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MIMO 2X2 Patch Rectangular Antenna Design For Wifi 6 Application On 5GHz Band

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ABSTRACT

The development of wireless network technology, particularly WiFi 6 at 5GHz, offers greater reliability and data transfer capacity. Antenna design is a crucial aspect in optimizing WiFi 6 networks in complex wireless environments. The study examined a rectangular patch 2x2 MIMO Antenna for WiFi 6 at 5GHz with a focus on improving network parameters such as return loss, bandwidth, VSWR, and gain. The use of various methods and references from Balanis (2005) and Webster (2021) supports the development of antenna technology, while previous research by Ni Putu Kartika Dewi (2019) strengthens the understanding of microstrip antennas for LTE applications. The main objectives of the study were to design and simulate a rectangular patch 2x2 MIMO Antenna for WiFi 6, as well as analyze simulation data using CST Studio Suite 2019 software. This research uses hardware in the form of Acer Aspire laptops and CST Studio Suite 2019 as simulation software and antenna design. The simulation results show that this antenna is able to work in the frequency range of 4.5-5.2 GHz with a bandwidth of 55.4 MHz and return loss of -20.677981 dB, VSWR 1.2038357, and gain 3.429 dBi with omnidirectional radiation patterns. However, the addition of antenna patches has an impact on decreasing gain. This study provides an in-depth understanding of MIMO antenna design to support WiFi 6 performance in complex wireless environments.

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1. INTRODUCTION

The development of wireless communication technology has become the main foundation in supporting faster and reliable connectivity. One of the most important evolutions is WiFi 6 networking technology, designed to address the need for better connectivity, especially in usage-heavy environments.WiFi 6 technology operates at a frequency of 5GHz and offers higher data transfer rates, better reliability, and greater network capacity compared to its predecessor. Antenna design plays a very important role in supporting the optimal performance of WiFi 6 networks in complex wireless environments.

MIMO (Multiple Input Multiple Output) is an antenna system built with many antennas on the transmitter and receiver sides, where the information sent can be sent and received by several antennas simultaneously. This antenna has an important role in transferring high-speed data, namely this 5G technology, which requires a high data rate. This is because the ability of MIMO antennas is also very good at reducing multipathfading depending on the number of antennas used. [1]

There are several methods in increasing MIMO antenna gain such as the use of high frequency can produce high gain, besides that the use of substrates that work at high frequencies is relatively expensive. In addition to the use of substrate parasitic radiators by adjusting the distance between substrateparasitic and substrateantenna MIMO to obtain the greatest increase in gain, this method has been widely used. [2] One of the main equipment used in telecommunications is antennas. According to C. A. Balanis (2016) A microstrip antenna is an antenna consisting of very thin radiation elements (conductors) placed on the ground plane where between the fields with radiation elements (conductors) are separated by substratedielectrics. [2]

The study designed a system to remotely monitor television transmitting devices. The system uses LoRa technology for data transmission and MQTT protocol for security. Sensor nodes are capable of communicating over a distance of more than 500 meters. Environmental conditions do not significantly affect the voltage and current of the device. The voltage of the device works at an average value of 4.8V and the current at 0.34A. Environmental conditions affect data communication, with signals reaching -61 dBm. Sensor data can be displayed in real-time on monitoring websites. [4]

In a previous study by Ni Putu Kartika Dewi (2019) conducted research on a 4-element dipole microstrip antenna for LTE applications. The study produced an antenna with a bandwidth of 600 MHz, a return loss of -27,685 dB and a gain of 6.81 dBi with an omnidirectional radiation pattern. MIMO antenna is an antenna consisting of several antenna elements with each antenna element having a transmitter and receiver. [4] The antenna elements on MIMO antennas are placed in a specific arrangement to produce a stronger and more stable signal. MIMO antennas are used in WiFi systems to increase throughput and signal stability on WiFi networks. MIMO antenna is a popular antenna technology used in wireless communication systems, including WiFi. MIMO antenna technology can produce antennas that are lightweight, thin, and have stable radiation patterns. Therefore, in this study, a MIMO antenna will be designed using MIMO (Multy Input Multy Output) 2x2 rectangular patch antenna technology for WiFi 6. [3]The antenna will be designed to meet the characteristics required to support WiFi 6 network performance.

2. LITERATURE REVIEW

Beberapa penelitian sebelumnya juga telah dilakukan menggunakan teknologi antena *Microstrip* dan MIMO pada sistem WiFi dan teknologi nirkabel lainnya. Alqadami, A. S., Saeed, S. M., & Al-Nidawi, M. M. (2021). *Design of Dual-Band* MIMO *Antena Basedon Sierpinski Carpet Fractal for Wireless Applications*. Merancang antena MIMO *dual-band* berbasis *fractal Sierpinski Carpet* untuk aplikasi nirkabel. Hasil penelitian menunjukkan bahwa antena MIMO berbasis *fractal* dapat meningkatkan performa sistem nirkabel pada berbagai frekuensi. [2]

Ahmed, R., Rasheed, T., &; Abbas, S. (2021). Multi-Band MIMO Antenna for WLAN, Bluetooth, and WiMAX Applications. Design multi-band MIMO antennas for WLAN, Bluetooth, and WiMAX applications. The results showed that multi-band MIMO antennas can improve network throughput and performance on wireless systems. [6] Hassanein, H., Aziz, M. A., &; Abdalla, M. (2020). Design and Performance of Microstrip Antenna Array for 5G Communication. Designing Microstrip array antennas for 5G communication. The results showed that Microstrip array antennas can improve signal performance on 5G networks. [2]

Mochamad Rizal Sumpena, Hanny Madiawati, Elisma (2020). 4x2 Rectangular Patch Microstrip Stacking Antenna Design For 5G Applications. Designing 4x2 Rectangular Patch Microstrip Stacking antennas For 5G Applications. The results showed that changes in the width and length of the microstrip antenna patch had an effect on the mid-frequency shift. When the width and length of the patch are enlarged, the center frequency will shift to the left or shrink and vice versa. [7] Asri Wulandari, Riski Martha Fitriani and Fadli Kurniawan (2017). Design a 2x2 MIMO Microstrip Antenna For 802.11n WiFi Applications at 2.4 GHZ Frequency. Designed a 2x2 MIMO microstrip antenna for WiFi at a frequency of 2.4 GHz. A 2x2 MIMO Microstrip Antenna can perform well compared to a Default Dipole Antenna based on the results of signal level and data transfer rate tests. [8]

3. METHOD

The research methods used are:

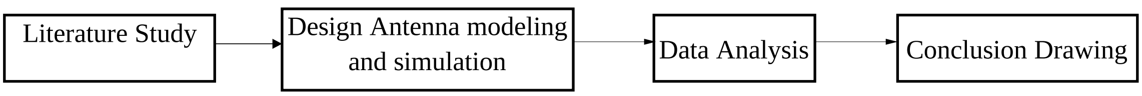

Figure 1. Stages of Research

The literature study in figure 1 of this final project begins by collecting literature related to the title of the final project used as a reference. Literature refers to journals both national and international, internet media, books related to research, and articles that can support theoretically the problems raised. References are needed to know the concept of microstrip antennas, types of substrates and patches used in design. The design of a 2-patch MIMO antenna begins with determining the type of substrate, and the thickness of the dielectric material. Then determine the dimensions of the microstrip antenna with a formula that has been obtained from previous studies to be systematic. Design is assisted by using simulator software.

After the antenna optimization has been designed, the next step is to analyze and discuss the parameters set with simulation results obtained from antenna optimization. Conclusions and suggestions from the study were obtained based on analysis and discussion that had been carried out based on data from the results of microstrip antenna simulations that had been designed. The steps to design an antenna with CST Studio Suite software can be seen in figure 2:

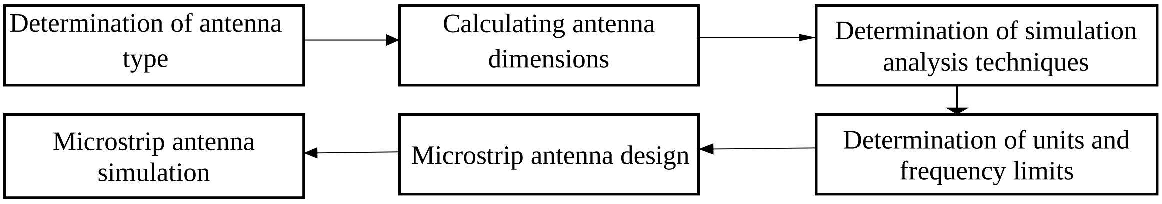

Figure 2. CST Studio Suite Antenna Design

Briefly can be seen in the following flow chart:

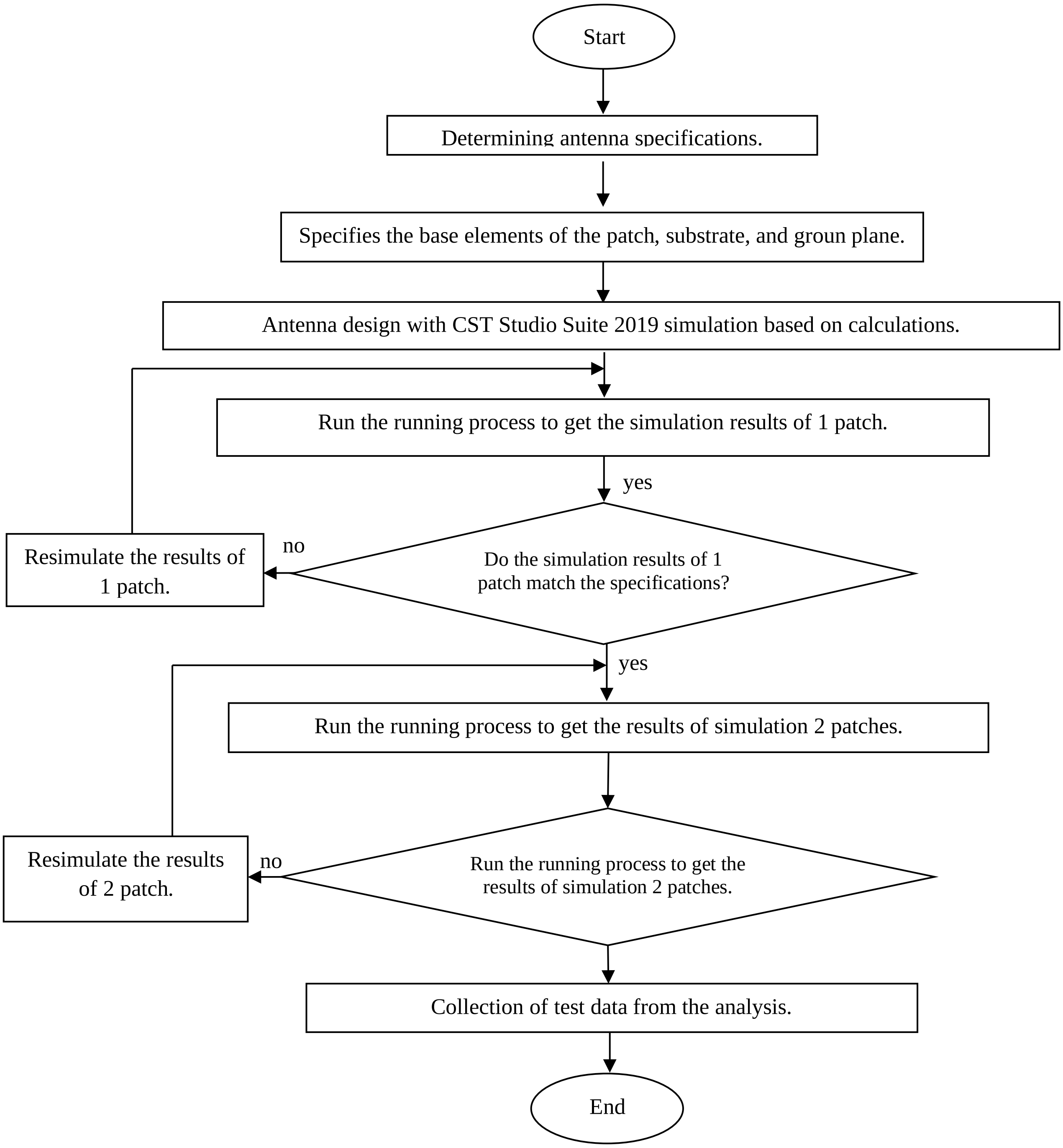

Figure 3. Designing Antenna Flowchart

As stated in the flow chart in Figure 3, then antenna type determination is the process of determining the type of antenna to be made. Antennas have various types, for example MIMO antennas, aperture antennas, and microstrip antennas. Next we calculate antenna dimensions is the process of determining antenna dimensions through formulas or calculations that match the formula that has been obtained in theory, making it easier to determine the area of the antenna dimensions. After calculating the dimensions of the antenna according to the formula, then the determination of the analysis technique is the process of determining the analysis to be used to simulate. There are 3 types of analysis, namely analysis based on period and frequency. Analysis by period for antennas that have a wide bandwidth or work at multiple frequencies. Then the determination of the unit and working frequency is the process of determining the unit of each antenna parameter to be made, and determining the working frequency limit to be used for the display of antenna simulation results. The last thing to do is the microstrip antenna design has stages, namely: making a substrate, determining the type of material and dimensions will affect the results of antenna simulation.

4. RESULTS AND DISCUSSION

After determining and taking into account several parameters to design a rectangular patch 2x2 MIMO antenna antenna, proceed with design and simulation using CST Studio Suite 2019 software. Visualization in the form of three-dimensional images with specifications of size, type of material, and size of the appropriate ground plane to be simulated with the type of material in accordance with specifications, such as copper for patches. Antenna design at CST Studio Suite 2019.

4.1 Parameter Results For Single Rectangular Patch MIMO Antenna Design Based On Calculations

Before optimizing using two rectangular patches, the appropriate parameters are needed for one rectangular patch first. The first step is to design the shape of a single rectangular patch antenna, according to the calculation of antenna dimensions and the type of material that has been determined. After the antenna design is complete, the next step is to run the program. Running program is needed to get simulation results from the antenna that has been designed, if the simulation results do not meet the antenna specifications that have been determined then it is necessary to optimize the antenna design. The following is the design result of a single rectangular patch antenna based on calculations.

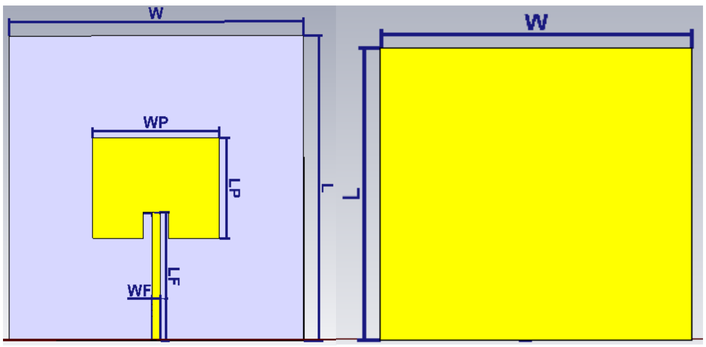

Figure 4. (a) Front View (b) Rear view

Table 1. Rectangular Single Patch Antenna Parameters Based On Calculation

Parameters	Size (mm)
W (substrate width)	25.715
L (substrate length)	25.715
Lp (patch length)	14.29
Wp (patch width)	15.20
G (gap)	0.2358
Wf (feedline width)	0.9
Lf (feedline length)	5.711
Ground Plane	12

Antennas with dimensions that have been calculated first in Table 1, then simulated using CST Studio Suite 2019 software. In this antenna the frequency is at 4.7484-4.9372 GHz based on a return loss value equal to -10 dB. So that the antenna has not entered the frequency range of 2.4 or 5 GHz. This antenna has a middle frequency at 4.84 GHz.

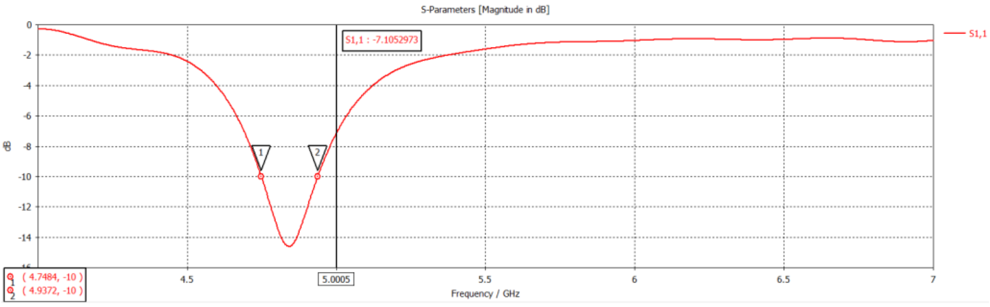

Figure 5. Return loss Antenna One Patch Rectangular Based On Calculation

The return loss value in figure 5 shows antenna 1 rectangular patch at a frequency of 2.45 GHz, which is –7.4705 dB. The value does not meet the expected parameter of ≤ -10 dB.

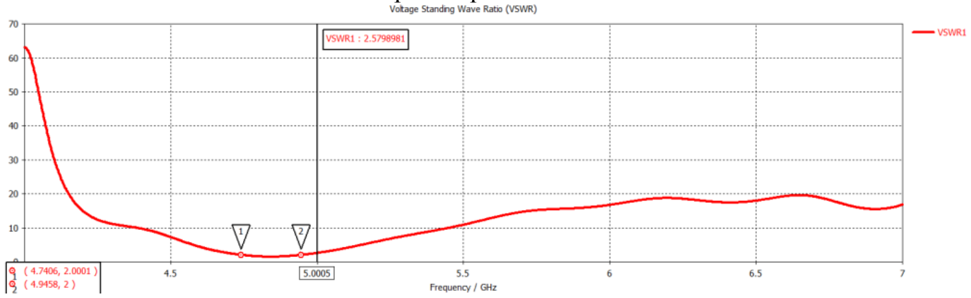

Figure 6. VSWR Rectangular Single Patch Antenna Based On Calculation

Figure 6 shows that the VSWR value of a single patch antenna is based on calculations with a patch length of 14.29mm for a frequency of 5 GHz which is 2.579. This value does not meet the requirements of the antenna parameter, namely VSWR ≤2.

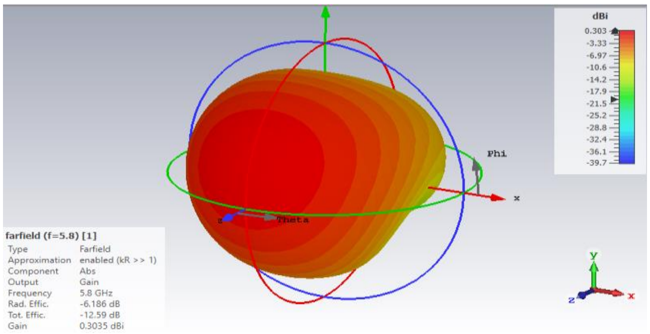

Figure 7. Antenna Gain One Patch Rectangular Calculation

Antenna gain results based on IEEE Gain from CST Studio Suite software for one patch can be seen in Figure 7, with a value of 0.3035 dBi. The result is very small, not meeting the antenna gain parameter of >2 dBi.

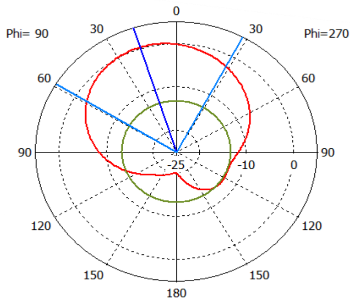

Figure 8. Radiation Pattern One Rectangular Patch Antenna

For the radiation pattern of the rectangular patch MIMO antenna shown in Figure 8, the radiation pattern produced by the patch is omnidirectional, where the radiant pattern points in all directions.

Table 2. Preliminary Simulation Results

Parameters Antenna	Desired Specifications	Initial Simulation
VSWR	≤2	2.579
Return loss	≤ -10 dB	- 7.4705
Gain	>2 dB	0.3035
Bandwidth	≥ 100 Mhz	188.8
Pola Radiasi	Omnidirectional	Omnidirectional

This antenna can be known that the return loss, VSWR, and gain values for the 14.29mm patch length frequency have not met the 5 GHz frequency. So it needs to be optimized. Optimization is done by adjusting the size of the patch length, patch width, gap (patch distance from one another), and ground plane.

4.2 Parameter Results For Single Rectangular Patch MIMO Antenna Design Based On Optimization

Based on the results of the design of a single patch antenna with a patch size of 14.29 mm, it can be seen that the center frequency of the antenna is not in accordance with the desired parameters, namely the range between 4.6-5.2 GHz so it needs to be optimized. Optimization was carried out based on variations in patch length used measuring 11.28 mm to 16.29 mm to determine the effect of patch length on the center frequency. In addition, optimization is made to the best patch width and ground plane height. For variations the patch width values are 10.2 mm, 11.2 mm, 12.2 mm, 13.2 mm, 14.2 mm, 15.2 mm, 15.8 mm, 15.9 mm, 16 mm, 16.1 mm, 16.2 mm and 17.2 mm. The value variants for groundplane height used are 0, 0.715 mm, 5.715 mm, 10.715 mm, 15.715 mm, 20.715 mm and 25.715 mm. The following graph of Return loss and VSWR results sequentially against patch length can be seen in Figure 9 and Figure 10.

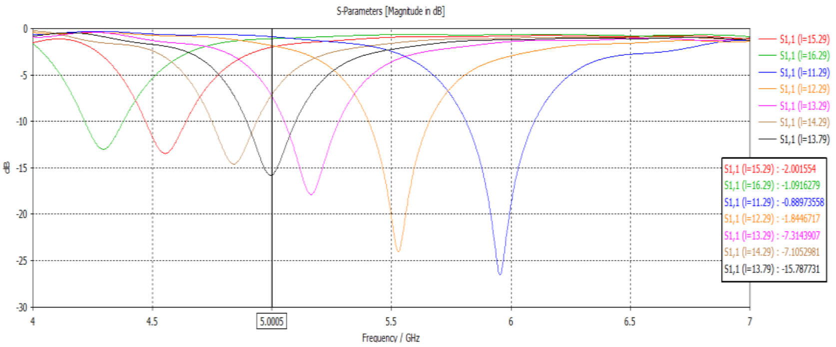

Figure 9. Rectangular Patch Length (Lp) Comparison Graph to Return loss Value

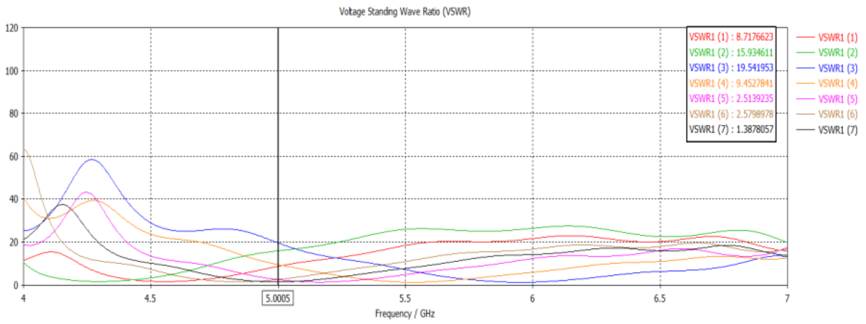

Figure 10. Rectangular Patch Length (Lp) Comparison Graph against VSWR

Figure 9 and Figure 10 show that all patch lengths (lp) that have been entered are qualified, but the best return loss value (return loss value ≤ -10) lies at a patch length of 13.79 mm which is -15.788 dB and VSWR of 1.3878. With the trial-error method, the author can find out the best patch length, which is 13.79 mm.For the results of patch width variations based on return loss and VSWR values can be seen in Figure 10 and Figure 11.

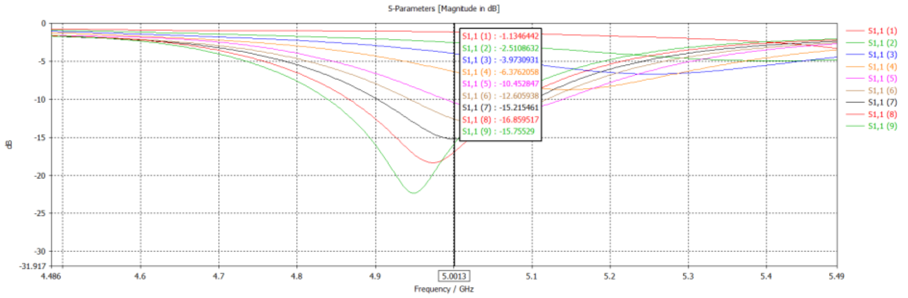

Figure 11. Rectangular (Wp) Patch Width Comparison Graph to Return loss Value

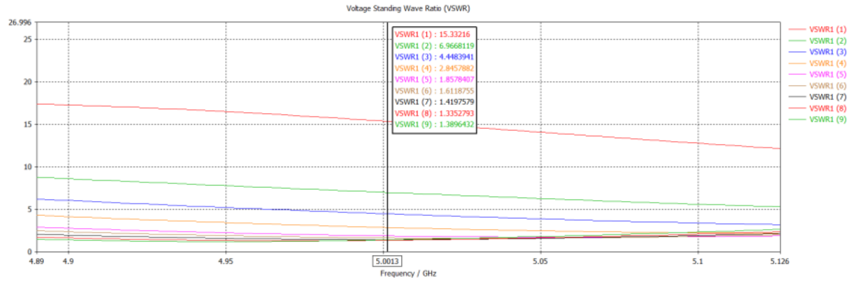

Figure 12. Rectangular (Wp) to VSWR Patch Width Comparison Graph

Based on Figure 11 and Figure 12 it can be seen that, for the width of the patch (Wp) that has met the parameters, namely at Wp equal to 16 mm. The best return loss value (return loss value ≤ -10) lies in a patch width of 16 mm, which is -16.9321 dB and VSWR of 1.332.This graph can be seen that the greater the width of the patch used, the value of return loss and VSWR increases significantly. For the results of ground plane height variations based on return loss and VSWR values can be seen in Figure 12 and Figure 13.

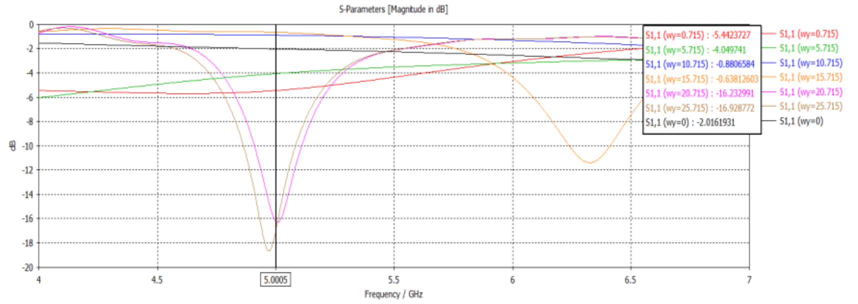

Figure 13. Comparison of Ground Plane Height to Return loss Value

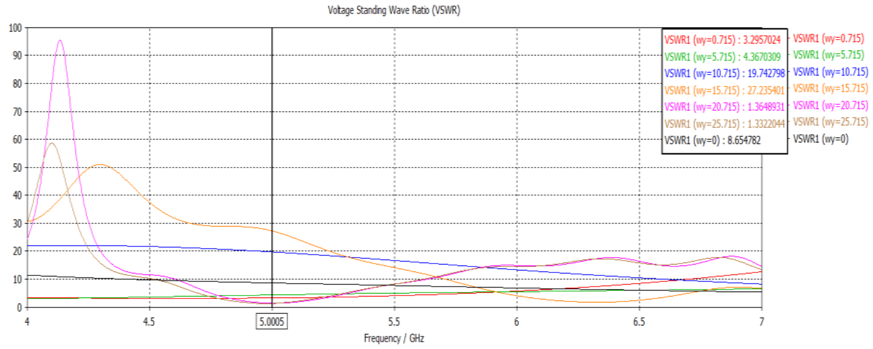

Figure 14. Comparison of Ground plane height to ReturnLoss value

Figure 13 and Figure 14 show a graph comparing ground plane height (g) to return loss and VSWR values. The best return loss value (return loss value ≤ -10) lies in the ground plane width of 25.715 mm which is -16.9877 dB and VSWR of 25.715. After optimization of antenna design in CST software, the results of return loss, VSWR, gain, and radiation patterns are shown in Figure 11, Figure 12, Figure 13, and Figure 14. The following parameters have been optimized.

Table 3. MIMO Antenna Parameters One Patch after Optimization

Parameter	**Ukuran (mm)**
W (substrate width)	25.715
L (substrate length)	25.715
Lp (patch length)	13.79
Wp (patch width)	16
g (gap)	0.2358
Wf (feedline width)	0.9
Lf (feedline length)	5.711
Ground Plane	25.715

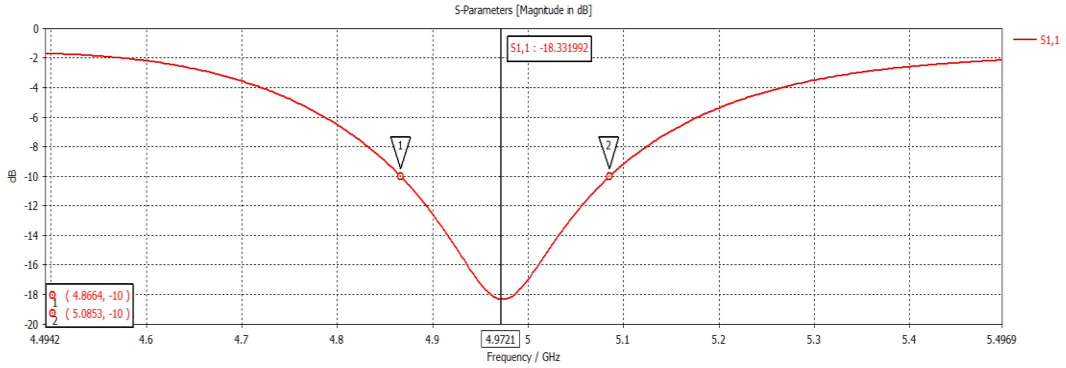

Figure 15. Single Rectangular Patch Return loss Results After Optimization

$$f_c = \frac{f_2 + f_1}{2} = \frac{5.0853 + 4.8664}{2} = 4.97585\ GHz$$

$$BW = f_2 - f_1 = 5.0853 - 4.8664 = 0.2189\ GHz = 218.9\ MHz$$

Figure 15 shows that the return loss results of one patch antenna after being optimized with a frequency of 4.97 GHz, which is -18.3319 dB. The return loss results are in accordance with the requirements of the antenna design parameters, which are less than -10 dB. The middle frequency and bandwidth are generated respectively at 4.97585 GHz, and bandwidth 218.9 MHz.

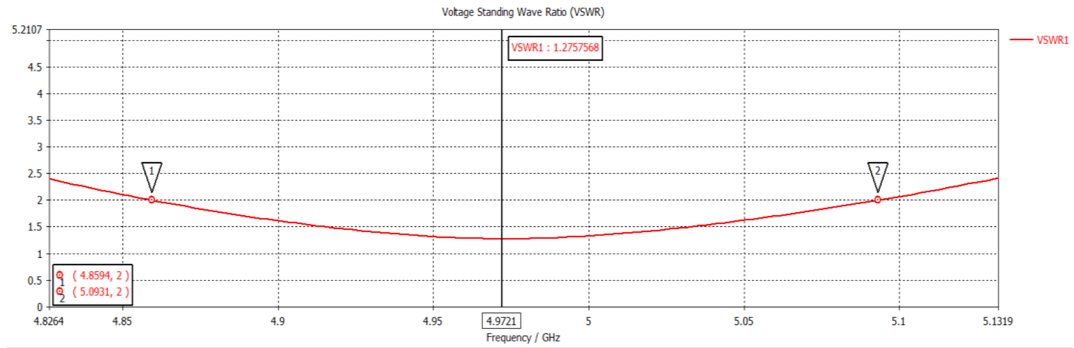

Figure 16. VSWR Results One Rectangular Patch After Optimization

Figure 16 VSWR value of a single patch MIMO antenna after optimization shows a figure of 1.2757. The VSWR results have met the requirements of the antenna design parameter, which is <2. The VSWR value has approached 1 which is 1.2757, that the VSWR value will indicate the input impedance against the feeder there is no reflection when the channel is in a perfect matching state.

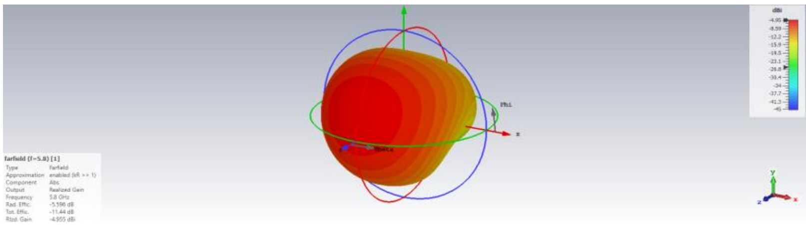

Figure 17. Single Rectangular Patch Gain Results After Optimization

Antenna gain results based on IEEE Gain from CST Studio Suite software for one patch can be seen in figure 17, with a value of 4,955 dBi. The results are small, not meeting the antenna gain parameter of >2 dBi. To increase the gain value, the antenna is designed by increasing the number of antenna patches.

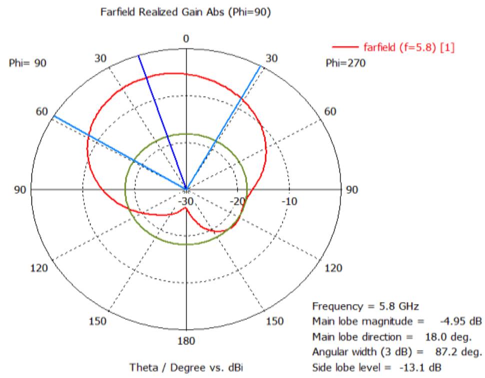

Figure 18. Results of Radiation Patterns After Optimization

For the radiation pattern of the MIMO antenna one patch after optimization shown in figure 18, that the radiation pattern produced by the patch is omnidirectional, where the radiant pattern points in all directions. The resulting radiation pattern is in accordance with the requirements of the predetermined antenna design parameters. Table 4 shows a comparison of return loss, VSWR, and antenna gain results one patch before optimization and after optimization. As the table below:

Table 4. Results of One Patch Rectangular Antenna Parameters Calculation and Optimization

Calculation			**Optimization**		
Return loss (dB)	VSWR	Gain (dBi)	Return loss (dB)	VSWR	Gain (dBi)
- 7.4705	2.579	0.3035	-18.3319	1.2757	4.955

4.3 Two Patch Rectangular MIMO Antenna Design

Once a one-patch MIMO antenna has been optimized, then a two-patch antenna can be designed. The function of impedance matching so that the input impedance matches the output impedance, in addition to maximizing the sending power from source to load, and minimizing losses (friction current in copper) in the channel. Here is the design of the two rectangular patch antennas showing the front and rear views shown in Figure 19 and Figure 20.

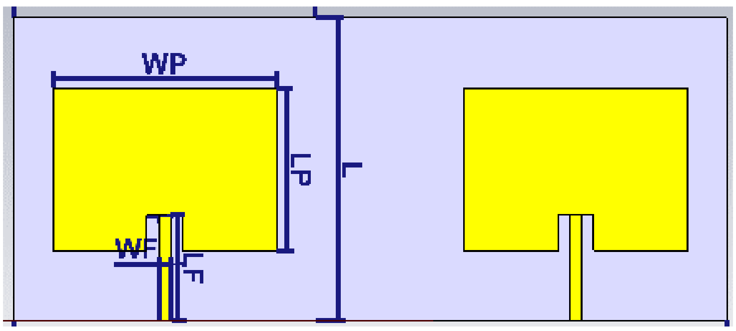

Figure 19. Front View MIMO Antenna Two Patch Rectangular

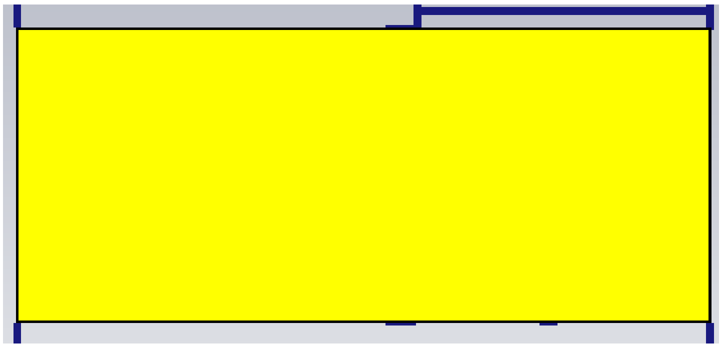

Figure 20. Rear View MIMO Antenna Two Patch Rectangular

Table 5. Two Patch MIMO Antenna Parameters

Parameters	Ukuran (mm)
W (substrate width)	35
L (substrate length)	60.72
Lp (longpatch)	13.79
Wp (patch width)	18
G (gap)	1
W1 (feedline width 50 Ω)	0.9
L1 (Feedline length 50 Ω)	5.711
d (Patch Antenna Spacing)	12
hgp (Ground Plane Height)	19.715

The size of the dipole patch length (lp) on a two-patch MIMO antenna has a significant increase in patch length on a single-patch MIMO antenna. The length of the single patch has been optimized from 13.79 mm to 11 mm. This is due to the addition of ground plane height, and so on.

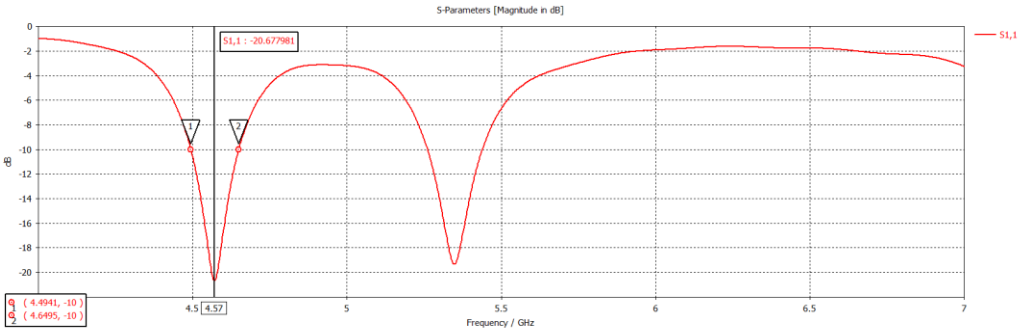

Figure 21. Return loss results of Two Rectangular Patches

$$f_c = \frac{f_2 + f_1}{2} = \frac{4.6495 + 4.4941}{2} = 4.5718\ GHz$$

$$BW = f_2 - f_1 = 4.6495 - 4.4941 = 0.1554\ GHz = 155.4\ MHz$$

Figure 21 shows that the antenna return loss results two patches after being simulated. The return loss results are in accordance with the requirements of the antenna design parameters, which are less than -10 dB with a frequency range from 4.5-5.2 GHz, including in the 5 GHz range. The middle frequency and bandwidth are produced sequentially which is 4.57 GHz with a return loss result of -20.677981 dB with a bandwidth of 55.4 MHz.

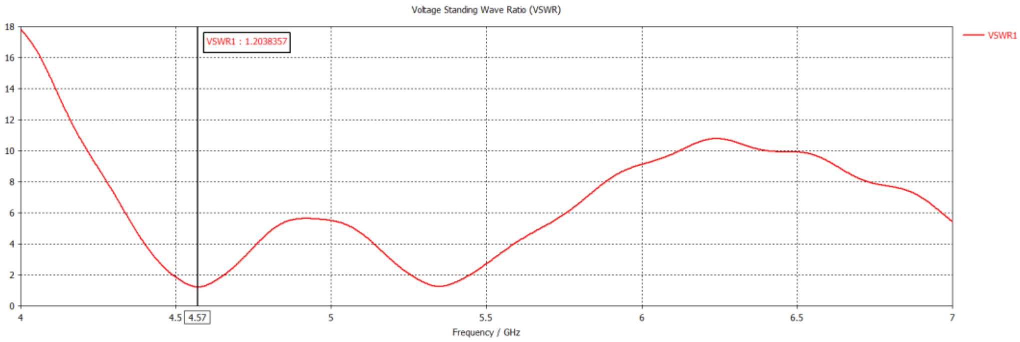

Figure 22. VSWR Results of Two Rectangular Patch MIMO Antenna

Figure 22 shows the VSWR value of a two-patch MIMO antenna after optimization with a center frequency of 4.57 GHz which is 1.2038357. The VSWR results have met the requirements of the antenna design parameters, namely VSWR <2.

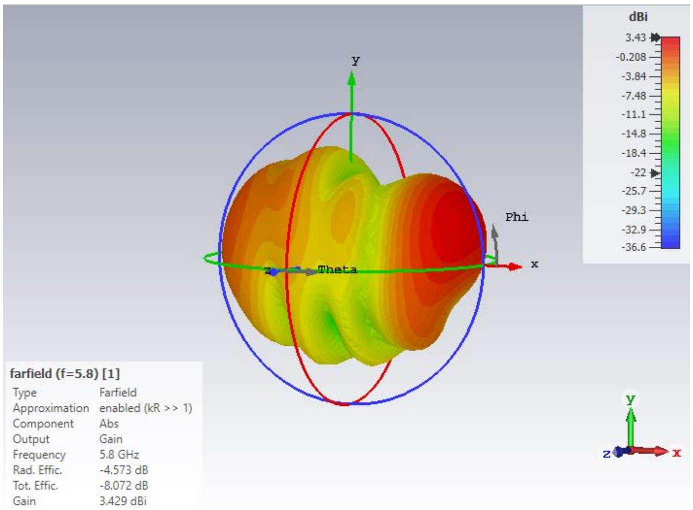

Figure 23. Two Patch Rectangular MIMO Antenna Gain

Antenna gain results based on IEEE Gain from CST Studio Suite software for two MIMO patches can be seen in Figure 23. The 3D result shows a gain value of 3,429 dBi. The two-patch MIMO antenna gain result meets the design requirements of the antenna gain parameter, which is >2 dBi.

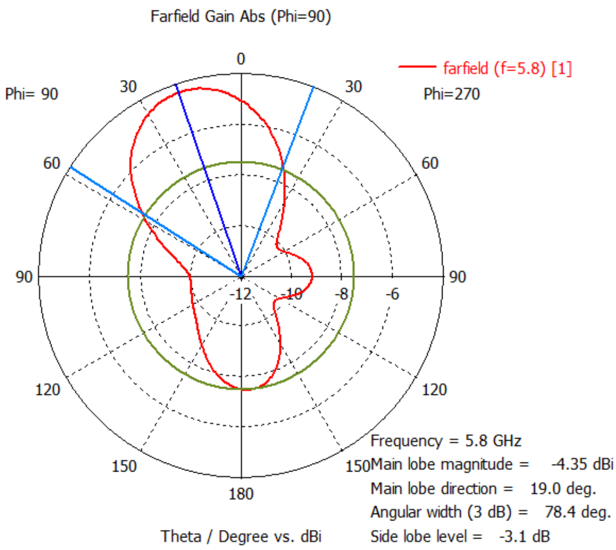

Figure 24. Two Patch Rectangular MIMO Antenna Radiation Pattern

For the radiation pattern of the two-patch MIMO antenna after restimulation it is shown in Figure 24, that the radiation pattern produced by elevation is omnidirectional, where the radiant pattern is pointing in all directions. The resulting radiation pattern is in accordance with the requirements of the predetermined antenna design parameters.

Table 6. Results of Two Patch MIMO Antenna Parameters

Parameters	Result
Return loss (dB)	-20.677981dB
VSWR	1.2038357
Gain (IEEE) (dBi)	3.429 dBi
Middle Frequency (GHz)	4.57 GHz
Frequency Range (GHz)	4.5 – 5.2 GHz
Bandwidth (MHz)	55.4 MHz
Radiation Patterns	Omnidirectional

5. CONCLUSION

Based on the results of the design, simulation process and repeating simulation, it can be concluded that the rectangular patch 2x2 MIMO antenna that has been designed is able to work at a frequency of 4.5-5.2 GHz with a bandwidth of 55.4 MHz with a middle frequency of 4.57 GHz which has a return loss of -20.677981 dB, VSWR is 1.2038357, gain 3.429 dBi, and Omnidirectional radiation patterns. The antenna has a patch length of 15 mm with total antenna dimensions of 99.71x35x1.64 mm^3 . The increase in the number of antenna patches affects the increase in gain. Like the 2x2 MIMO antenna, the rectangular patch has a gain of 3,429 dBi, smaller than that of a single patch which has a gain of 4,955 dBi.

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