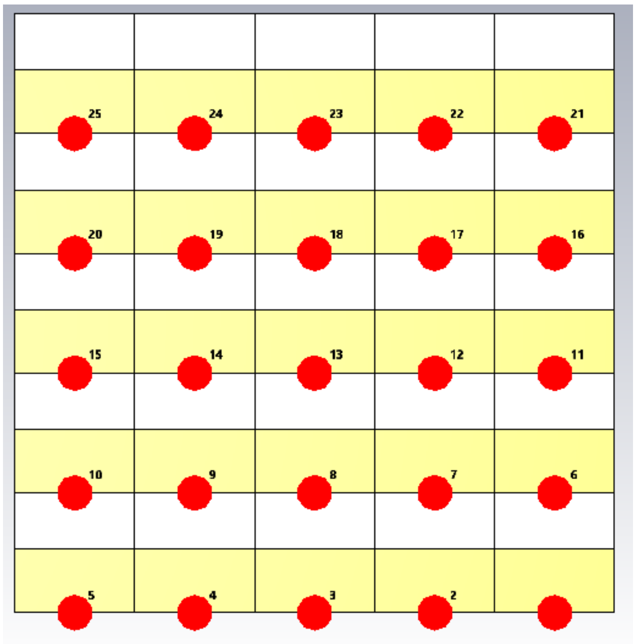
CST was utilized to analyze and improve both the MIMO and single element antenna designs. The antenna's working frequency is 37 GHz. The antenna’s performance is based on the following parameters.

A. *S-Parameter*

The s-parameter of the suggested antenna design is shown in Fig. 4. It is clear from looking at Fig. 4 that the antenna is working at 37.008 GHz. The measured bandwidth at -10dB is 1.8 GHz.



(a) Front view



(b) back view

Fig. 3. MIMO antenna design of the proposed antenna.

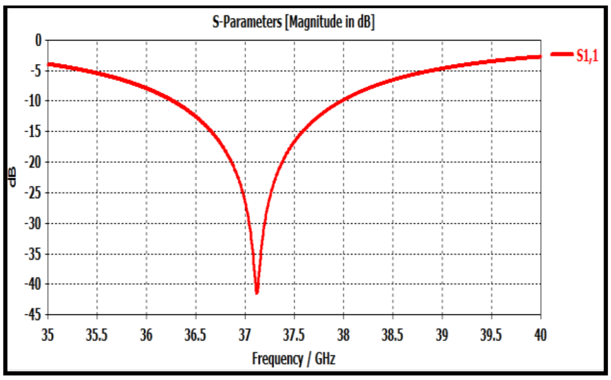


Fig. 4. Simulated S-Parameters

B. Radiation Patterns

The radiation pattern of the proposed antenna at 37 GHz are depicted in Fig. 5. It is noted that the angular breadth of the E-field and H-field at 3 dB is 46.3° in the 2D polar plot.

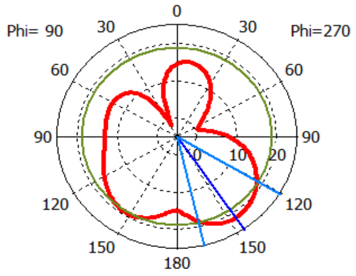


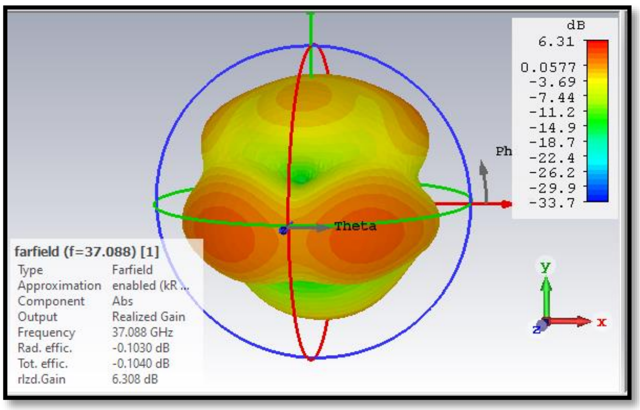
Fig. 5. 2D radiation pattern

C. Efficiency of single-element antenna

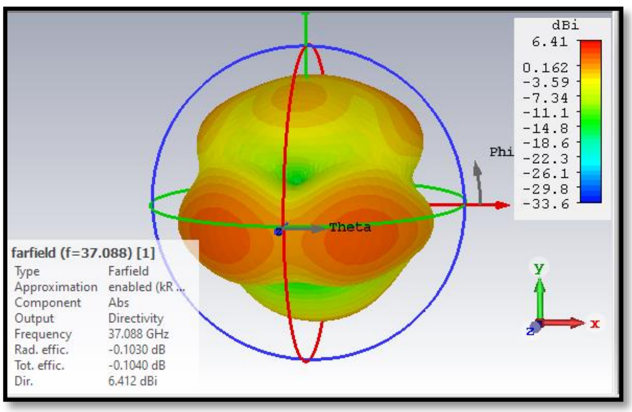
Efficiency is a metric used to describe how successfully an antenna tends to radiate when stimulation is supplied through a feedline. It ensures that the antenna is capable of great performance. The single element of the proposed antenna yields an efficiency of 97.63%. This demonstrates the excellent efficiency and practicality of antenna.

D. Gain and Directivity

The realized gain for the proposed antenna is 6.308 dB, and the directivity is 6.412 dBi. Figure 6 depicts the gain and directivity of the designed antenna.



(a) Gain at resonance



(b) Directivity at resonance

Fig. 6. Gain and directivity of the proposed antenna.

E. MIMO Antenna S-Parameters

The twenty-five elements MIMO are all working, when the first eight elements exhibit a drop below -10 dB. Fig. 7 depicts the reflection coefficient or return loss of a 5x5 MIMO antenna.

F. Gain and Efficiency of MIMO

Throughout the working spectral spectrum, each MIMO antenna component displays a distinct gain and efficiency value depending on the monitor being used. The suggested MIMO antenna's various gain and efficiency values are displayed in table II.

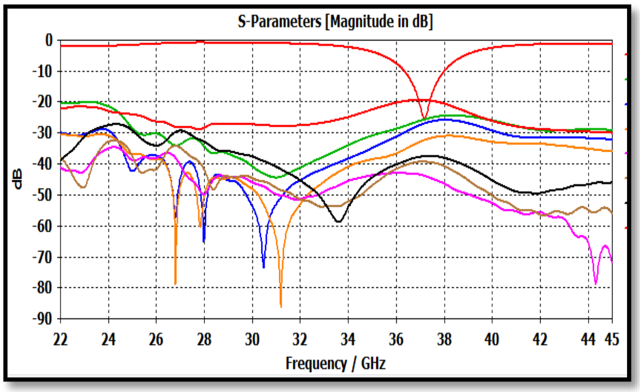


Fig. 7. Proposed MIMO antenna s-parameters

TABLE II. MIMO GAIN AND EFFICIENCY VALUES

Ant. #		Frequencies GHz					
		36.2	**36.5**	**36.8**	**37.1**	**37.4**	**38**
1	Gain (dB)	6.0	6.4	6.7	6.8	6.9	6.4
2		6.1	6.4	6.6	6.5	6.3	6.2
3		6.1	6.4	6.6	6.5	6.3	6.2
4		6.0	6.4	6.7	6.8	6.9	6.4
5		6.1	6.4	6.7	6.8	6.6	6.0
6		6.3	6.5	6.6	6.4	6.1	5.9
7		6.3	6.5	6.6	6.4	6.1	5.9
8		6.1	6.4	6.7	6.8	6.6	6.0
1	Efficiency (%)	83.9	89.6	93.7	95.5	94.8	86.2
2		82.7	88.3	92.4	94.6	94.2	86.2
3		82.7	88.3	92.4	94.6	94.2	86.2
4		83.9	89.6	93.7	95.5	94.8	86.2
5		88.2	92.8	95.4	95.3	92.8	81.5
6		87.2	91.8	94.5	94.8	92.6	82.0
7		87.2	91.8	94.5	94.5	92.6	82.0
8		88.2	92.8	95.4	95.3	92.8	81.5

IV. PERFORMANCE PARAMETER OF MIMO

For 5G, the FCC is taking steps to open more spectrum. Below is a discussion of some of the crucial MIMO factors that must be considered:

A. Envelope Corelation Coefficient

ECC determines the variation in radiation patterns between two nearby antennas. It considers the relative phase, polarization, and form of radiation patterns. Keep it to a minimum. ECC should fall between 0 and 1, with 0.5 being considered an acceptable number. The isolation between any two neighboring antennas is decreased when the ECC is above 0.5, and an ECC of less than 0.3 appears to be in good shape. For the proposed twenty-five element MIMO antenna operating at 37 GHz, the achieved ECC is depicted in Fig. 8.

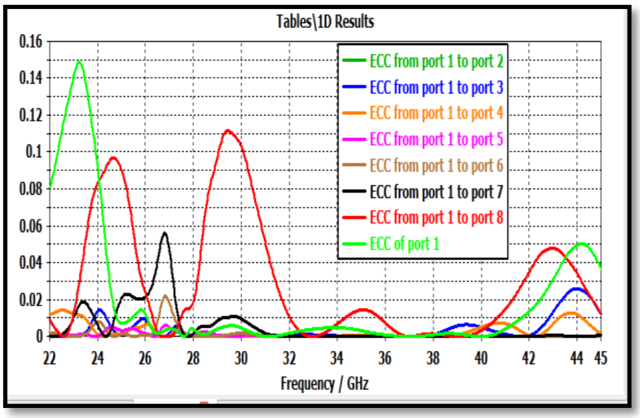


Fig. 8. ECC of first eight MIMO antenna

B. *Effective Diversity Gain (EDG)*

It determines how much better the MIMO antenna's SNR is than a single reference antenna. The following is the formula for determining a MIMO antenna's EDG:

$$EDG = \sum_{k=1}^{N} \frac{1}{K}$$

The EDG of a proposed MIMO antenna structure is presented in Fig. 9.

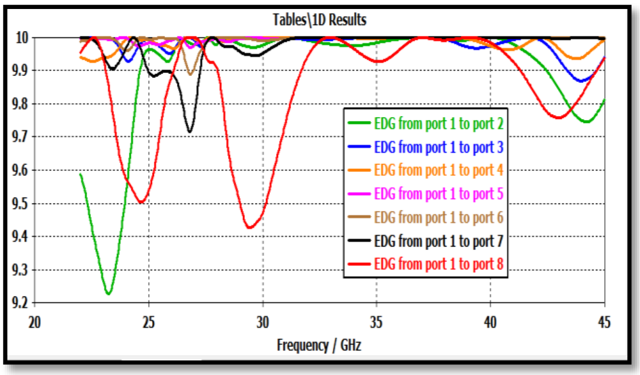


Fig. 9. EDG of first eight MIMO antenna

C. *Mean Effective Gain (MEG)*

It is used to measure an antenna's capacity to take in EM power in a multi-path environment (MIMO). Table III displays the MEG for the proposed antenna on each port. The same MEG measurements provide a reliable indication of both incident and receiving power. When the MEG ratio gets close to 1, the design is more effective, and the coupling is excessively strong.

TABLE III. MEG (-DB) OF ALL ANTENNAS

Ant.#	**Frequencies (GHz)**					
1	**36.2**	**36.5**	**36.8**	**37.1**	**37.4**	**38**
2	2.999	2.999	2.999	2.999	2.999	2.999
3	3.001	2.999	2.999	2.999	2.999	2.999
4	2.999	3.001	3.001	2.999	2.999	2.999
5	2.999	2.999	2.999	2.999	2.999	2.999
6	2.999	2.999	3.001	2.999	2.999	2.999
7	3.001	2.999	2.999	2.999	3.001	2.999
8	2.999	2.999	2.999	2.999	2.999	2.999

TABLE IV. COMPARISON WITH LITERATURE

Ref. paper	**Ports**	**Size (mm^2)**	**BW (GHz)**	**ECC**	**MEG**	**Isolation (-dB)**
[16]	6	100	1.6	0.007	-	17
[17]	2	1120	4.1	0.002	6.96	28
[18]	7	224	1.11	0.01	3.01	15
[19]	16	88	1.01	0.014	3.01	23
Proposed	25	2500	1.8	0.002	3.01	20

V. CONCLUSION

The suggested designs would improve MIMO antenna gain and efficiency while also enabling us to communicate over a larger bandwidth with reduced resource usage. The parameters are very significant since they provide us with operational information. MIMO antennas therefore appear to be a more realistic method for 5G communication. Single element antenna has a bandwidth of 1.8 GHz. The MIMO parameters, such as isolation (transmission coefficient), and ECC are 20 dB and 0.0002, that seems perfect for future generation applications.

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