

# DESIGN AND ANALYSIS OF SISO AND MIMO PATCH ANTENNA FOR 5G WIRELESS COMMUNICATION SYSTEMS.

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**ABSTRACT :** In order to improve the coverage area of the millimeter-wave frequency being used for this communication system, the 2×2 array microstrip patch antenna (MPA) design is proposed in this research for 5G wireless communication. Here, FR4-epoxy material is used as the substrate, and the Multi Input Multi Output feeding technique is applied to enhance the performance of the suggested design at a resonant frequency of 25 GHz has a 4.4 dielectric constant, and is 1.6, mm thick, we use it. According to the simulation analysis, the gain is 2.8 dB, while the return loss is -73.8 dB. Additionally, two MPA designs and the circular array MPA and the single element MPA are created to verify the suggested antenna design. Comparison research has demonstrated that the 2x2 rectangular array MPA is preferable for the 5G wireless communication system compared to the other two designs such as single element MPA and 2 2 circular array MPA.

## INTRODUCTION

Within this digital communication environment, communication has evolved quickly from telegraphy to wired, and then successfully sent and received radio frequency waves, which were first introduced by G.Marconi in 1901. Wireless communication is the result of this evolution, and it continues to advance due to its widespread use in daily life. Additionally, there were different versions of wireless communication to deal with: first generation (1G) was analogue transmission, and fourth generation (4G) was digital transmission based on internet protocol (IP).The generation that is currently using 4G connection is being used more and more frequently as a result of technological advancements. The 4G data speed is gradually decreasing during peak hours despite rising consumption, which complicates the data

sharing procedure for end users. The fifth generation (5G) of communication systems is anticipated by the digital communication environment as a result of this event, which is creating a significant need for systems that will handle high volumes of traffic in the future. The primary objective of this generation development is to achieve the following: user-enduring data at a speed of 100 Mb/s, area traffic capacity of 106 devices/km<sup>2</sup>, peak data rate of 20 Gb/s, latency of 1 ms, and forward compatibility for future evolution that is efficient. The 5G communication system is a part of a wireless communication ecosystem, not a stand-alone technology. Regarding this 5G, The main reason millimetre wave is recommended is because of its extraordinarily high frequencies, which range from over 30GHz to 300GHz.

Transmitter, receiver, and medium make up the fundamental communication system. Using a medium, radio frequencies are sent from transmitter to receiver in a communication system. Here, the term "antenna" refers to the transmitting or receiving instrument. As a result, the antenna is crucial to the wireless communication system. For antennas to function well, their designs must be acceptable for the uses for which they are intended. An antenna's parameters determine its performance. Although there are many characteristics, the most important ones for this task are radiation pattern, gain, return loss, VSWR, bandwidth. Gain is an important antenna parameter that describes the strength of radio frequency signals sent or received in a specific direction.

To find the ratio of the reflected frequencies to the applied frequencies, the antenna's return loss is determined. Consequently, an antenna's return loss value needs to be lower. The voltage standing wave ratio, or VSWR, is used to determine how well an antenna transmits radio frequency power. A good antenna design will have a VSWR value that is within the range of 1 to 2.

The range of frequencies that an antenna can effectively transmit or receive radio frequencies is measured by its bandwidth. For a good antenna, this also needs to be gotten as little as possible. The energy emitted by the antenna is represented by its radiation pattern.

## 1. DESIGN PARAMETERS OF PROPOSED MPA

Design parameters	Description	Optimized values for performance(m m)
$W_p$	Width of patch	22
$L_p$	Length of patch	22
$W_g$	Width of substrate and ground plane	24
$L_g$	Length of substrate and ground plan	24
$W_f$	Width of feed line	1.6
$L_f$	length of feed line	2

The obtained designing parameters are depicted in the table1.

The above-mentioned optimized values (table1) are applied for the microstrip patch antenna design to attain efficient results. The utilization of these parameters for the design of proposed microstrip patch antenna is described clearly in the following sections.

## 2. DESIGN AND ANALYSIS OF MPA

The design and analysis for the three types of microstrip patch antenna (MPA) such as Single element MPA, 2x2 rectangular array based MPA, and circular array based MPA are described in this section. The 2x2 rectangular based MPA can be used for 5G wireless communication. The whole design analysis process is conducted in High-Frequency Structure Simulation (HFSS) which is the platform of ANSYS software. The designed

antennas are validated by attaining the parameters such as Gain, Return loss, VSWR, and Bandwidth.

The parameter values of three MPA designs are compared to find the efficient antenna for the 5G wireless communication. The copper material with 0.0175mm is utilized for the patch and ground plane. The resonance frequency for these three-antenna designs is taken as 25GHz which is best for the 5G wireless communication.

### 2.1. Design of single element MPA

In this section, single element MPA is designed and validated by attaining the validation parameters such as Gain, returnloss, VSWR, and bandwidth. Single element antenna contains single patch and single feed line which are utilized as the transmitter or receiver. The antenna geometry is utilizing the optimized parameters for the single element MPA design. The figure1 shows the 2D design for the designed single element MPA and figure2 shows the 3D design for the single element MPA

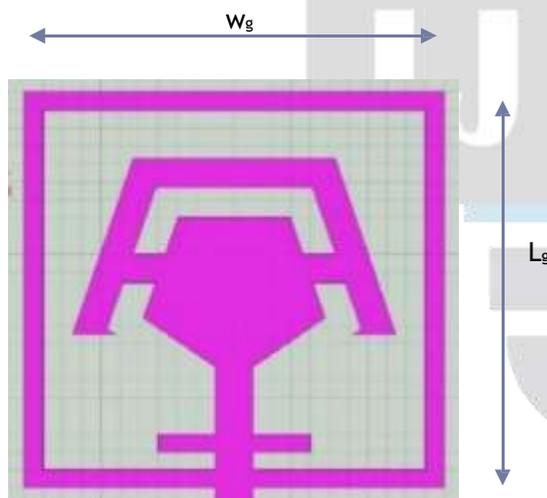


Fig.1 2D design of single element MPA

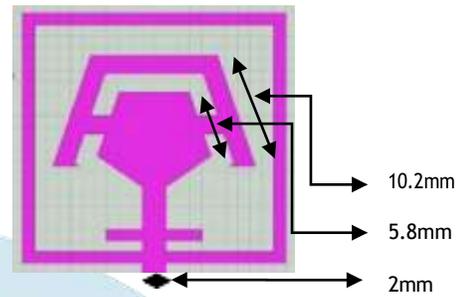


Fig.2 measurement of single element MPA

At first, the substrate is designed in the HFSS by utilizing the optimized design parameters and the property of the substrate is selected in the solids which are presented in the HFSS. Then the patch and feed line are designed as per the optimized parameters over the one side of the substrate and the other side is covered by the ground plane. Then port design is in appropriate location. Finally, the radiation box is designed with 24mm length, 24mmwidth, and 1.6mm height which are randomly selected. After the completion of design portion, the boundaries are assigned for the analysis process. Patch, feed line and ground plane are assigned as finite conductivity and the radiation box is assigned for the radiation boundary. The port is assigned as the model lumpedport excitations and the analysis setup is proceeded for the simulation process and this setup is called as sweep. Here, the frequency is set to 5GHz and the maximum number of passes is set as 21.

### 2.2. Design of 2x2 rectangular array

In this section, the structure of 2x2 rectangular array design for the microstrip patch antenna is designed and analyzed. The design parameters are patches, four ports and four feed lines. Here, MIMO design structure is implemented for this 2x2 rectangular array design. These patches and feed lines are located in 2x2 rectangular array formation over the substrate..

The radiation box is designed with 26mm length, 26mm width, and 3.6mm height. Here, two patches placed in nearby with 0 of rotation

and the other two patches are placed on top side of the located patches with the rotation of 90 as shown in figure3. In figure 4, measurement for 2x2 rectangular array MPA is shown.

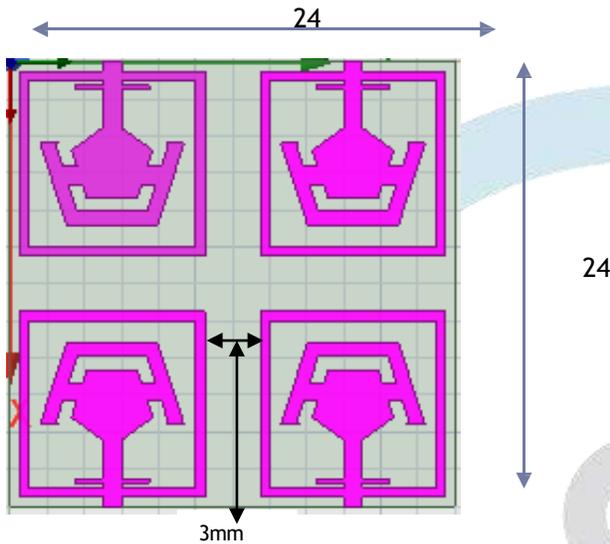


Fig.3 2D design for the 2x2 rectangular MPA array

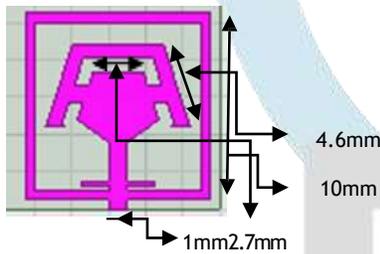


Fig.4.measurement for the 2x2 rectangular MPA array

Here, the design and analysis setup steps are similar to the single element MPA instead of the array steps. When designing the 2x2 rectangular array, the patches and feed lines are placed over the substrate as shown in figure 4.

### 2.3. Design of circular array MPA

This section describes the details about designing methods for the proposed circular array MPA. Here, also the same design parameters are used which are already utilized for the single element MPA and 2x2 rectangular array MPA. It

also has four patches, four feed lines, and four ports. The dimensions of the substrate and the ground is remaining similar as 2x2 rectangular array. The radiation box of the circular array MPA design is same as 2x2 rectangular array MPA. The patches are located as shown in figure 5 and the 3D view of the proposed circular array MPA is shown in figure 6.

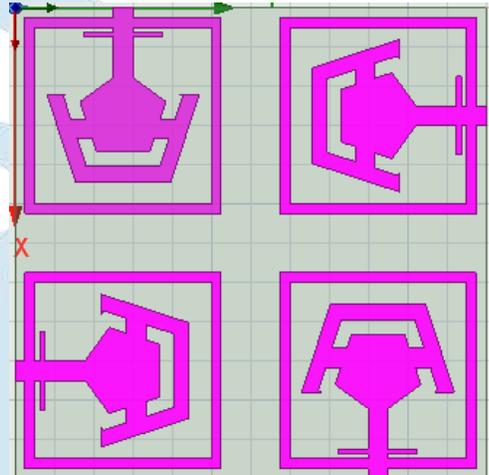


Fig.5. 2D design for the novel circular array MPA

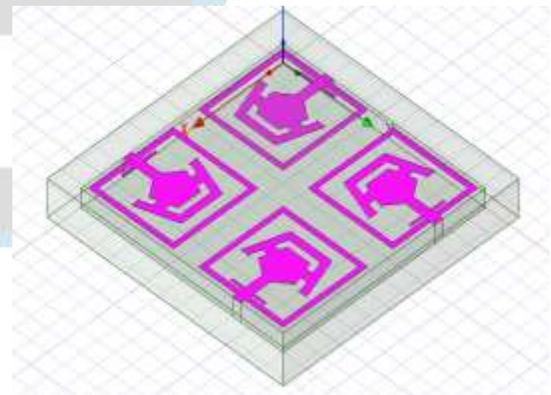


Fig.6. 3D design for the novel circular array MPA

The design of circular array structure is located over the substrate as shown in figure 5. The steps similar to the 2x2 rectangular array MPA. The MIMO design structure is

implemented and each patch is located in various angles of rotations such as 0, 90°, 180°, and 270°. Analysis setups are done as per the single element and 2x2 rectangular array MPA setups.

### 3. RESULTS AND DISCUSSION

#### 3.1. Performance analysis of single element MPA

In sweep setup, the distribution of the frequency is set as linear step and the start and end of the frequency range is set between 1GHz to 50GHz. At last, the single element MPA design is analyzed by running the simulation. The obtained results are showed in the table 2.

Table 2. The obtained results from the analysis of single element MPA

Resonance frequency (GHz)	Gain (dB)	Return loss (dB)	VSWR	Band width (GHz)	Radiation efficiency (abs)
15.5	1.9	-32.4	1.04	2(14.3-16.3GHz)	0.8124

From the table2, the obtained gain value for the single element MPA is 1.9dB, the return loss for the single element MPA is obtained as - 32.4dB, the VSWR value is 1.04, and the Bandwidth of the single element MPA obtained is 2GHz (14.3-16.3ghz).Theradiation efficiency is obtained in 0.812abs. Return loss graph is shown in figure 7. As shown in the figure single element MPA attained - 10dB return loss and 16.3GHz bandwidth.

#### Return Loss for single element MPA

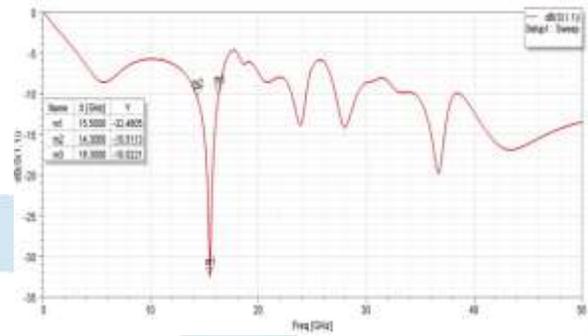


Fig 7. The rectangular plot for the Return Loss of the single element MPA

The VSWR graph for the single element MPA is shown in figure 8. As shown in the figure single element MPA attains 1.04dB VSWR.

#### VSWR for single element MPA

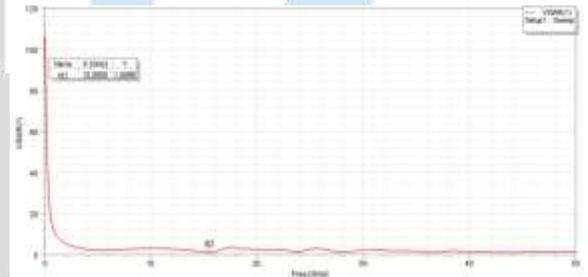


Fig 8. VSWR of the single element MPA

#### 3.2. Performance analysis of 2x2 rectangular array MPA

The analysis and sweep settings are setup same as single element MPA and each port of the patch has the same impedance value which was taken for single element MPA. Finally, the simulation is run for obtaining the results and the obtained results are tabulated in table 3

Table 3. The obtained results from the analysis of 2x2 rectangular array MPA

Resonance frequency (GHz)	Gain (dB)	Return loss (dB)	VSWR	Band width (GHz)	Radiation efficiency (abs)
25	2.6	-73.8	1.9	8.3(20.6-28.9)	0.814

From the table 3, the gain for the 2x2 rectangular array MPA is obtained as 2.6dB, the return loss is obtained as -73.85dB, the band width is attained as 8.3GHz (20.6-28.9GHz), the VSWR for this array obtained is 1.6 and the radiation efficiency of the designed 2x2 rectangular MPA array 1.02. The obtained return loss is plotted in figure 10. As shown in the figure, the 2x2 rectangular array MPA obtains -73.8dB return loss.

**Return Loss for 2x2 rectangular element MPA**

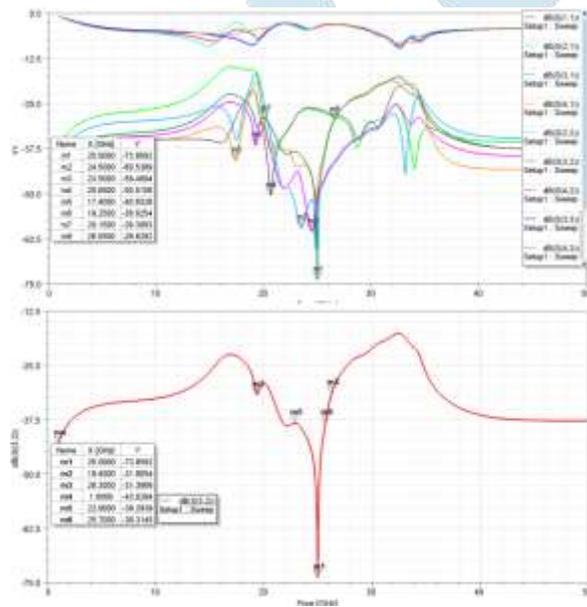


Fig 9. Return Loss of the 2x2 rectangular array MPA

**3.3. Performance analysis of the proposed circular array MPA**

The obtained values are tabulated in table 4

Resonance frequency (GHz)	Gain (dB)	Return loss (dB)	VSWR	Band width (GHz)	Radiation efficiency (abs)
24.7	2	-62.9	2	6.5(21.3-27.8)	0.75

From the table4, the gain obtained for the circular array MPA is 2dB, the return loss for this array structure is obtained as -62.9dB, The VSWR is maintained as 2, and the bandwidth is obtained as 6.5GHz (21.3-27.8GHz). The radiation efficiency also obtained in 0.75abs. The return loss is shown in figure14. As shown in the figure, the proposed circular array MPA attains -62.9.dB return loss.

**Return Loss for circular element MPA**

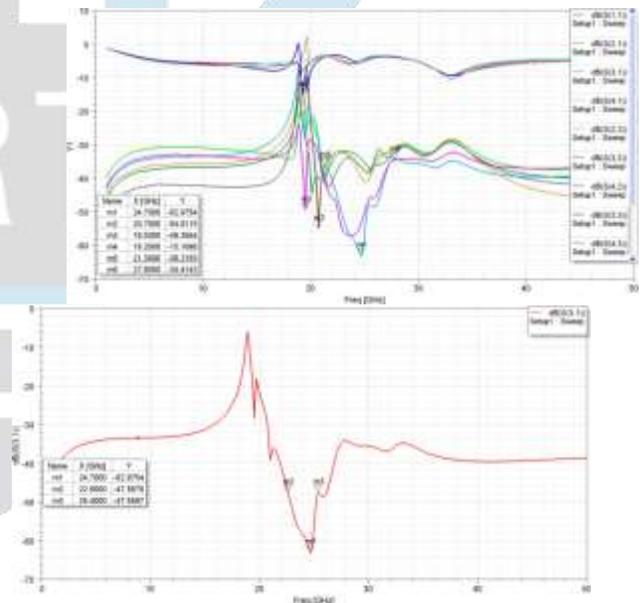


Fig10. the Return Loss of the proposed circular array MPA

### 3.4. Comparative Analysis

In this section, the comparative analysis is performed between three MPA design such as single element MPA, 2x2 rectangular array MPA, and proposed circular array MPA. Here, the parameters such as Gain, return loss, VSWR, bandwidth, and radiation efficiency of three MPA are compared, for all three MPA design,

14.3GHz to 28.9GHz frequency is utilized as the resonance frequency. Table 5 depicts the comparison of the antenna parameters for three different antenna structures. The 2x2 rectangular array MPA performs efficiently in Gain compared to the other designs and also has the lowest return loss. The VSWR attained is 2.

Table 5. The comparative analysis of three type of MPA

	Gain (dB)	Return loss (dB)	VSWR	BW (GHz)	Radiation efficiency (abs)
Single element MPA	1.9	-32.4	1.04	2	0.812
2X2 Rectangular array MPA	2.6	-73.8	1.9	8.3	0.814
circular array MPA	2.1	-62.9	2	6.5	0.815

From the table 5 it is also seen that the 2x2 rectangular array MPA has higher bandwidth (8.3GHz) compared to the other two MPA designs. All the three MPA designs have the same radiation efficiency with the value of 0.8abs. From the comparative analysis of the parameters such as Gain, return loss, VSWR, bandwidth, and radiation efficiency, the 2x2 rectangular array MPA is performing efficiently in overall when compared to the other two designs such as single element MPA and circular

array MPA. Therefore, the proposed 2x2 rectangular array MPA is more suitable and efficient MPA design for the 5G wireless communication.

### 4. CONCLUSION

Providing an effective microstrip patch antenna design for 5G wireless communication is the primary driving force behind this work. The ANSYS software platform, the HFSS, is used for the implementation process. Initially, the three MPA designs the proposed circular array MPA, the 2x2 rectangle array MPA, and the single element MPA are created in HFSS software using the suitable optimised parameters. The simulation is run to analyse these three MPA designs after the design portion is finished. In order to determine which MPA design performs the best for 5G wireless communication, the findings are compared and the performance of the three designs is examined. The suggested 2x2 rectangular array microstrip patch antenna design performs well in all aspects, including gain, VSWR, bandwidth, and radiation efficiency, according to the comparison analysis. For 5G wireless transmission, the suggested 2x2 rectangle array MPA is therefore the most desirable option. We intend to introduce a meta-heuristic algorithm for microstrip patch antenna design in the future.

### CONFLICTS OF INTEREST

No conflicts of interest are disclosed by the writers.

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