Asymmetric-Slit Method on WiFi Antenna with 2.4 GHz and 5 GHz Frequency

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***Abstract*—Wireless Fidelity (WiFi) devices are often used to access the internet network, both for working and in information searching. Accessing the internet can be administered anywhere provided that the area is within the WiFi devices range. A WiFi device uses 2.4 GHz and 5 GHz operating frequencies. There were several methods employed in the previous studies so that an antenna design could work in two different frequencies, i.e., winding bowtie method, Sierpinski method, and double-circular method. This paper employed a simple method, the slit method. The objective of this paper is to discover a simple antenna model that works on 2.4 GHz and 5 GHz frequencies. This paper employed a square patch microstrip antenna with a slit method. The dimensions of the designed square patch microstrip antenna were 42.03 mm × 27.13 mm × 0.035 mm. The antenna worked at 2.4 GHz and 5 GHz frequencies. The obtained simulation results after the optimization showed that the square patch microstrip antenna using the slit method acquired a value of S11 (return loss) of -10.15 dB at a frequency of 2.4 GHz and -37.315 dB at a frequency of 5 GHz.**

***Keywords*— Wireless Fidelity, Microstrip, Square Patch, Slit.**

I. INTRODUCTION

With today's technology, the world's internet network can be accessed from anywhere, under a condition that there is access to internet services within an area. Internet access can use Wireless LAN (WLAN), Wireless Fidelity (WiFi), or more extensive access, i.e., the Worldwide Interoperability for Microwave Access (WiMax).

This paper addresses the use of WiFi devices in the community environment. It is well known that WiFi devices work at 2.4 GHz and 5 GHz operating frequencies. There are WiFi devices that work at 2.4 GHz, as per the IEEE 802.11b and IEEE 802.11g standards, and there are also WiFi devices that work at 5 GHz, following the IEEE 802.11a standard. In addition, there is also a development of WiFi devices that work on both frequencies, as per the established standards, i.e., IEEE 802.11n. This paper aims to discover a simple antenna model that works precisely at the desired frequency. In addition, this paper aims to investigate the work process if the device works with multiband frequency; to create antenna designs that work with the multiband frequency with several methods; to make amplifiers for existing antennas, both for the 2.4 GHz frequency and the 5 GHz frequency; and to find a WiFi multiband strengthening method.

A square patch antenna model is an antenna model that is commonly used in antenna studies. A study conducted in 2017 employed the bowtie winding method to obtain an operating frequency of 2.4 GHz and 5.8 GHz [1]. This research has a relatively difficult design and requires high accuracy in designing it. In 2018, a study was conducted using the Sierpinski method [2]. This method is a shape-repetition method that was previously designed on the patch. In the same year, there was also a study conducted using the double circular method or commonly called double dish [3]. In this method, a double-circular shape was added to the patch.

In addition to these methods, there are also several methods used on microstrip antennas, including the wall method [4], slot method [5], metamaterial ring method [6], Substrate Integrated Waveguide (SIW) method [7], and the Defected Ground Structure (DGS) method [8]. The wall method is a method conducted by providing a metamaterial barrier, such as a wall between the radiating antennas. Another method widely used in the research is the slot method. This method can have a significant influence on the frequency use, and it can improve radiation patterns, as in the studies using the rectangular slot method in designing antennas with working frequencies of 2.4 GHz and 3.6 GHz [9]. If it is noticed, this research uses the same method, and the differences are only on the slip's asymmetrical shape and the number of slots used. Other than those two methods, other methods such as SIW and DGS also give a significant effect on the radiation patterns.

Parameters fully considered in this paper are the return loss and Voltage Standing Wave Ratio (VSWR). These two parameters are used in this paper to enable the antenna to operate at WiFi frequencies, i.e., the 2.4 GHz and 5 GHz frequencies, in one device. By looking at the return loss parameter, the magnitude of power returned to the transmitter device can be seen, while the VSWR parameter can determine the ratio magnitude between the transmitting waves to the reflected waves. Return loss and VSWR are interconnected, as shown in (1) [10], [11].

$$\textit{Return loss}\,(\mathrm{dB}) = 20\log\Gamma \tag{1}$$

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{2}$$

where Γ is the reflection coefficient.

This paper discusses and analyzes the work process of devices operating on multiband frequencies using the slit method. This method is a development from the well-known slot method. The difference between the slot method and the slit method lies in the defect position in the antenna patch. A slot method is a defect that is done around the patch antenna, while the slit method is an antenna patch defect from the outer

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into the inner antenna patch. Some slit methods had been used in the previous studies, such as in the research using a slit method in a microstrip antenna aimed to radiate circular polarization with a wide angle [12]. Other studies have employed triangular-shaped slit methods with an operating frequency range of 0-15 GHz [13]. A study using some strip and loop loading methods has been conducted [14]. In this paper, the placement of the antenna patch defect pattern was set on the xy plane. The utilized defect pattern was a rectangular defect pattern.

This paper is organized as follows. Section I, the introduction, discusses the understanding and differences of the slit method and the slot method as well as discusses the reasons for using an asymmetrical slit method on both sides as one way to shift the operating frequency. Section II discusses the antenna design before and after using the asymmetric-slit method. Furthermore, in Section III, the test results are presented and discussed, and Section IV presents the conclusion.

II. Antenna Design

This part discusses the antenna design, i.e., the 2.4 GHz and 5 GHz WiFi antennas using the square slot and slit methods. Before designing the antenna, there was a calculation for the media of the utilized antenna. The formula used in designing the antenna was as follows [11].

$$\textit{Length of Patch } (LP) = L_{eff} - 2\Delta L \tag{3}$$

$$L_{eff} = \frac{c}{2 f_r \sqrt{\in_{reff}}} \tag{4}$$

$$\in_{reff} = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}\left[1 + 12\frac{Ts}{WP}\right]^{-1/2} \tag{5}$$

$$\Delta L = 0.412 Ts \frac{(\in_{reff} + 0.3)\left(\frac{WP}{Ts} + 0.264\right)}{(\in_{reff} - 0.258)\left(\frac{WP}{Ts} + 0.8\right)} \tag{6}$$

$$\textit{Width of Patch } (WP) = \frac{c}{2 f_r}\sqrt{\frac{2}{\in_r + 1}} \tag{7}$$

where

- LP = the length of antenna's patch
- WP = the width of antenna's patch
- Ts = the thickness of antenna's substrate
- ΔL = length increase
- c = speed of light (3×10^8 m/s)
- L_{eff} = effective length
- f_r = resonant frequency
- $\in_{eff}$ = effective dielectric constant
- $\in_r$ = substrate dielectric constant.

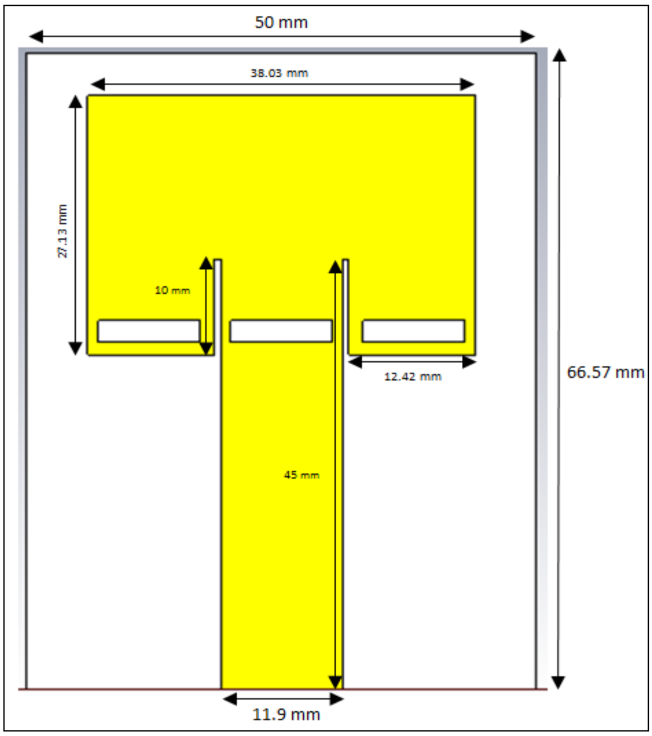

Fig. 1 The antenna design without the asymmetric-slit method.

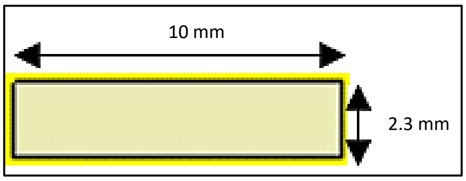

Fig. 2 Size of slot antenna design.

A. Antenna Design without the Asymmetric-Slit Method

Fig. 1 shows the antenna design without using the asymmetric-slit method, with antenna patch dimensions of 27.13 mm × 38.03 mm × 0.03 mm, feedline size of 35 mm × 11.9 mm × 0.035 mm, and substrate dimensions of 66.57 mm × 50 mm × 1.6 mm. The antenna was designed to work on multiband frequencies, which were 2.4 GHz and 5 GHz. It can be seen that the slot and slit method use is symmetrical between the right and left antenna patches. The antenna design was made to a minimum, but the return loss and VSWR parameters values remained at the standard range. The size of the antenna slot used was 10 mm × 2.3 mm × 0.035 mm, which was within the antenna patch. There were significant slot and slit effects that were utilized against return loss and VSWR values. Fig. 2 is the utilized antenna slot sizes in the antenna design, both for the antenna design with and without the asymmetric-slit method.

Fig. 3 is a simulated result of an antenna design without asymmetric-slit method which displays the return loss value on the desired operating frequency, i.e., -1.2 dB at a frequency of 2.4 GHz and -4.5 dB at a frequency of 5 GHz. The return loss values of -1.2 dB and -4.5 dB are not desired values since the operating frequency is not shown in the graph.

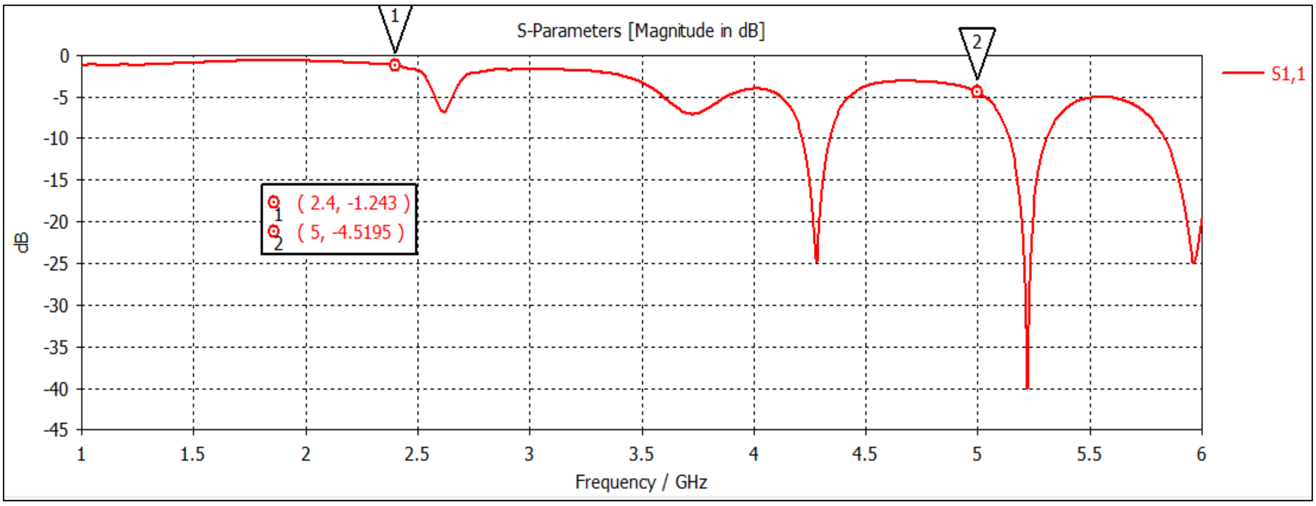

Fig. 3 Return loss S-Parameter (S11) of antenna design without an asymmetric-slit method.

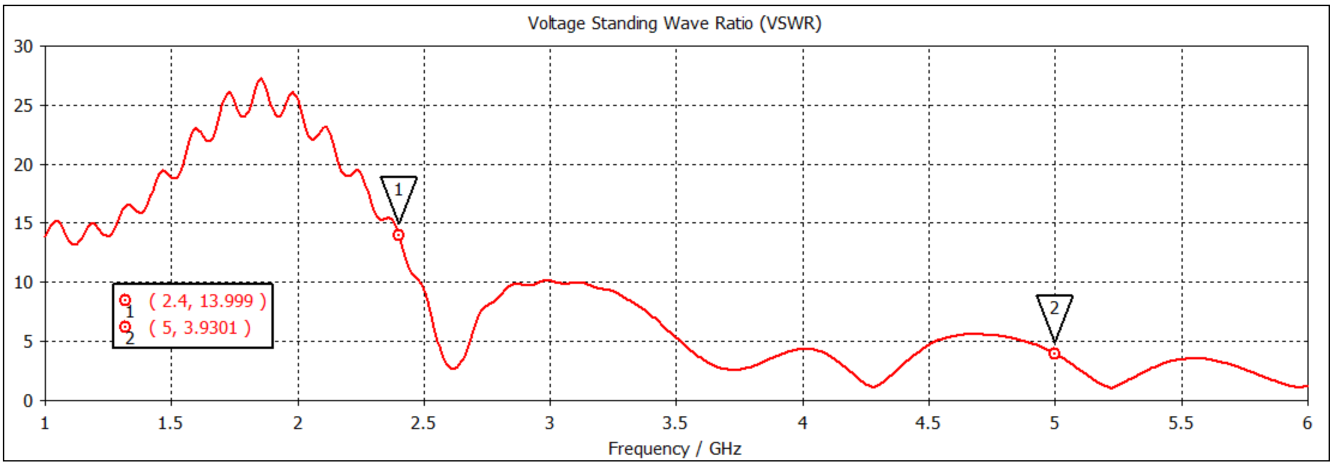

Fig. 4 VSWR S-Parameter of antenna design without asymmetric-slit method.

In Fig. 4 shows the VSWR value, which is not within a range of considered good VSWR values. The graph shows the VSWR value of 13.999 at the 2.4 GHz frequency and 3.9301 at the 5 GHz frequency.

The two antenna parameters, i.e., return loss and VSWR, do not indicate that the employed antenna design can work well at 2.4 GHz and 5 GHz frequencies. Therefore, another method is needed so that the antenna design can work at the expected frequency. The antenna dimensions without the asymmetric-slit method are presented in Table I.

Table I is obtained from the microstrip antenna calculations and is applied, as shown in Fig. 1. The calculation data is the maximum antenna calculation to obtain return loss and VSWR values. However, based on the results in Fig. 3 and Fig. 4, the return loss and VSWR results on the designed antenna have not been maximized so that if it is applied in the antenna devices in the market, it will not function maximally. Furthermore, optimization is administered several times. The first optimization employed the slot method, and its results were not yet reaching the desired value range. Then, the slit method was added, but constraint was found, namely the shifting frequency, which was not precisely at 2.4 GHz and 5 GHz. Afterward, the slit method was optimized. The firstly performed slit method was the left slit patch antenna so that the Cartesian x and y plane were arranged. The same thing was administered in the right

TABLE I
ANTENNA SPECIFICATION WITHOUT SLIT-ASYMMETRIC METHOD

Parameters	Value
Operating frequency	2.4 GHz and 5 GHz
Substrate Type	FR-4
Patch Type	Copper
Dielectric Constants	4.4
Substrate Length (Lg)	66.57 mm
Substrate Width (Wg)	50 mm
Copper Thickness (Tc)	0.035 mm
Substrate Thickness (Ts)	1.6 mm
Patch Length (Lp)	27.13 mm
Patch Width (WP)	38.03 mm
Groundplane Length	Substrate length (Lg)
Groundplane Width	Substrate width (Wg)
Feedline length (L1)	35 mm
Feedline width (W1)	11.9 mm

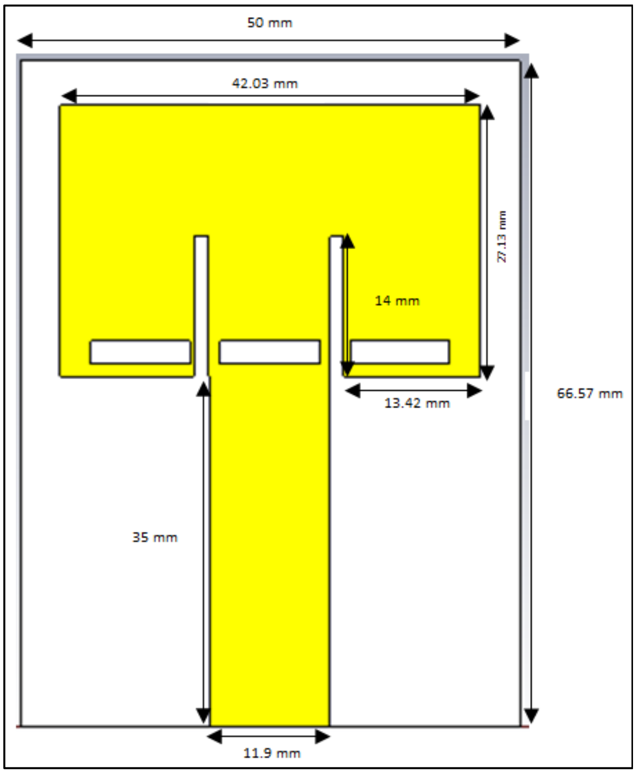

Fig. 5 Antenna design with the asymmetric-slit method.

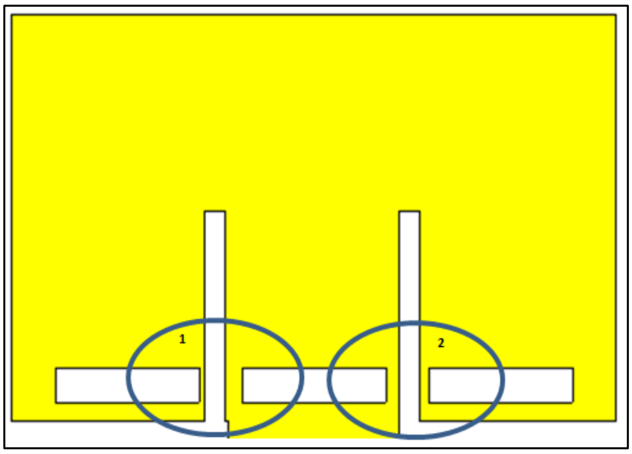

Fig. 6 Asymmetric-slit method.

slit of the antenna patch until the antenna design was obtained, as shown in Fig. 5.

B. Antenna Design with Asymmetric-Slit Method

Fig. 5 shows the antenna design using the asymmetric-slit method. The slot size follows the same slot as the design in Fig. 2. Fig. 5 shows the asymmetrical state between the left and right sides of the patch antenna. The antenna patch asymmetrical state is shown in Fig. 6.

Fig. 6 can explain the use of the asymmetric-slit method in patch antennas. Distance between slots and slits at number 1 in Fig. 6 is different from the distance between slots and slit in number 2. Table II explains in more detail the different sizes of the two methods.

TABLE II
SLIT METHOD SIZE DIFFERENCES IN THE DESIGN WITH AND WITHOUT ASYMMETRIC-SLIT

Parameter List	Value	
	Without the Asymmetric-Slit Method	With the Asymmetric-Slit Method
Minimum distance of X square slot (Xmin_Slot)	-18 mm	-18 mm
Maximum distance of X square slot (Xmax_Slot)	-8 mm	-8 mm
Minimum distance of Y square slot (Ymin slot)	-12.3 mm	-12.3 mm
Maximum distance of square Y slot (Ymax_Slot)	-10 mm	-10 mm
Minimum distance of X slit (Xmin_Slit)	-6.6 mm	-7.6 mm
Maximum distance of X slit (Xmax_Slit)	-5.95 mm	-6.2 mm
Minimum distance of Y slit (Ymin_Slit)	-3.565 mm	-10.435 mm
Maximum distance of Y slit (Ymax_Slit)	-13.565 mm	-13.565 mm

TABLE III
ANTENNA SPECIFICATION WITH ASYMMETRIC-SLIT METHOD

Parameters	Value
Work Frequency	2.4 GHz and 5 GHz
Substrate type	FR-4
Patch Type	Copper
Dielectric Constants	4.4
Substrate length (Lg)	66.57 mm
Substrate Width (Wg)	50 mm
Copper thickness (Tc)	0.035 mm
Substrate thickness (Ts)	1.6 mm
Patch length (LP)	27.13 mm
Patch width (WP)	42.03 mm
Groundplane length	Substrate length (Lg)
Groundplane width	Substrate width (Wg)
Feedline length (L1)	35 mm
Feedline width (W1)	11.9 mm

The distance between slit and slot use in this paper can be seen in Table II. There is no distance adjustment in the slot use, but there is a change in the slit distance. Previously, without using the asymmetric-slit method, the distance was 0.65 mm in the Cartesian X plane and -10 mm in the Cartesian Y plane, whereas in the asymmetrical-slit use the distance is 1.4 mm in the Cartesian X plane and 3.13 mm in the Cartesian Y plane. Fig. 6 shows the results of these changes. Antenna design results using the asymmetric-slit method are shown in Fig. 7 and Fig. 8.

The graph in Fig. 7 shows the value of S-parameter at the right return loss at 2.4 GHz, which is equal to -10.15 dB and at 5 GHz of -37.315 dB. The return loss value fulfills the best value range requirements, which is -10 dB. The VSWR value is shown in Fig. 8.

Fig. 8 visualizes the VSWR values graph of the antenna design using the asymmetric-slit method. The figure shows that

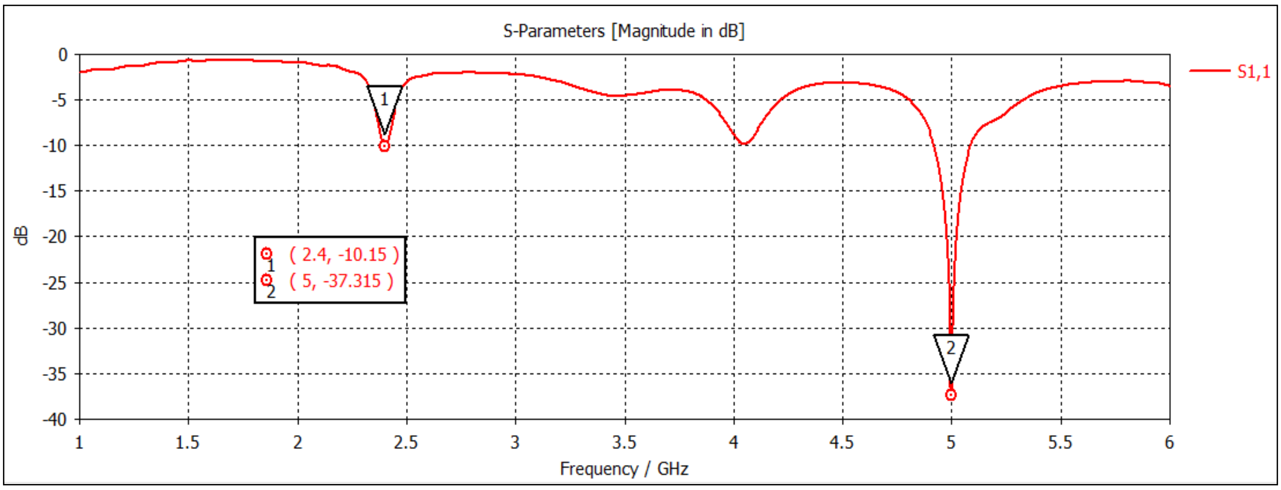

Fig. 7 Return loss S-parameter (S11) of antenna design using the asymmetric-slit method.

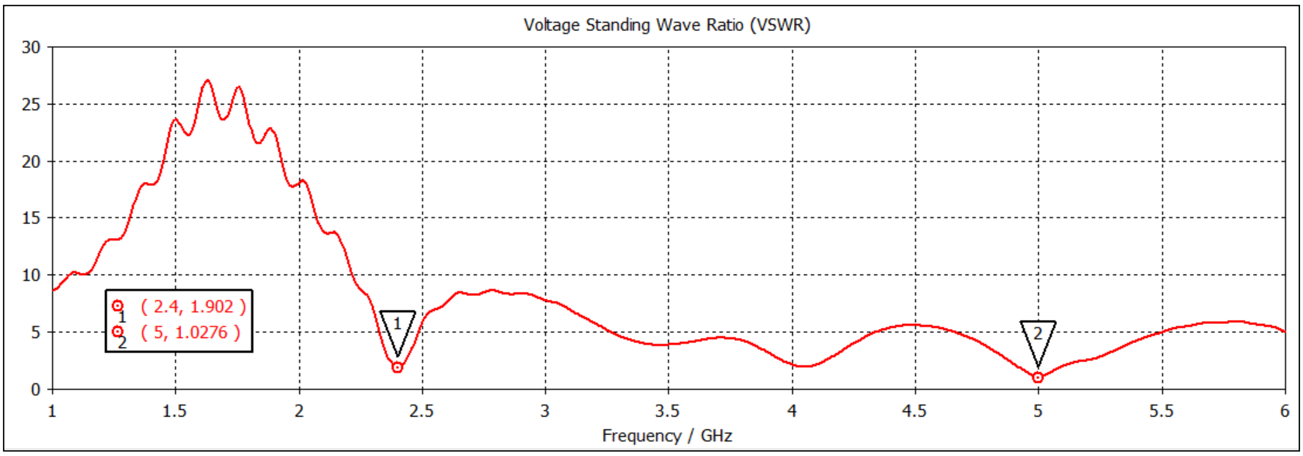

Fig. 8 VSWR S-parameter of the antenna design with the asymmetric-slit method.

the VSWR values at frequencies of 2.4 GHz and 5GHz are 1.902 and 1.0276, respectively. The VSWR value meets the best value range of the commonly used VSWR value, which is 2. Size of the antenna design in Fig. 5 follows Table III; therefore, the antenna size using the asymmetric-slit method refers to the values as presented in Table III.

III. Results and Discussions

Fig. 9 is a comparison of return loss on antenna design with and without asymmetric-slit method. It can be explained that the slit method use can shift the antenna's operating frequency. By moving the slit from the patch antenna towards the Cartesian X and Y plane, the antenna's operating frequency can be shifted. The slit distance is adjusted so that the operating frequency can shift, at 2.4 GHz and 5 GHz.

The slit method can also shift the VSWR value based on the desired operating frequency. This is shown in Fig. 10. This paper developed a one-slit method so that the obtained frequency worked precisely at the desired frequency. The difference of this paper to previous research lies in the use of the slit method to obtain the operating frequency in accordance with the device [15]. Previous studies utilized an operating frequency of 3.5 GHz and 5.2 GHz, while this paper utilized frequencies according to devices on the market, namely 2.4 GHz and 5 GHz.

IV. Conclusions

From the analysis and visualization in Fig. 9 and Fig. 10, it can be concluded that one way to shift the antenna's operating frequency is to use the slit method. If two slits are used in the patch antenna, two work frequencies are generated. In this paper, a minimalist antenna with a multiband operating frequency, i.e., 2.4 GHz and 5 GHz, was made. The graph in Fig. 9 in green shows a 2.4 GHz operating frequency with a return loss value of -10.15 dB, while a red graph, which also shows a 2.4 GHz operating frequency, obtains a value of -1.243 dB. Graph showing the 5 GHz frequency also shows the return loss values. The green graph, which uses the asymmetric-slit method, obtains a value of -37.315 dB, while the red graph, which is without the asymmetric-slit method, obtains a value of -4.5195 dB. In Fig. 10, the blue graph shows a good VSWR value, which is 1.9 at the 2.4 GHz frequency and 1.02 at the 5 GHz frequency, when compared to the orange graph. The weakness of the antenna in this paper is that the gain is not maximal at each operating frequency, 2.4 GHz and 5 GHz; moreover, the correlation between the slit method shift against

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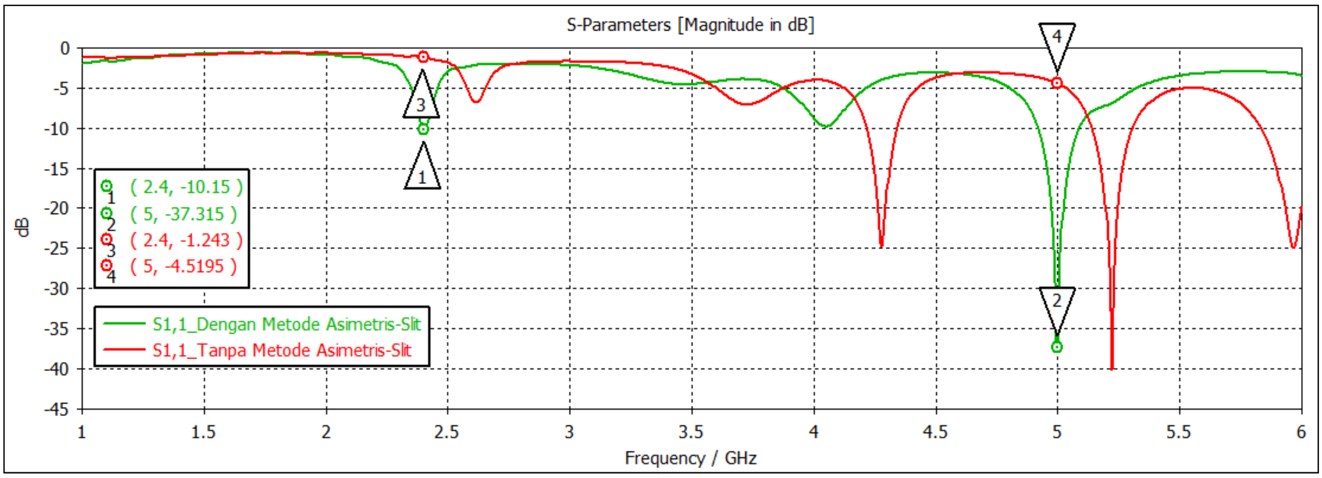

Fig. 9 The comparison of the antenna's return loss parameters with and without the asymmetric-slit method.

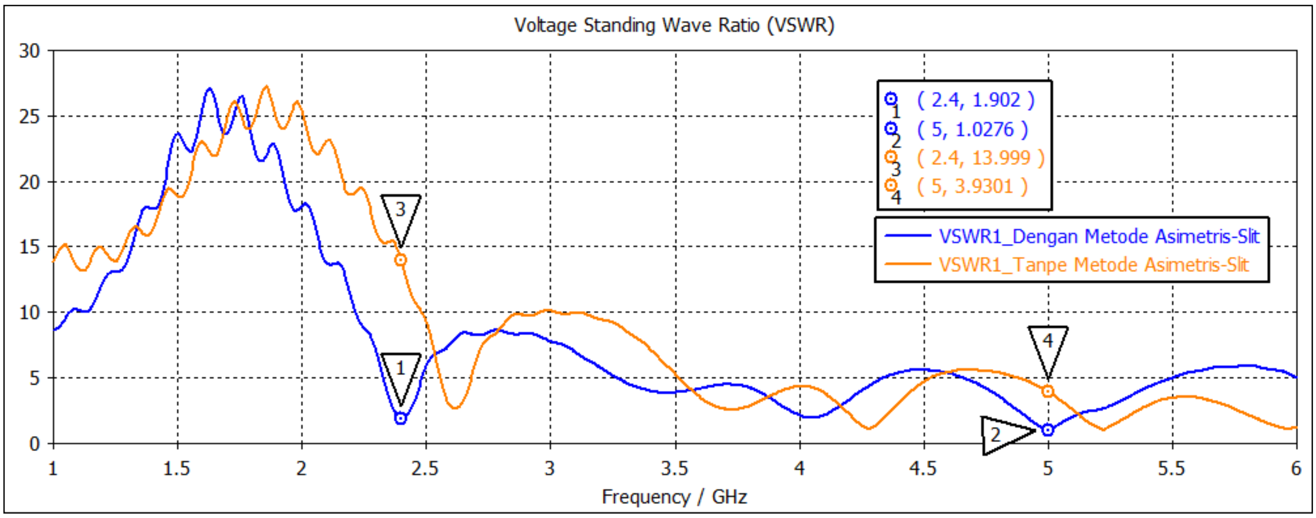

Fig. 10 Comparison of antenna's VSWR parameters with and without the asymmetric-slit method.

the operating frequency could not be explained using the formula.

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