Journal of Physics:
Conference Series

PAPER • OPEN ACCESS

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To cite this article: A Irfansyah *et al* 2021 *J. Phys.: Conf. Ser.* **2117** 012028

Design of Rectangular Microstrip Antenna 1x2 Array for 5G Communication

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Abstract. Microstrip antennas are currently popular because they have the advantage and meet the demand for small and lightweight antennas so that they are compatible and easy to integrate. This study aims to design an antenna microstrip rectangular 1x2 array, a rectangular patch microstrip antenna consisting of two elements. The antenna has a patch size of 19.5 mm x 26.5 mm array 1x2 with a frequency of 3.5 GHz. The antenna design is made in a simulation that works at a frequency of 3.5 GHz, and the substrate material is made of FR 4, which has a constant ($\varepsilon r$of) of 4.3, while patch materials are made of copper. Calculating the value of the initial antenna parameters will be optimized by sweeping the parameters to obtain the desired return loss, VSWR, gain, bandwidth, and directivity. The results of optimization of the rectangular microstrip antenna design 1x2 array work at a frequency of 3.5 GHz with a return loss -12.54 dB in the frequency range 3. 47 GHz up to 3.53 GHz, bandwidth 66.5 MHz, VSWR value of 1.6 and produce a gain of 5.5 dB.

1. Introduction

With the increasing number of users, the frequency allocation is decreasing due to limited channel bandwidth. In the same frequency bandwidth, the number of users cannot exceed the specified limit. Also, co-channel interference increases with an increase in the number of users. After the evolution of high definition video (HD) resolution and quadruple high definition (QHD), it became tough for handheld devices to send or receive large volume videos on 3G and 4G frequency channels. Thus, it is necessary to have wider bandwidth and faster data rates for short transmission and wireless reception of high-quality multimedia from one terminal to another. To solve this problem, 5G frequencies are being scrutinized for their wider bandwidth. 5G offers a greater bandwidth with a more significant number of frequency channels compared to 3G and 4G making it suitable for an increasing number of users demanding fast data speeds on the go.

In recent times 5G technology is being projected in Indonesia, 5G technology is a new generation in radio systems that have a network architecture that presents broadband connectivity, ultra-robust, extremely low latency to massive network for the community and internet of things [2]. The application of 5G technology is to use frequencies in high-frequency domains but has a small wavelength, or that is covered with Millimeter Wave (mmWave) [3]. Millimeter-wave frequency is a high domain frequency name with a carrier frequency range between 3 GHz – 300 GHz, in millimeter-wave technology developed for short-distance service communication but can also be used as a backbone in communication network systems. The best frequency range candidates in Indonesia have frequencies of 700 MHz, 3.5 GHz, 26 GHz, and 28 GHz [4]. The world's 5G frequency range has diverse candidates for more details to be seen in the table below.

Table 1. Frequency band candidates in the world [5]

No	Country	Spectrum Band
1.	Australia	3575–3700 MHz; 25.25–27 GHz
2.	China	3300–3600 MHz ; 4800–5000 MHz; 24.75–27.5 GHz; 37–43.5 GHz
3.	Hong Kong	between 3300 MHz and 3400 MHz; between 3400 MHz and 3600 MHz; 4830-4930 MHz; 24.25 Hz to 28.35 GHz
4.	India	3600 MHz; 3600-3700 MHz, 24.25–27.5 GHz, 27.5–29.5 GHz; 29.5–31.3 GHz, 31.8–33.4 GHz; 37– 43.5 GHz
5.	Indonesian	24.25–27 GHz; 27–29.5 GHz; 3.4–3.6 GHz
6.	Japan	3.6–4.2 GHz; 4.4–4.9 GHz; 27–29.5 GHz
7.	South Korea	3.42–3.7 GHz; 26.5–28.9 GHz
8.	Malaysia	700 MHz
9.	New Zealand	3410, 3690 MHz; 24.25–28.35 GHz; 1427–1518 MHz
10.	Pakistan	3500 MHz
11.	Singapore	800 MHz; 1427-1518 MHz; between 3400 MHz and 3600 MHz; 24.25-29.5 GHz
12.	Taiwan	3400 MHz; 3600 MHz; 28 GHz
13.	Thailand	850 MHz; 1800 MHz
14.	Vietnam	700 MHz ; 2600 MHz ; 24.25–27.5 GHz; 27–43.5 GHz

The evolution of mobile communication technology has had a huge impact on the lives of the world's people. In the last decade we have witnessed a revolution in how humans communicate, share ideas and live through wireless communication networks. Both use third generation (3G) and fourth generation (4G) mobile networks. The world is currently preparing with the fifth generation (5G) as a *platform* that can integrate various wireless communication technologies with various types of services in it as well as the ability to provide connections whenever and wherever we are. Based on Vigilante [6] and Dahmal[7] t5G ecology will surpass previous technologies giving birth to a term called *networked society,* which is a connection that can reach everything around us.

In cellular telecommunication systems, antennas are one of the most important components. The use of high frequencies can cause the dimensions of an antenna to shrink, so 5G technology requires an antenna that is easy to integrate. One type of antenna that is suitable to be a candidate for 5G technology, namely microstrip antennas. Microstrip antennas are thin, small, easy to integrate and can operate at high frequencies. However, microtsrip antennas have a disadvantage, namely narrow *bandwidth* [8], so special techniques are needed to be able to increase the *bandwidth of* microstrip antennas. In addition, microstrip antennas produce a small gain, so the technique of array preparation is needed. Array array array arrangement can increase *the gain* and rectivity of an antenna [8], so that the direction of the antenna beam becomes more directional. This is indispensable in 5G technology [9].

In the previous study in 2019, research that has been conducted by (Fajar Wahyu Ardianto, et al., 2019), has conducted research by designing a microstrip antenna with *a rectangular patch* shape that is added *U-slot*on the patch with the aim to increase antenna *bandwidth* and ableto work at a frequency of 28 GHz, then arranged in *an array* of 1×2 to increase antenna *gain.* In addition, the designed antenna has a unidirectional radiation pattern and is linearly polarized. Thus, antennas are used for communication purposes in 5G [10] technology. In this study, researchers will design and analyze the performance of the *rectangular* 1x2 *array* microstrip antenna at a frequency of 3.5 GHz and expected the results of the Voltage Standing Wave *Ratio* (VSWR) parameter test ≤ 2 and test the return *loss* parameters ≤ -10 dB.

2. Antenna Design

The microstrip antenna forms a rectangular patch 1x2 *array* working at a frequency of 3.5 GHz. The study used Cooper and FR-4 materials. Cooper material will be used as a patch and ground material with a thickness of 0.035 mm, while FR-4 material has a thickness of 1.6 mm used for substrate material. An antenna will work well if it meets several conditions, including having a Voltage Standing Wave *Ratio* (VSWR) value of ≤ 2, a return *loss* value of ≤ -10 dB, and a *gain* of ≥ 3 dBi.

The antenna design is designed to be able to work on Band-L frequencies. This study is expected to have the following parameters:

- Frequency : 3.5 GHz
- Dielectric constant : 4.3
- Dielectric thickness : 1.6 mm
- Conductor Thickness : 0.035 mm
- Substrate Type : Epoxy

Microstrip antennas consist of thick*(h),* width (W), and length (L). To design a rectangular patch microstrip antenna, calculations are performed using the following formula:

a. Dimensions of *Rectangular Patch* Microstrip Antenna

In *the* design of rectangular patches, the dimensions of the antenna need to be known are the length (L) and width (W), the thickness of the substrate material (h), and the dielectric constant of the substrate material (ε_r), the frequency of the working of the antenna (f_r) in units of Hz. In the design of rectangular patch *antennas* obtained with equations 1 to 4.

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \tag{1}$$

$$L = L_{eff} - 2\Delta L \tag{2}$$

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \tag{3}$$

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \tag{4}$$

As for calculating the length and width *of the ground plane* and *substrate* can be calculated using equations 5 and 6.

$$L_g = xh + L \tag{5}$$

$$W_g = xh + W \tag{6}$$

L_g is the length of the ground plane and substrate, is the width *of the ground plane* and *substrate*, and X is the multiplier factor with a value of ≥6.

b. Feed Channel Width on Rectangular Patch Microstrip Antenna

The width of the antenna utilization channel also greatly affects the performance of the antenna. Therefore the width of the antenna utilization channel can be calculated using equations 7 and 8.

$$w = \frac{2h}{\pi}\left\{B - 1 - \ln(2B-1)\frac{\varepsilon r-1}{2\varepsilon r}\left[\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon r}\right]\right\} \tag{7}$$

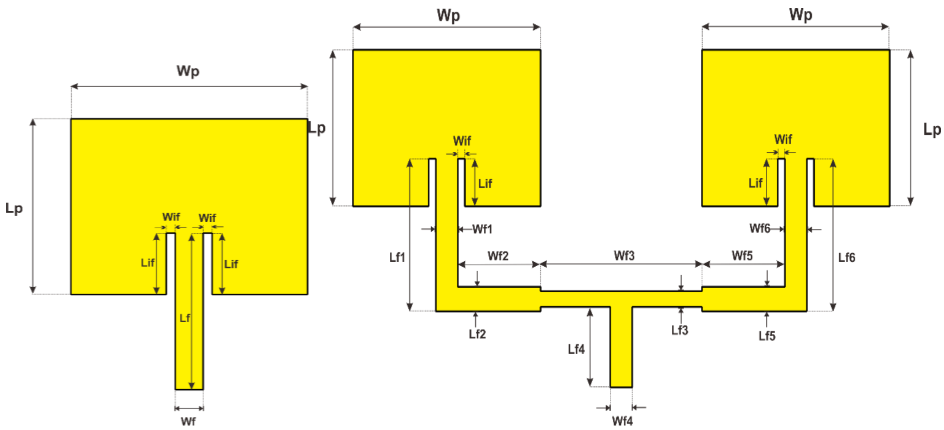
$$B = \frac{60\pi^2}{Zo\sqrt{\varepsilon r}} \tag{8}$$

h is the thickness of the substrate material, π is the constant that has a value of 3.14, ε_r is the dielectric constant of the substrate and Z is the impedance value of the feed line. From the equations described above, it can be known the importance of parameters to make the design of rectangular microstrip antennas as follows:

Tabel 2. Parameters of Single Patch Microstrip Antenna

Specifications	Symbol	Value
Patch Width	Wp	20 mm
Patch Length	Lp	26.3 mm
Feedline Width	Wf	17.8 mm
Feedline Length	Lf	3.1 mm
Patch Thick	t_p	0.035 mm
Width of Ground	Wg	40.4 mm
Ground Length	Lg	52.6 mm
Thick Ground	t_g	0.035 mm
Width Substrate	Ws	40.4 mm
Substrate Length	Ls	52.6 mm
Substrate Thickness	h	1.6 mm
Width of Insert Feeding	Wif	1 mm
Length of Insert Feeding	Lif	7 mm

Once the entire parameter value is known, the researcher can create a single patch microstrip antenna design as in figure 1. a and Figure 1.b is a combination of a patch, substrate, and ground plane design. The length and width of the ground plane element is the same as the substrate, but has a different thickness. The ground plane element is 0.035 mm thick using Copper, while the substrate thickness is 1.6 mm using FR-4.



(a) (b)

Figure 1. Single patch microstrip antenna design and 1x2 patch array

Figure 1.a is a single patch microstrip antenna design, and figure 1.b is a 1x2 microstrip array antenna design. After the design of the simulation software and the values calculated by the equations described above for the design antenna design and can be known the values of parameters to create the design of a rectangular 1x2 array microstrip antenna are as follows:

Table 3. Parameters of 1x2 Array Rectangular Microstrip Antenna

Specifications	Symbol	Value
Patch Length	Lp	19.5 mm
Patch Width	Wp	26.5 mm
Feedline Length$_{1.6}$	Lf	19.29 mm
Feedline Width$_{1.6}$	Wf	3.1 mm
Feedline Length$_{2.5}$	Lf	3.1 mm
Feedline Width$_{2.5}$	Wf	11. 7 mm
Feedline Length$_3$	Lf	2 mm
Feedline Width$_3$	Wf	22.7 mm
Feedline Length$_4$	Lf	10.19 mm
Feedline Width$_4$	Wf	3.1 mm
Patch Thick	t_p	0.035 mm
Width of Ground	Wg	70 mm
Ground Length	Lg	100 mm
Thick Ground	t_g	0.035 mm
Width Substrat	Ws	70 mm
Substrate Length	Ls	100 mm
Substrate Thickness	h	1.6 mm
Width Insert Feeding	Wif	1 mm
Length Insert Feeding	Lif	6 mm

Once the entire parameter value is known, the researcher can create a rectangular 1x2 *array* microstrip antenna design as in figure 1.b above. Patch elements use Copper material with a material thickness of 0.035 mm. The design of the microstrip rectangular 1x2 *array* antenna patch element consists of 2 rectangular antenna elements. The feedline is used as a connection between patches that can be searched by the *Wilkinson power divider technique.* Design a 1x2 array microstrip rectangular antenna patch with a patch length of 19.5 mm and a patch width of 26.5 mm at a frequency of 3.5 GHz.

3. Antenna Result

Antenna measurement starts from a working simulation at a frequency of 3.5 GHz with a 1x2 array microstrip antenna design for 5G communication with several specifications, namely rectangular patch shape, 3.5 GHz frequency, produces a return loss value of less than -10 dB with a gain of more than 3 dBi, has a VSWR value of 0 to less than equal to 2 and vertical polarization.

Return Loss

Return loss compares the amplitude of the reflected wave to the amplitude of the transmitted wave. *Return loss* can occur due to impedance discrepancy*(mismatched)*between the transmission line and load input impedance (antenna). The return loss value must be less than -10 dB for the antenna to be used. So the smaller the return loss value, the better the antenna to be designed.

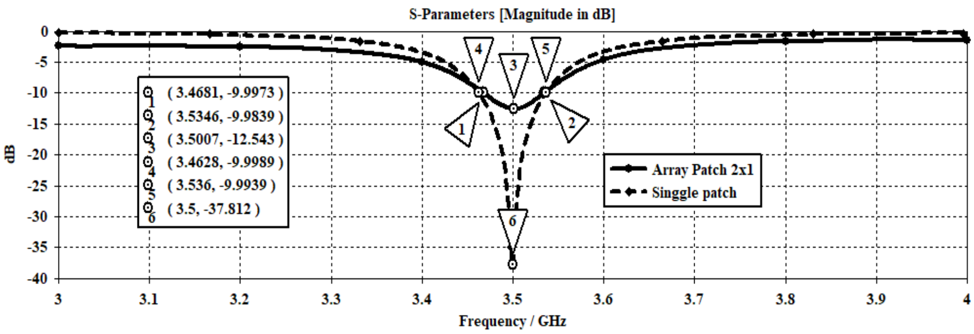


Figure 2. S-Parameter Simulation Results

Figure 2 above is a graph of the combination of return loss values for single patch antennas and 1x2 array antennas. It can be seen from the graph above that the return loss value for the single patch antenna is symbolized by the type of dashed line and diamond shape marker, the return loss value found at the 3.5 GHz intermediate frequency is -37.812 dB, the return loss value found at the lower frequency 3.4628 GHz is -9.9989 dB, and the top frequency of 3.536 GHz is -9.9939 dB, resulting in a bandwidth of 73.2 MHz. The return loss value on the 1x2 array antenna is symbolized by the type of solid line and circular shape marker, the return loss value contained in the 3.5 GHz intermediate frequency is -12,543 dB, the lower frequency of 3.4681 GHz is -9.9973 dB, and the upper frequency is 3.5346 GHz. of -9.9839 dB resulting in a bandwidth of 66.5 MHz.

Voltage Standing Wave Ratio (VSWR)

VSWR is the ratio between the maximum standing wave amplitude (standing wave) (| V|max) with minimum (|V|min). There are two components of voltage waves in the transmission line, namely the voltage transmitted (V0 +) and the reflected voltage (V0-). The comparison between the reflected voltage and the one transmitted is referred to as the voltage reflection coefficient(Γ)[12].

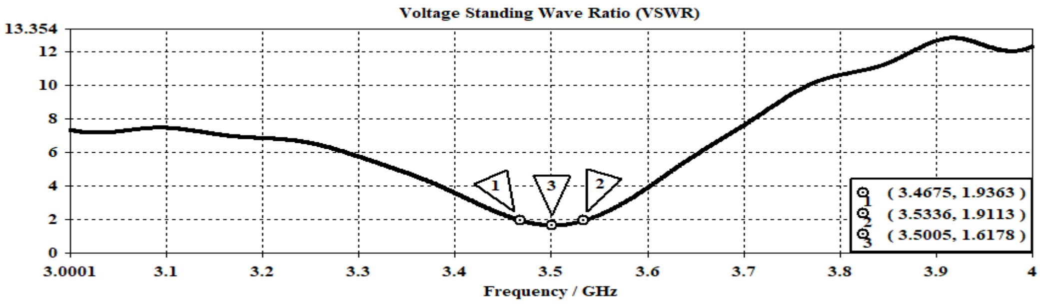


Figure 3. VSWR simulation results

In figure 3 above, it can be known that the Voltage Standing Wave Ratio (VSWR) value on the 1x2 array microstrip antenna with a frequency of 3.5 GHz is 1.16178, which means the simulation results are still categorized in both because it is still within the maximum VSWR limit of below 2, there is a frequency below 3.4675 GHz VSWR value of 1.9363 and upper frequency 3. 5336 GHz by 1.9113. For VSWR values on single patch microstrip antennas with an intermediate frequency of 3.5 GHz of 1, frequencies below 3.4628, VSWR values of 1.95, and upper frequencies of 1.92.

Gain

A *gain* is related to the antenna's ability to direct its signal radiation and also the reception of the signal from a certain direction. *The gain* of an antenna is the ratio of the maximum radiation intensity of an antenna to the radiation intensity of a reference antenna with the same *input* power. The amount of antenna *gain* is expressed in dB units against the reference antenna. Figure 5 below shows the frequency graph against the gain value with the unit dB, in the graph there is a value of frequency and gain [11].

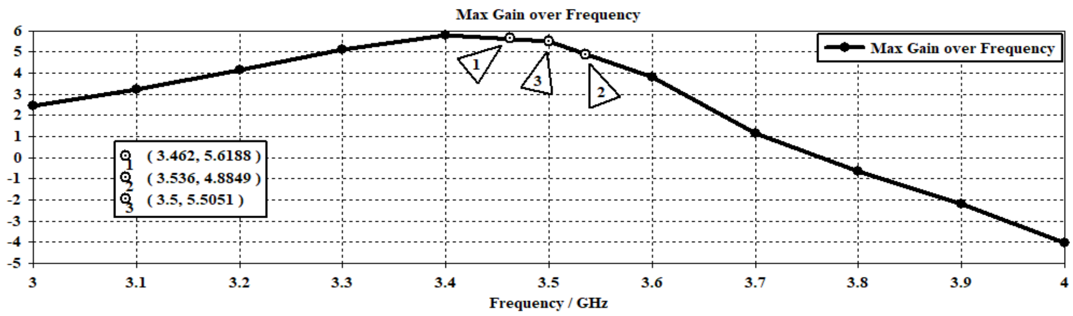
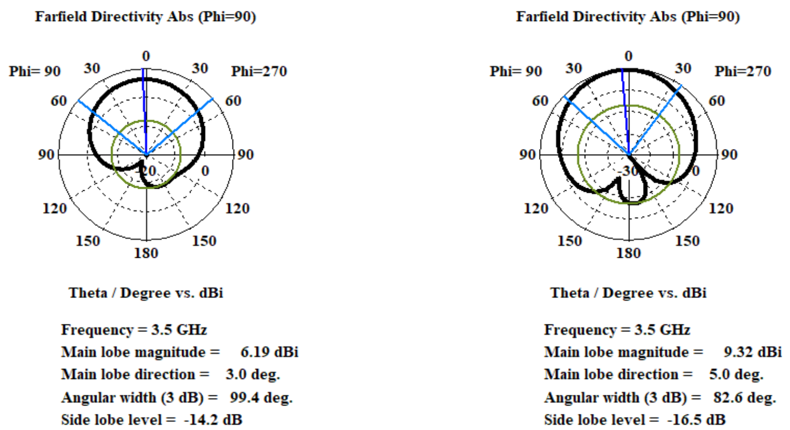


Figure 4. 1x2 Array Microstrip Antenna Gain Value

In the design of rectangular antenna 1x2 array for 5G communication with a frequency of 3.5 GHz. In figure 5 above, it can be known that the value of gain at the intermediate frequency of 3.5 GHz is 5.5051 dB, at upper frequencies 3.536 produces a gain of 4.8849 dB, and at frequencies below 3.462, the gain value is 5.6188 dB. The microstrip antenna single patch produces gain at intermediate frequency 3.5 GHz of 5. 4668 dB, while at the top frequency 3.536 GHz is 5.4598 dB, and at frequencies below 3.462 GHz has a gain value of 5.4937 dB.

Radiation Pattern

A radiation pattern is a graphically characteristic image of the radiation of an antenna. Antenna radiation patterns are called*field patterns*if theones depicted are strong fields. To state radiation patterns graphically, radiation patterns can be described in absolute or relative form. Relative form means a normalized radiation pattern, where each value of the radiation pattern is divided by its maximum value. In figure 6 below shows a graph of radiation patterns resulting from simulated directivity of single antenna microstrip antennas and 1x2 arrays.



(a) (b)

Figure 5. Results of Simulation of Radiation Pattern single patch and array patch 1x2

In figure 6.a above, it can be known that the value of the result of the antenna radiation pattern at a frequency of 3.5 GHz produces the main lobe magnitude of 6.19 dBi, main lobe direction of 3.0 degree, angular width (3dB) of 99.4 degrees, and sidelobe level of -14.2 dB. In figure 6.b, main lobe magnitude value of 9.32 dBi, main lobe direction of 5.0 degree, angular width (3dB) of 82.6 degrees, and sidelobe level of -16.5 dB.

4. Conclusions

The result of the design of a rectangular 1x2 array and single patch microstrip antenna with a frequency of 3.5 GHz, then the conclusion that can be taken is for the 1x2 array microstrip antenna to produce a return loss value of -12.6 dB, VSWR 1.6, gain 5.5 dB, bandwidth 66.5 MHz. On microstrip antenna single patch produces a return loss value of -37.8 dB, VSWR 1, gain 5.5 dB, bandwidth 73.2 MHz.

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