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Design and Implementation of a Shined Length Periodic Microstrip Antena for 2.4 GHz and 5.8 GHz Double Wi-Fi

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***Abstract*-- This research aims to design and implement a twin slit rectangular microstrip antenna for 2.4 GHz and 5.8 GHz dual-band Wi-Fi using CST Studio Suite 2019 software and in antenna measurements using a Vector Network Analyzer. Some of the antenna parameters produced are return loss, bandwidth, VSWR, radiation pattern, and gain. This antenna has an antenna size of 45 x 53 mm. The antenna is designed based on the characteristics of several antenna parameters, namely having a return loss ≤-10 dB gain value ≥1 dB, and VSWR ≤2. The type of substrate used is FR-4 (lossy) with a dielectric constant specification of 4.3, a characteristic impedance of 50 ohms, and a thickness of 1.6 mm. The ground plane material used is copper with a thickness of 0.035 mm. The microstrip antenna parameter optimization results are in the form of a return loss of -13.64 dB with a frequency of 2.4 GHz and -30.40 dB with a frequency of 5.8 GHz, VSWR values of 4.38 with a frequency of 2.4 GHz and 5.45 with a frequency of 5.8 GHz and have unidirectional pola radiation. In comparison, the return loss value of the fabricated antenna is obtained at -4.52 dB at a frequency of 2.5 GHz and -6.32 dB at a frequency of 5.8 GHz. VSWR values of 4.38 at a frequency of 2.4 GHz and 5.45 at a frequency of 5.8 GHz.**

***Keywords*-- Microstrip Antenna; Wi-Fi; Return Loss; Bandwidth; VSWR; Polaradiation; and Gain.**

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I. Introduction

Telecommunication is very important at this time, the era of information technology now demands fast, real-time communication, anywhere and anytime. The wireless communication system is a communication system with transmission media in the form of electromagnetic wave propagation without having to be connected to a cable. An example of the application of this system is Wi-Fi.

In its application, one of the devices used to access Wi-Fi is an antenna. The antenna is used to transfer guided electromagnetic waves into waves that are radiated in a free medium to be transmitted to the receiving antenna. In addition, the antenna on Wi-Fi also functions as a transmitting power amplifier.

The quality of an antenna greatly affects the quality of the information received, so the antenna as one of the telecommunications devices must be made with small dimensions, flexible, practical, and quality. Various antennas have been developed for various applications, one of which is the Microstrip antenna. Microstrip antennas have characteristics that are small, light, thin, easy to fabricate, easy to install, and low cost but microstrip antennas also have disadvantages including narrow bandwidth. The bandwidth of the antenna can be increased by various methods such as increasing the thickness of the substrate with a low constant dielectric value, by inset feeding, cutting slots, and trying antennas with different shapes.

There are several studies that the author refers to as the preparation of this final project, namely "Low Return Loss Slotted Rectangular Microstrip Patch Antenna at 2.4 GHz" [1], "Design of Dual Band Rectangular Microstrip Patch Antenna 1.8 GHz and 2.4 GHz" [2], and "Design and Realization of Circular Microstrip Patch Antenna Using H Slot for Wi-Fi Application" [3]. In this section, the author recreates and implements an antenna in research entitled twin-slot rectangular microstrip antenna for dual-band Wi-Fi 2.4 GHz and 5.8 GHz [4].

II. THE MATERIALS AND METHOD

The stages of the method carried out in this research are as follows:

1. Use of CST Studio Suite 2019: This software designs and optimizes rectangular microstrip antennas. CST Studio Suite 2019 allows users to specify antenna parameters such as patch length, feed line width, and substrate dielectric constant.
2. Simulation: A rectangular microstrip antenna is designed and simulated using CST Studio Suite 2019 to determine its performance before it is realized. This simulation includes the analysis of return loss, VSWR, bandwidth, gain, and radiation pattern.
3. Fabrication: After getting the optimization results on an antenna and by the expected specifications, then carry out the fabrication process.
4. Measurement: The designed and simulated antenna is fabricated and measured to verify the simulation results.

These stages are explained as follows:

A. Antenna Design Flowchart

The figure below displays a flow chart of the antenna design process.

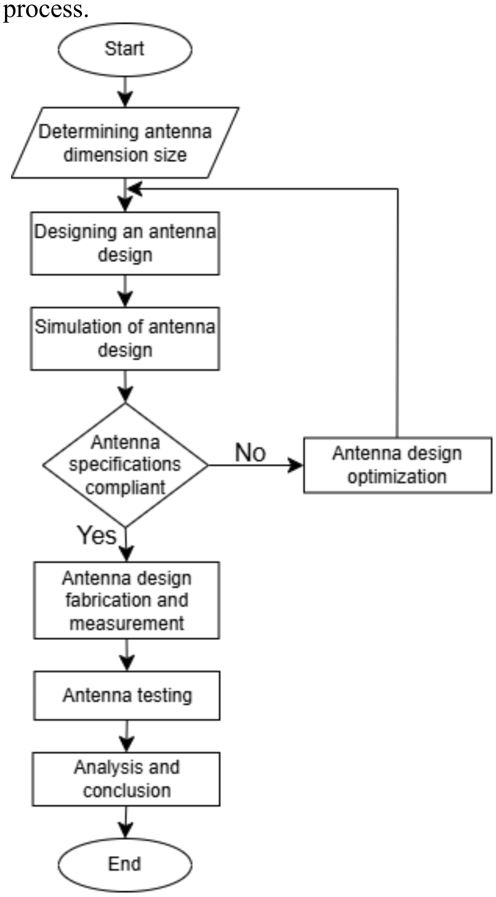

Fig. 1 Flowchart of Antenna Design Process

B. Tools and Materials

The tools and materials used in making the antenna are as follows:

TABLE I
TOOLS AND MATERIALS NEEDED

Tools	Materials
Solder	SMA Female Jack Connector
Tin Sucker	Double Layer PCB
Iron	PCB Layer Transfer Paper
Sandpaper	Solution (H_3 and HCL H_2O_2)
Permanent Marker	Solder Paste
Plastic Container	Tin
Steel File	Thinner

C. Antenna Design

The purpose of designing an antenna is to get more detailed and specific design results so that it is as desired. The desired rectangular patch antenna specifications are determined according to their uses, with predetermined specifications that will make it easier in the optimization stage. The specifications of the antenna are listed in Table 2.

TABLE II
ANTENNA SPECIFICATIONS

Specifications	Descriptions
Antenna Design	Patch Rectangular
Working Frequency	2.4 Ghz and 5.8 GHz
Impedance	50 Ω
Return Loss	≤ - 10 dB
VSWR	≤ 2
Polaradiation	Unidirectional
Substrate	FR-4 Epoxy

A rectangular microstrip antenna is designed at frequencies of 2.4 GHz and 5.8 GHz according to the specifications in Table 3.

TABLE III
ANTENNA DESIGN PARAMETERS OR SIZES BEFORE OPTIMIZATION

Parameter	Value
Lf (Feeding Length)	13
Gpf (Insert Feeding)	1
H (Substrate Thickness)	1.6
L_2_slot (Length of Twin Slot 2)	9.3
Lg (Ground Length)	45
Lp (Patch Length)	29.5
L_slot (Twin Slot Length)	3.2
t (Thickness)	0.035
W_2_slot (Twin Slot 2 Width)	1.5
Wf (Feeding Width)	2.9

Wg (Ground Width)	53
Wp (Patch Width)	29
W_slot (Twin Slot Width)	3.2

The final design results before optimization can be seen in Figure 2 below.

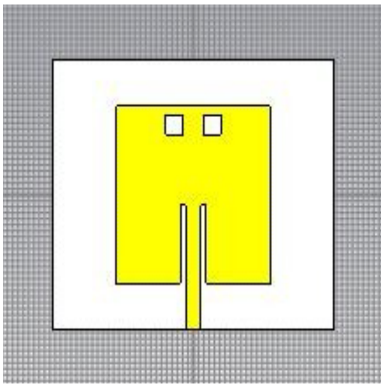

Fig. 2 Antenna Design Before Optimization

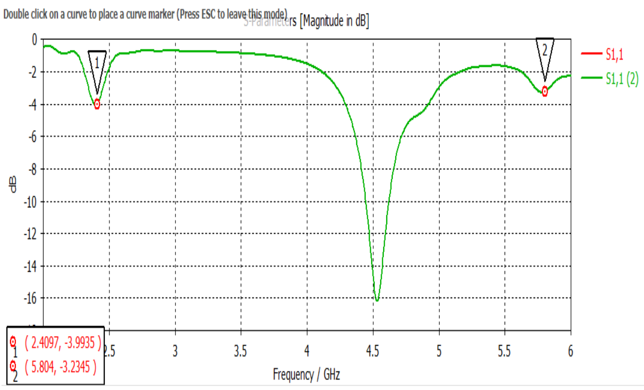

Fig. 3 The Return Loss Display of the Antenna at Frequencies 2.4 GHz and 5.8 GHz

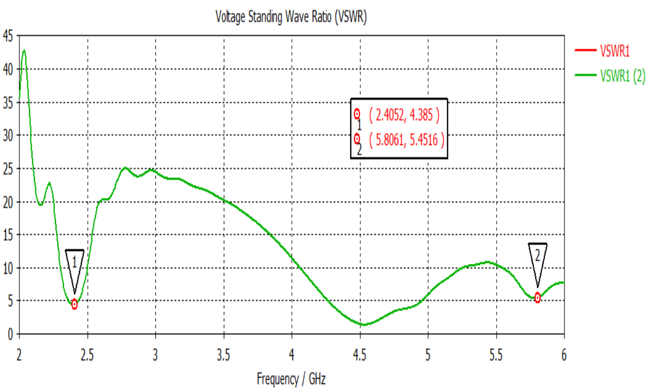

Fig. 4 The VSWR Display of the Antenna at Frequencies 2.4 GHz and 5.8 GHz

In the results of this first simulation, the generated parameters are still far from the desired values, so an optimization process needs to be carried out.

D. Parametric Study

A parametric study is a process conducted to obtain the desired antenna parameters, aiming to observe changes in the designed microstrip antenna, such as changes in the patch, ground plane, slot, or other parameters. This parametric study is carried out by reducing or increasing the size of the antenna design.

1) Change in Slot Size on the Patch

After analyzing the appropriate antenna design, optimization or parametric studies were conducted on several antenna elements by changing the size or dimensions. Here, the first change made was to the slot size on the antenna. The use of slots in microstrip antennas has several advantages, namely it can increase antenna gain, improve VSWR value, reduce antenna size, and widen the antenna's operating frequency range [5].

The simulation results can be seen in Figure 5.

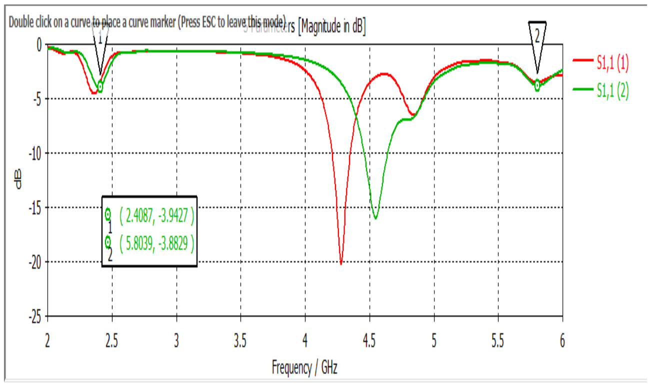

Fig. 5 Slot Simulation Results

In the addition of slot size, there is a change in return loss. When the slot sizes are l_slot = 3.2, l2_slot = 2, w_slot = 3.2, w2_slot = 2 mm, marked in green on the graph, they yield a smaller return loss value compared to the sizes (l_slot = 3.2, l2_slot = 9.3, w_slot = 3.2, w2_slot = 1.5) mm, marked in red. However, a parametric study must be conducted to achieve better parameters such as bandwidth, gain, and so on.

2) Determining the Size of the Feedline Patch

The last parametric study conducted was to change the feedline size on the antenna, in order to achieve better parameter values as expected. The simulation results can be seen in Figure 6.

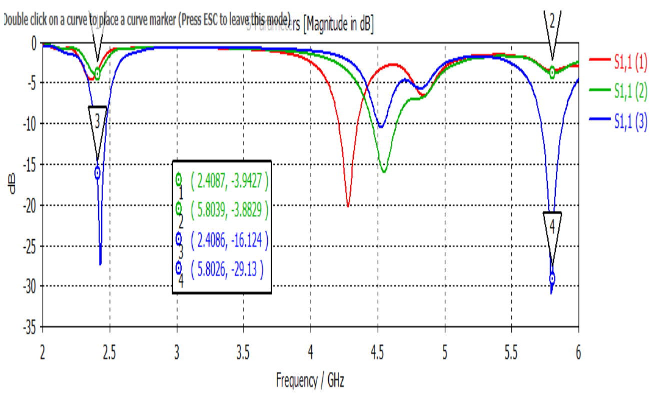

Fig. 6 Feedline Simulation Results

The simulation results on the change in feedline length can be seen in Figure 6, specifically at a feedline length of 13 mm marked in red on the graph, a feedline length of 13 mm marked in green on the graph, and a feedline length of 9 mm marked in green on the graph. It can be analyzed that the return loss, bandwidth, VSWR, and gain are better in the simulation results with a 9 mm feedline length. Therefore, the feedline length for this final project antenna is 9 mm.

From the parametric study that has been conducted, the optimal antenna results were obtained with the following dimensions:

TABLE IV
ANTENNA DESIGN PARAMETERS OR SIZES AFTER OPTIMIZATION

Parameters	**Value (mm)**
Ground Width (Wg)	53
Ground Length (Lg)	45
Patch Width (Wp)	29
Patch Length (Lp)	29.5
Twin Slot Width (w_slot)	3.2
Twin Slot Length (l_slot)	3.2
Twin Slot Width (W_2_slot)	2
Twin Slot Length (L_2_slot)	2
Feeding Width (Wf)	3.11
Feeding Length (Lf)	9

Here are the results of the antenna design after optimization:

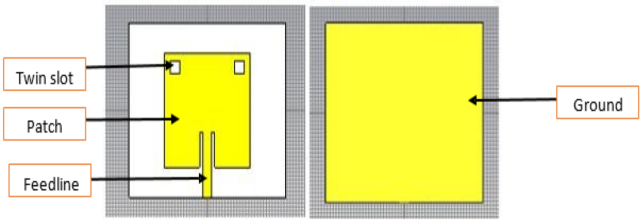

Fig. 7 Antenna Design After Optimization

E. Fabricated Antenna

After obtaining the optimized results for the antenna and confirming that they meet the expected specifications, proceed with the fabrication process. The fabricated antenna uses FR-4 substrate material with a thickness of 1.6 mm and is equipped with a Jack Female SMA Connector.

Here are the results of the antenna fabrication that have been carried out:


Fig. 8 Antenna Fabrication Results

F. Antenna Measurement

The measurement is performed by directly connecting the antenna under test (AUT) without the assistance of other tools. This measurement utilizes a Vector Network Analyzer (VNA). The antenna to be measured is connected to one of the ports on the Vector Network Analyzer.

The antenna measurement process can be seen in the following Figure 9:

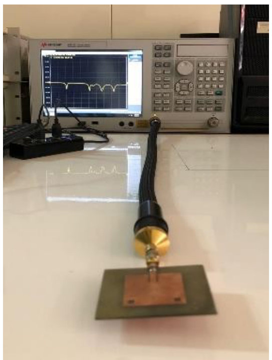
Fig. 9 Antenna Measurement

III. RESULT AND DISCUSSION

A. Optimization Result Parameters

The parameters obtained from the optimized microstrip antenna simulation are return loss, VSWR, gain, radiation pattern, and bandwidth.

1) Return Loss

Return loss is the comparison between the amplitude of the reflected wave and the amplitude of the transmitted wave. Return loss can occur due to discontinuities between the transmission line and the load input impedance (mismatched), and the magnitude of return loss varies depending on the frequency [6].

A good return loss value for an antenna is below -10 dB. This parameter value serves as one of the references to determine whether the antenna can operate at the desired frequency or not. This means that 90% of the signal can be absorbed and 10% is reflected, so it can be said that the transmission line is matched.

Here are the return loss values resulting from the optimization in Figure 10 with the green line:

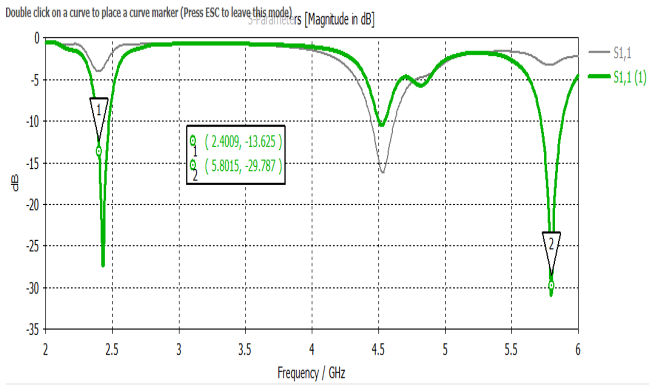

Fig. 10 Return Loss Optimization Results

Based on Figure 10, the optimized return loss values were obtained at a frequency of 2.4, which is -13.62 dB, and at a frequency of 5.8, which is -29.78 dB.

2) *Voltage Standing Wave Ratio (VSWR)*

VSWR is a standing wave that arises due to an unbalanced signal condition, causing a reflected wave to travel back along the transmission line toward its source. The ideal VSWR value is 1 or at least ≤ 2. The optimized VSWR values can be seen in Figure 11 with green lines:

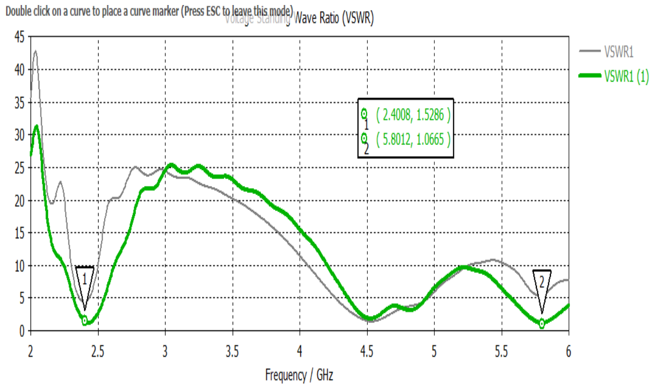

Fig. 11 VSWR Optimization Results

In Figure 11, the ideal VSWR value obtained from optimization is 1.52 dB at a frequency of 2.4 GHz and 1.06 dB at a frequency of 5.8 GHz.

3) *Bandwidth*

Figure 12 below shows the bandwidth value of the optimized antenna. The bandwidth value can be determined using the following equation:

$$BW = f_{upper} - f_{lower}$$

Where;

f_{upper} = upper frequency

f_{lower} = lower frequency

Bandwidth optimization at a frequency of 2.4 GHz:

= 2,4756 GHz – 2,3846 GHz

= 0,091 GHz = 91 MHz

Bandwidth optimization at a frequency of 5.8 GHz:

= 5,8799 GHz – 5,705 GHz

= 0,1749 GHz = 174,9 MHz

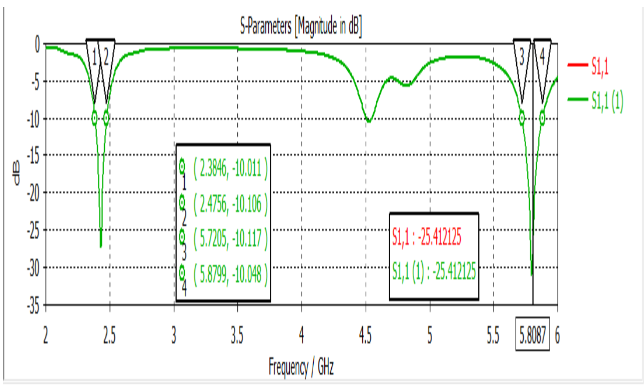

Fig. 12 Bandwidth Optimization Results

The image shows the bandwidth produced by the antenna after optimization, which is valued at 174.9 MHz.

4) *Gain*

Gain is an antenna characteristic with the ability to focus its signal radiation or receive signals from a specific direction. Gain is not a quantity that can be measured in general physical units such as watts, ohms, or others, but rather a form of comparison. Therefore, the unit used for gain is decibels [7].

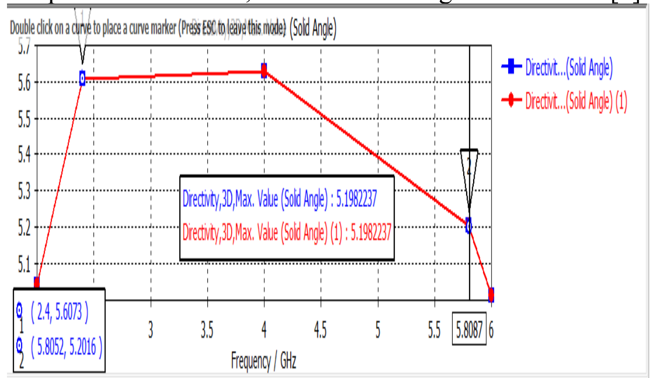

Fig. 13 Gain Optimization Results

In Figure 13, it can be seen that for the frequency of 2.4 GHz, a gain value of 5.6073 dBi was obtained, and for the frequency of 5.8 GHz, a gain value of 5.2016 dBi was obtained. Based on the reference journal, the gain value obtained for the frequency of 2.4 GHz was 5.5973 dBi, and for the frequency of 5.8 GHz, the gain value was 4.872 dBi. Therefore, the gain value obtained after optimization has reached the desired parameter values.

5) *Polaradiation*

In the optimization process, a unidirectional radiation pattern, also known as a one-way radiation pattern, was obtained as shown in figures 14 and 15 below:

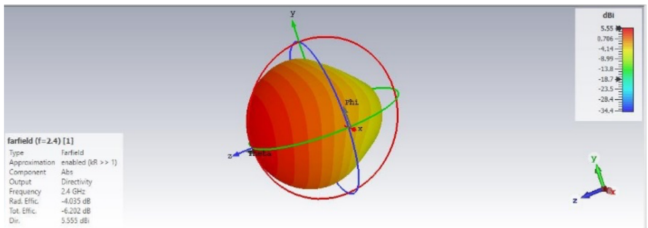

Fig. 14 Radiation Pattern Display at 2.4 GHz Frequency

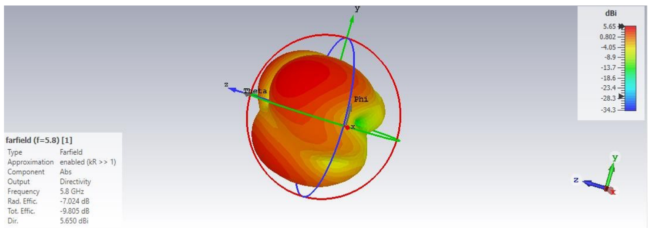

Fig. 15 Radiation Pattern Display at 2.4 GHz Frequency

With this radiation pattern, the antenna's transmission distance is greater compared to an omnidirectional antenna, assuming both antennas have the same transmission power.

B. *Measurement Analysis*

Based on the measurement results that have been conducted, the parameter results obtained are slightly different from the simulation results, but the fabricated microstrip antenna is still considered good because it meets the characteristics of the existing parameters. Several factors cause the fabricated antenna to not match or almost match the simulation, which is due to inaccuracies or other issues during fabrication, such as PCB cutting, etching, and connector installation.

1) Return Loss

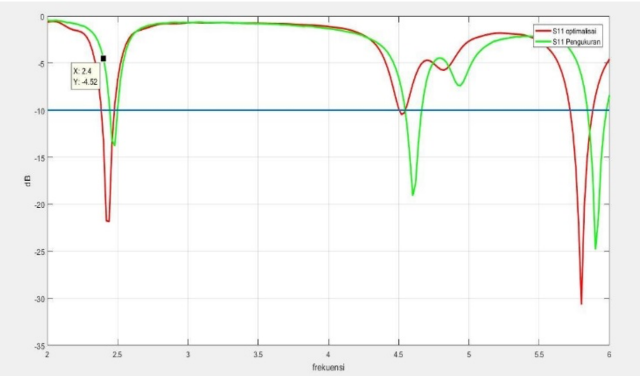

Fig. 16 Measurement Results of Return Loss at 2.4 GHz Frequency

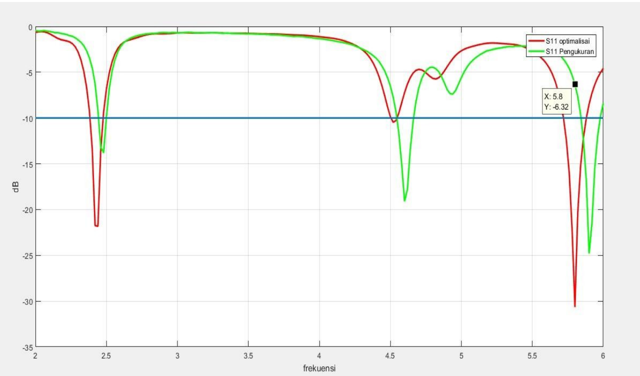

Fig. 17 Measurement Results of Return Loss at 5.8 GHz Frequency

In Figure 16, it can be seen that the return loss value from the antenna fabrication measurement at a frequency of 2.4 GHz is -4.52 dB, marked with a green line. In Figure 17, it is shown that the antenna fabrication measurement result at a frequency of 5.8 GHz obtained a return loss value of -6.32 dB, marked with a red line. Both return loss values obtained have met the good return loss value and are following the desired parameter value, which is below -10 dB.

2) Voltage Standing Wave Ratio (VSWR)

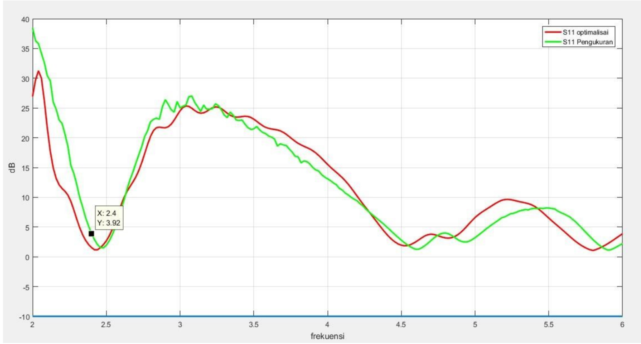

Fig. 17 Measurement Results of VSWR at 2.4 GHz Frequency

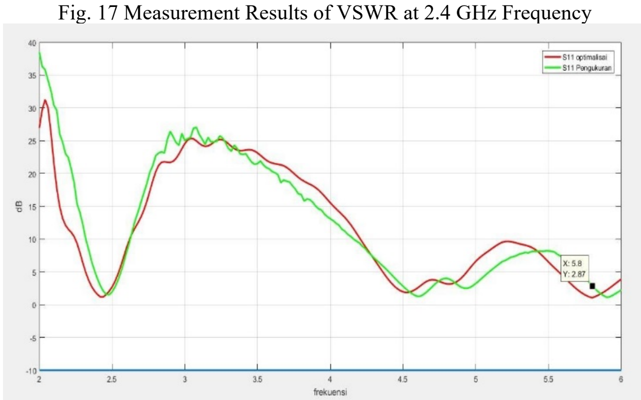

Fig. 18 Measurement Results of VSWR at 5.8 GHz Frequency

Based on figures 17 and 18, it is shown that the measurement results of the antenna fabrication at a frequency of 2.4 GHz yielded a VSWR value of 3.93, and at a frequency of 5.8 GHz, a VSWR value of 2.87 was obtained. Both VSWR values produced are not ideal and do not meet the good VSWR value and the desired parameter value, which is ≤ 2.

C. Analysis of Antenna Simulation and Fabrication Results

1) Return Loss

Based on Figure 10, the return loss value from the optimization simulation at a frequency of 2.4 GHz is -13.62 dB, and at a frequency of 5.8 GHz is -29.78 dB.

In Figures 19 and 20, the return loss value from the antenna fabrication measurement at a frequency of 2.4 GHz is -4.52 dB, and at a frequency of 5.8 GHz is -6.32 dB. The fabrication results shifted upwards by 9.1 dB from the 2.4 GHz frequency and 23.26 dB from the 5.8 GHz frequency, which does not match the simulation results. This may be caused by a lack of precision during the fabrication process. In the fabrication results that achieved return loss values according to the desired parameters, the frequencies were 2.46 GHz with -13.2 dB and 5.86 GHz with -12.4 dB, as shown in Figures 19 and 20.

Based on the two measurement results between simulation and fabrication, the return loss value that meets the desired parameters is in the simulation results.

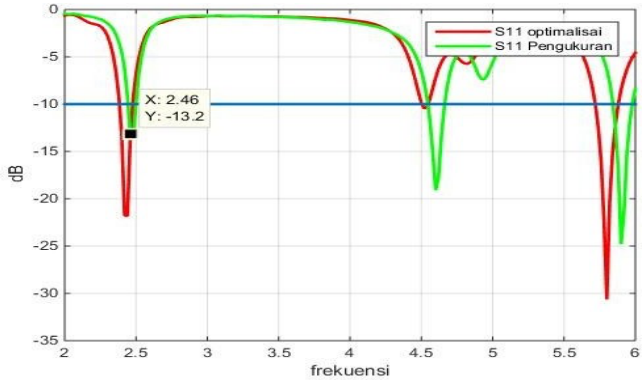

Fig. 19 Measurement Results Approaching -10 dB are at a Frequency of 2.46 GHz

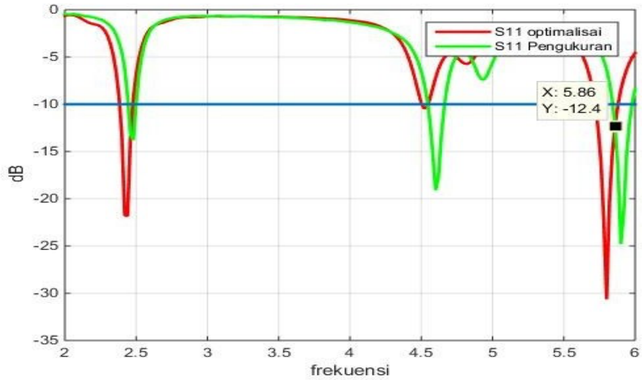

Fig. 20 Measurement Results Approaching -10 dB are at a Frequency of 5.86 GHz

Based on the data, it can be analyzed that the return loss value of the antenna in the simulation results (optimization) is better than the return loss value of the antenna in the fabrication results because the main benchmark for whether a designed antenna is good or bad must have a return loss value $\leq -10\ dB$. This could be caused by several factors, such as the lack of precision in cutting the PCB and suboptimal performance during the etching process. In addition, the soldering process also greatly affects the measurement results, where if the soldering is not good, such as the solder not adhering well to the patch due to insufficient sanding of the patch and connector, resulting in an uneven patch surface, making it difficult for the solder to adhere to the patch.

2) Voltage Standing Wave Ratio (VSWR)

In Figure 11, the VSWR value from the optimization simulation at a frequency of 2.4 GHz is obtained as 1.52 and 1.06 at a frequency of 5.8 GHz. In Figures 17 and 18, with the results of the antenna fabrication measurement, a VSWR value of 3.93 is obtained at a frequency of 2.4 GHz and 2.87 at a frequency of 5.8 GHz. Based on these two VSWR values, the results that meet the good VSWR value and the desired parameter value (≤ 2 dB) are from the optimization results. The fabrication results that achieve the desired parameter value are at a frequency of 2.46 GHz with a value of 1.56 and at a frequency of 5.88 GHz with a value of 1.34, as shown in Figures 21 and 22.

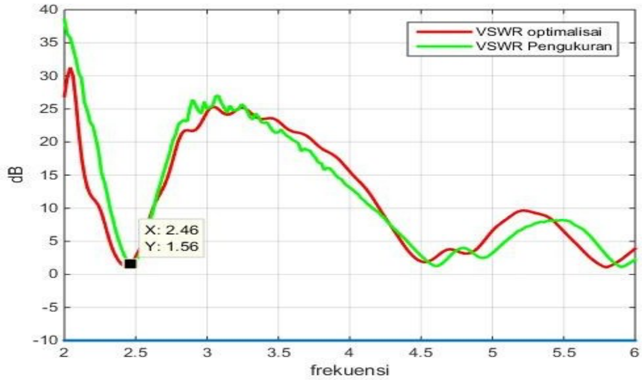

Fig. 21 Measurement Results ≤ 2 are at a Frequency of 2.46 GHz

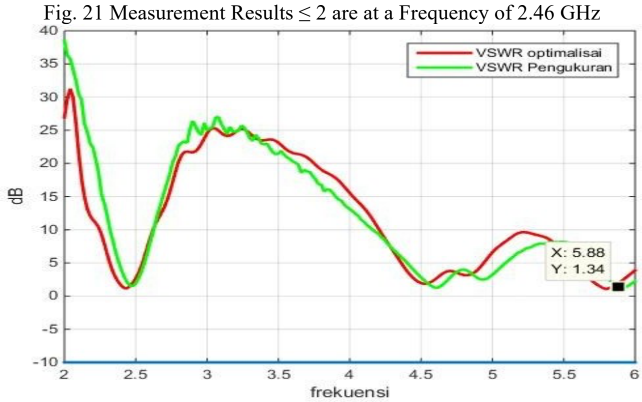

Fig. 22 Measurement Results ≤ 2 are at a Frequency of 5.88 GHz

D. Testing Antennas on WI-FI

The testing of this microstrip antenna was conducted at the Politeknik Negeri Padang, specifically in building G on the 3rd floor, using several tools such as an access point, LAN cables connected to the campus network, coaxial cables, and a mobile phone with the installed application for testing.

Antenna testing was conducted from several distances, namely 1 meter, 3 meters, and 5 meters in a straight line from the antenna, and testing was also done in different directions. The testing process was carried out using a speed test, where the antenna power or gain, upload and download speeds, ping, and jitter on the application were observed. This antenna testing was conducted by comparing the values with the campus wi-fi at Politeknik Negeri Padang.

On the campus wi-fi, the antenna gain/power value obtained was -61, and the ping value was 30 ms, where ping is used to measure network connection latency. So, the lower the ping value, the faster the signal moves. The jitter value on the campus wi-fi is 42 ms, where the jitter is the time required to send data. If the jitter value is low, it indicates that data packets arrive consistently and stably. The download speed on this antenna is 35.6 Mbps, where a high download speed indicates that data can be retrieved from the internet quickly. The upload speed on the antenna is 48.4 Mbps, and a high upload speed shows that the internet connection can send data at a higher speed. The speed test display on the campus wi-fi can be seen in Figure 23 below:

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Fig. 23 Speedtest Display on Campus Wi-Fi

1) Testing at Distances of 1 meter, 3 meters, and 5 meters with Position Aligned with the Antenna


Fig. 24 Test Results at Distances of 1 meter, 3 meters, and 5 meters Aligned with the Antenna

Based on Figure 24, it can be seen that in the straight direction from the antenna position, an output power of -55 dBm is produced at a distance of 1 meter, an output power of -59 dBm is produced at a distance of 3 meters, and an output power of -69 dBm is produced at a distance of 5 meters.

2) Testing Position 30 Degrees to the Right of the Antenna


Fig. 25 Test Results at Distances of 1 meter, 3 meters, and 5 meters with a Position 30 Degrees to the Right of the Antenna

Based on Figure 25, it can be seen that the output power at a distance of 1 meter from the antenna is -58 dBm, at a distance of 3 meters it produces an output power of -64 dBm, and at a distance of 5 meters it produces an output power of -87 dBm.

3) Testing Position 30 Degrees to the Left of the Antenna


Fig. 26 Test Results at Distances of 1 meter, 3 meters, and 5 meters with a Position 30 Degrees to the Left of the Antenna

Based on Figure 26, it can be seen that at a distance of 1 meter, an output power of -60 dBm is obtained, at a distance of 3 meters an output power of -72 dBm is produced, and at a distance of 5 meters an output power of -74 dBm is obtained.

Based on the tests conducted, it can be concluded that as the test point distance increases from the access point position, the antenna produces a decreasing output power. Additionally, the position during testing greatly affects the output power because the antenna produces unidirectional radiation, meaning the antenna's emission direction is in a straight line. Therefore, testing in a straight condition yields better output power compared to testing at a 30-degree tilt to the right or left.

4) Testing Speed Test Results in Three Positions

Here is the speed test display with 3 positions, namely straight with the antenna, 30 degrees to the right of the antenna, and 30 degrees to the left of the antenna:

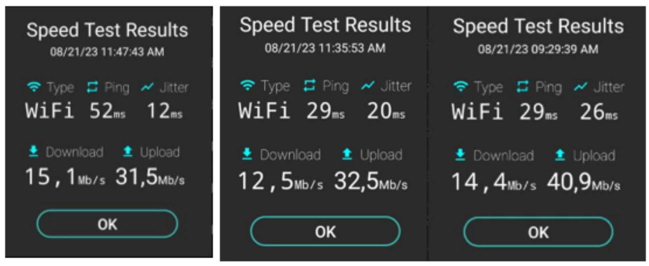

Fig. 27 Results of Speed Test Testing in Three Positions

Based on Figure 27, it can be seen that during the test under straight-line conditions with the antenna, a download speed of 15.1 Mb/s and an upload speed of 31.5 Mb/s was achieved, with a ping of 52 ms and a jitter of 12 ms. During the test under conditions 30 degrees to the right from the antenna's position, a download speed of 12.5 Mb/s and an upload speed of 32.5 Mb/s were achieved, with a ping of 29 ms and a jitter of 20 ms. Meanwhile, during the test under conditions 30 degrees to the left from the antenna's position, a download speed of 14.4 Mb/s and an upload speed of 40.9 Mb/s were achieved, with a ping of 29 ms and a jitter of 26 ms. The speed test results were obtained from the three tests based on the testing positions, where the results showed better and more stable download and upload speeds.

IV. CONCLUSION

Based on the process that has been carried out, several conclusions can be drawn, including:

1. The rectangular microstrip patch antenna with a dual-slot for dual-band Wi-Fi 2.4 GHz and 5.8 GHz was successfully designed using CST Studio Suite 2019 by inputting the antenna dimensions obtained through formula calculations.
2. Measurement of the fabricated antenna parameters was successfully conducted using a Vector Network Analyzer.
3. The values obtained from the antenna design using CST Studio Suite 2019 differ from those of the fabricated antenna.
4. The parameter values obtained from the antenna design results are a return loss of -13.64 dB at a frequency of 2.4 GHz and -30.40 dB at a frequency of 5.8 GHz, a VSWR of 4.38 at a frequency of 2.4 GHz and 5.45 at a frequency of 5.8 GHz, and it has unidirectional radiation.
5. The parameter values obtained from the antenna fabrication results are a return loss of -4.52 dB at a frequency of 2.5 GHz and -6.32 dB at a frequency of 5.8 GHz, with a VSWR of 4.38 at a frequency of 2.4 GHz and 5.45 at a frequency of 5.8 GHz.
6. The testing or implementation of the Wi-Fi antenna was conducted at several distances, namely 1 meter, 3 meters, and 5 meters, and from different directions. From the test results, it was concluded that the distance and direction of the antenna can affect the results of the antenna testing, as well as the less meticulous fabrication work.

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