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2×1 Truncated Corner Microstrip Array Antenna to Increase Gain and Bandwidth for LTE Applications at 2.3 GHz Frequency

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Abstract

In the development of telecommunications in Indonesia, cellular networks, especially 4G, have grown rapidly since the launch of 4G LTE services. In the implementation of LTE, an antenna that has performance values of bandwidth, working frequency, VSWR, and gain that meets the specifications was needed. This research aims to study a microstrip antenna for LTE applications at a frequency of 2.3 GHz on its effect on the gain and bandwidth parameters using the 2×1 array method and the truncated corner which was simulated using HFSS software. The microstrip antenna was made using FR4 substrate with a thickness (h) of 1.6 mm and a dielectric constant (ε_r) of 4.4 with an expected working frequency of 2.3 GHz with the desired parameters return loss ≤ -10 dB, VSWR ≤ 1.5, gain > 2 dB, and bandwidth > 200 MHz in the simulation. Based on the simulation results of the microstrip antenna with the 2×1 truncated corner array method, the return loss value= 18.171 dB, VSWR= 1.281, gain= 3.963 dB, and bandwidth= 283 MHz, which worked at a frequency of 2.3 GHz. Meanwhile, based on the results of the antenna measurements that have been implemented, the return loss value was= 11.07 dB, and the VSWR= 1.49, which works at a frequency of 2.2 GHz.

Keywords: microstrip antenna, HFSS, LTE (Long Term Evolution), truncated corner.

I. INTRODUCTION

The technology that is currently developing in the field of cellular communication is the LTE technology developed by 3GPP. Cellular networks in Indonesia are also growing rapidly, especially since the launch of 4G LTE services in 2014. This technology has been used on a global scale. The LTE system is an application that utilizes many frequency interval conditions or is given the term multiband. Therefore, in the implementation of LTE, an antenna device that can maximize LTE performance is needed, especially for the gain and bandwidth requirements. One type of antenna that is often used in the data transmission process is the microstrip antenna.

There have been several previous studies proposing antennas for LTE systems. These studies proposed a microstrip antenna with several methods. Among them were using a 4×4 MIMO microstrip antenna [1], which produced a gain of 7.3 dB and a bandwidth of 251.5 MHz at a frequency of 2.4 GHz and a microstrip antenna using a 2×1 truncated corner array method [2] which produced a gain of 7.974 dB at a frequency of 2.3 GHz. Previous contributions were using a rectangular microstrip antenna with a U-slot [3] which produced a return loss value of -14.55 dB, Voltage Standing Wave Ratio (VSWR) of 1.4, a gain of 3.72 dB and bandwidth of 111 MHz at a frequency of 1.8 GHz and using a dual-band rectangular microstrip antenna [4] which produced a bandwidth of 1.928 MHz and a gain of 4.8 dB at a frequency of 2.4 GHz. Then further research [5] was using a 2×2 MIMO microstrip antenna which produced a bandwidth of 85.3 MHz and a gain of 5.011 dB at a frequency of 1842.5 MHz.

Therefore, in this study, a 2×1 truncated corner microstrip array antenna is designed for 4G LTE applications with the aim of increasing bandwidth and gain using the array and truncated corner method, and this antenna is simulated with the help of a finite element method solver from electromagnetic software. The desired gain is at least 2 dB and bandwidth > 200 MHz in the simulation, return loss ≤ -10 dB, VSWR ≤ 1.5 from a frequency of 2300 MHz.

II. MICROSTRIP ANTENNA DESIGN

In the manufacture of microstrip antennas, the most important thing is to determine the size and design of the antenna as well as its application and the working frequency used, so that it can simplify the process of making microstrip antennas when using the software.

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A. Flow diagram

In the process, the 2×1 truncated corner microstrip antenna has several stages which can be seen in Figure 1. The initial design stage is conducting a literature study, then calculating the dimensions of the antenna according to the calculation and simulating it using software to get optimization results from a single element rectangular microstrip antenna, and last, designing and simulating a microstrip antenna with the truncated corner method in order to obtain better optimization results than the rectangular microstrip antenna. The next step is to design and simulate the microstrip antenna with a 2×1 rectangular array method so that better optimization results than the previous design are obtained. After optimizing the 2×1 rectangular array method, the design is carried out using the 2×1 truncated corner array method, and simulation is done. If the results are still not in accordance with the desired parameters, then optimization is performed again. The next step is to analyze if the results are desirable. Furthermore, the microstrip antenna simulation results are implemented and then measurements are carried out in the laboratory after the measurements are made. The results of the measurement of the antenna parameters were analyzed to determine the difference between the measurement results and the simulation. The next step is to analyze if the results are desirable. Furthermore, the microstrip antenna simulation results are implemented and then measurements are carried out in the laboratory after the measurements are made. The results of the measurement of the antenna parameters were analyzed to determine the difference between the measurement results and the simulation. The next step is to analyze if the results are in accordance with the desired standard. Furthermore, the microstrip antenna is realized and then measurements are carried out in the laboratory after the antenna is made. The results of the measurement of the antenna parameters were analyzed to calculate the same goal as the previous step did.

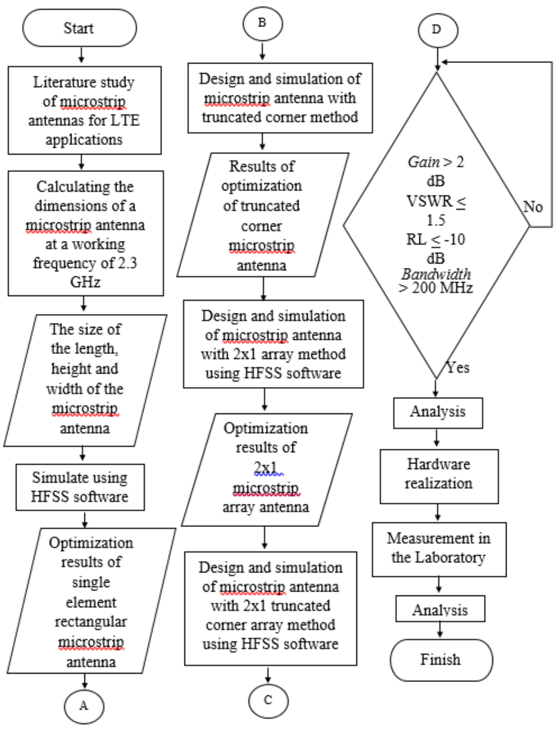

Figure 1. Flowchart of 2×1 truncated corner microstrip array antenna design

B. Microstrip Antenna

Microstrip antennas are very suitable for today's needs so that they can be integrated with other compact telecommunications equipment. However, the microstrip antennas as shown in Figure 2 also has several drawbacks, including restricted bandwidth, low directivity, and low efficiency. As a result, several ways must be used to adapt the microstrip antenna to overcome these flaws [6].

In designing a microstrip antenna, mathematical calculations are needed in determining the size of the antenna, the following is the formula used to design a square microstrip antenna. The design of the antenna begins by calculating the width of the radiating element (W) following the formula (1) [8].

$$W_{cw} = \frac{c}{2f\sqrt{\frac{\varepsilon r+1}{2}}} \tag{1}$$

where W_{cw} is the conductor width, εr is the relative dielectric constant, c is the speed of light (3×10^8), and f is the antenna working frequency.

Next, calculate the length of the radiating element as written in (2) [9],

$$L_{re} = L_{eff} - 2\Delta L_{RP} \tag{2}$$

to find the effective length, we can use (3).

$$L_{eff} = \frac{c}{2f\sqrt{\frac{\varepsilon r+1}{2}}} \tag{3}$$

Effective dielectric constant value is calculated using (4) [10].

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \tag{4}$$

where ε_{reff} is the effective dielectric constant, w is the width *patches* in mm, L_{eff} is effective length in mm, and h is the substrate thickness in mm.

Edge field effects on radiating elements is represented as (5) [11]. This radiating element is generally referred to as a radiator patch since it is formed

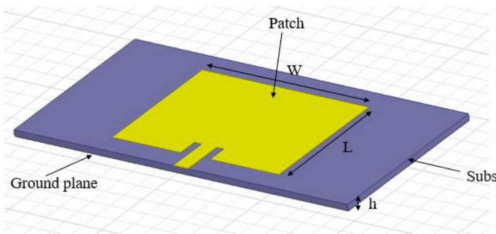

Figure 2. Parts of a microstrip antenna [7]

of a metal layer with a specific thickness. Copper has a conductivity of 5.8×10^7 S/m and is often used to make radiating elements.

$$\Delta L = 0.412 \times h \frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.256)(\frac{W}{h}+0.8)} \qquad (5)$$

A substrate is a dielectric material with a specific thickness, relative dielectric constant, and dielectric loss tangent. Because the substrate's length and width are the same as the ground's, the width of the substrate can be calculated using (6) [12]. Meanwhile, to find the length of the substrate, we can use (7) [13].

$$W = W_{cw} + 6h \qquad (6)$$

$$L = L_{re} + 6h \qquad (7)$$

C. Truncated Corner Microstrip Antenna

A truncated corner microstrip antenna is an antenna with a patch shape that is cut diagonally from the top right corner and the bottom left corner or vice versa, apart from being cut diagonally, the shape of the corner pieces can be shaped as desired in the form of a triangle, square, or semi-circle. The purpose of cutting the patch angle of the microstrip antenna in this study is to produce a large gain value and wide bandwidth, which can be seen in Figure 3. To determine the dimensions of the length of the cut at the edge of the patch antenna we can use (8) [14].

$$\Delta \mathrm{L_{TC}} = \frac{1}{4} \times \mathrm{L_{re}} \qquad (8)$$

D. Antenna Array (Array)

An antenna array (array) is an antenna made up of multiple elements that are connected to each other and arranged to form an antenna, as shown in Figure 4. To obtain the distance between the antenna elements in the array method, we can use (9) and (10).

$$\mathrm{d(ecp)} = \frac{\lambda}{2} = \frac{C}{2f} \qquad (9)$$

Figure 3. Method of a square truncated corner on microstrip antenna

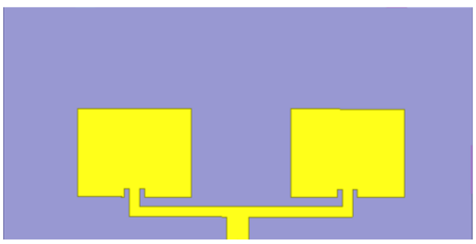

Figure 4. Antenna array (array)

Equation (9) is the distance between elements measured from the center point of the element to the center of the adjacent element. Meanwhile, to find the side distance between elements, we can use (10) [15]:

$$d = d(ecp) - w \qquad (10)$$

E. Antenna Parameters

In analyzing the performance of an antenna, parameters are needed to determine whether or not the antenna is good, the following are the parameters on the antenna:

1) *Gain*

The gain of a unit antenna is the ratio of its power density to that of a reference antenna in the same direction and with the same input power. Equation (11) can be used to find the gain value [16].

$$G = \eta \times D \qquad (11)$$

2) *Directivity*

The ratio of the radiation intensity in one direction to the average radiation intensity is known as directivity. Equation (12) can be used to get the directivity value [17]:

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}} \qquad (12)$$

where D is the directiveness, U is the radiation intensity, U_0 is the radiation intensity at an isotropic source, and P_{rad} is the total radiation power.

F. Transmission Line

The transmission line is a layer made up of conductors made of the same material as the patch and ground, and it consists of a line (strip) with a width (w) that is separated by a substrate with a thickness that is determined by their respective requirements. The transmission line of a microstrip antenna has two characteristics: one for W/h < 1 and another for W/h > 1, where W is the strip width and h is the substrate height. Equation (13) can be used to compute the dielectric constant W/h > 1 [18]:

$$\varepsilon_{eff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[\frac{1}{\sqrt{1+\frac{12h}{w}}}\right] \qquad (13)$$

Furthermore, to calculate the transmission line width (w), we use (14) [19]:

$$w = \frac{2h}{\pi}\left\{B - 1 - in(2B-1) + \frac{(\varepsilon r-1)}{2\varepsilon r}\left(in(B-1) + 0{,}39 - \frac{0.61}{\varepsilon r}\right)\right\} \qquad (14)$$

To find the length of the transmission line, we can use (15) [20]:

$$L = \frac{\lambda_g}{4} \qquad (15)$$

G. Inset Feed Line Feeding Technique

An example of a microstrip line feeding technique is the inset feed line. The patch resistance must be the same magnitude as the transmission line resistance (50 Ω). One model to match is to utilize an inset feed to estimate a resistance of 50 Ohms, which is the distance from the patch's edge; this value is known as the inset distance [21].

The length of the inset feed line (y_0) can be found using (16) [22].

$$y_0 = 10^{-4}(0.001699\ x\ \varepsilon_r{}^7 + 0.13761\ x\ \varepsilon_r{}^6 - 6.1783\ x\ \varepsilon_r{}^5 + 93.187\ x\ \varepsilon_r{}^4 - 682.69\ x\ \varepsilon_r{}^3 + 2561.9\ x\ \varepsilon_r{}^2 - 4043\ x\ \varepsilon_r + 6697)\ x\ \frac{L}{2} \quad (16)$$

Meanwhile, the width of the inset feed line or the width of the gap can be found using (17), the width of the gap (G) [23].

$$G_1 = \frac{1}{90}\left(\frac{w}{\lambda_0}\right) \quad (17)$$

H. 4G LTE

4G LTE refers to the fourth-generation standard, which is an advancement of 3G technology. Prior to 4G, WCDMA developed High-Speed Downlink Packet Access (HSDPA), often known as 3.5G technology, while EV-DO developed CDMA 2000 [24].

The frequency range for 4G LTE is 1800 MHz, 2100 MHz, and 2300 MHz. The greater the frequency, the better the bandwidth and data transfer capability provided. High frequencies, on the other hand, have the disadvantage of wave propagation being extremely susceptible to attenuation caused by obstructions. The appropriate antenna design is one of the technical methods for telecommunications engineers to deal with attenuation. On LTE/Advanced 2300 MHz, antennas with high gain and directional beamwidth can help overcome the difficulty of wave propagation. This antenna should be able to support high data transfer rates as well as quick customer/user movement [25].

III. MEASUREMENT, MANUFACTURING, AND DISCUSSION

A. Microstrip Antenna Design

The antenna design stage begins with determining the characteristics of the microstrip antenna used, the characteristics in investigation are antenna parameters such as working frequency, return loss, VSWR, gain, and bandwidth in Table 1.

The next stage in the design of the microstrip antenna is to determine the type of substrate to be used. In this research, the type of substrate is FR4 (epoxy) which has a thickness of 1.6 mm, with specifications that can be seen in Table 2.

TABLE 1
ANTENNA PARAMETERS

Parameter	Characteristics
Frequency of work	2.3 GHz
Return loss	≤ -10 dB
VSWR	≤ 1.5
Gain	> 2 dB
Bandwidth	> 200 MHz

TABLE 2
SUBSTRATE SPECIFICATIONS

Parameter	Score
Substrate type	FR4 (epoxy)
Relative dielectric constant (ε_r)	4.4
Dielectric loss tangent ($tan\ \delta$)	0.0265
Substrate thickness (h)	1.6 mm

B. Microstrip Antenna Size Design

1) *Design radiating element width (W)*

Based on the results of calculations using (1), the size of the radiating element or patch with a width of 39.69 mm was rounded to 39.7 mm.

2) *Effective dielectric constant* (ε_{eff})

To find the value of the edge field effect on the radiating element, the value of the effective dielectric constant was needed. So based on the results of calculations using (4) the value of the effective dielectric constant is 32.22 mm.

3) *Edge field effect on radiating elements* (ΔL)

After obtaining the value of the effective dielectric constant, we found the value of the edge field effect on the radiating element based on the results of calculations using (5), which was 2.2416.

4) *The effective length of the radiating element* (L_{eff})

The effective length of the irradiating element will be used for calculating the length of the irradiating element based on the results of calculations using (3), which was 32.22 mm.

5) *Microstrip antenna patch length design (L)*

Based on the results of calculations using (2), the size of the radiating element or patch with a length of 29.97 mm was rounded to 30 mm.

6) *Design of substrate width and ground plane width (W)*

Because the calculation of the width and length of the substrate was the same as the size of the ground, then based on the results of calculations using (6), the result was that the width of the substrate was 49.29 mm rounded to 49.3 mm.

7) *Substrate length and ground plane length (L)*

The width of the substrate based on the results of calculations using (7) was 39.57 mm long rounded to 40 mm.

8) *Transmission line length design (L)*

In the design of the length of the transmission line using an impedance of 50 Ω from the results of calculations using (15), the results of the size of the transmission line with a length of 16.27 mm are rounded up to 16.3 mm.

9) Design transmission line width (W)

Based on the results of calculations using (14), it was obtained that the width of the transmission line was 50 Ω with a value of 3.01 mm which was rounded up to 4 mm.

10) Inset feed line (Fi) length design

For the design of the length of the inset feed line, it can be found using (16) so that based on the results of calculations using this equation, the length of the inset feed line was obtained with a value of 12.1 mm.

11) Gap width design/ inset feed line width (G)

Meanwhile, for the design of the width of the gap/width of the inset feed line using (17), the size of the width of the gap/width of the inset feed line can be found with a value of 3.3 mm.

12) Truncated corner design (Δ*L*)

Based on the results of calculations using (8), the results of the size of a truncated corner was 9.92 mm rounded up to 10 mm.

13) Design of t-junction channel width 50 Ω (W)

For the design of the width of the t-junction line with the same impedance as the transmission line, namely 50 Ω, based on the results of calculations using (14), the same as the equation for the width of the transmission line, we obtained a value of 3.01 mm rounded up to 4 mm.

14) Design of 50 Ω (L) t-junction channel length

Meanwhile, for the design of the 50 Ω t-junction channel length, it can be found using (9) which was the same as the equation for the distance between elements. Based on the results of the calculations, the length of a t-junction channel with a length of 65.2 mm minus 4 mm in the width of the transmission line was 61.2 mm

15) Design distance between elements (d)

In designing the distance between elements, the purpose of designing the distance between elements was so that the microstrip array antenna between one element and another does not overlap. Based on the results of calculations using (10), the results of the distance between elements are 20.2 mm.

IV. RESULTS AND DISCUSSION

Figure 5 shows the size of the microstrip antenna with the optimized substrate, patch size, transmission line, inset feed line, and ground, so that the best size on the substrate was obtained with a width of 90 mm and a length of 45 mm. As for the patch size with a width of 45 mm and a length of 33.5 mm and the transmission line with a width of 4 mm and a length of 10.6 mm, the inset feed line was 2 mm wide and 5.1 mm long, and for the ground that had a width of 9 mm with a length of 5 mm, it was 40 mm.

After optimizing the single element rectangular microstrip antenna, the parameters obtained are return loss of -11.628 dB, VSWR of 1.489, gain of 1.142 dB, while the bandwidth is 109 MHz.

After optimizing all parts of the rectangular microstrip antenna, the truncated corner method was

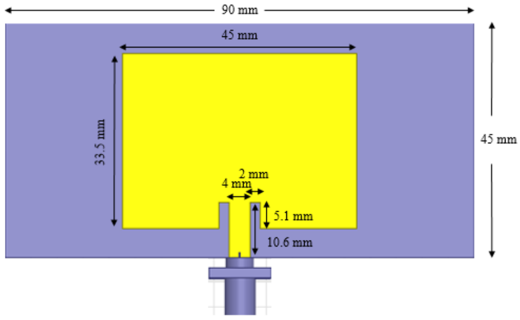

Figure 5. Rectangular single element microstrip antenna

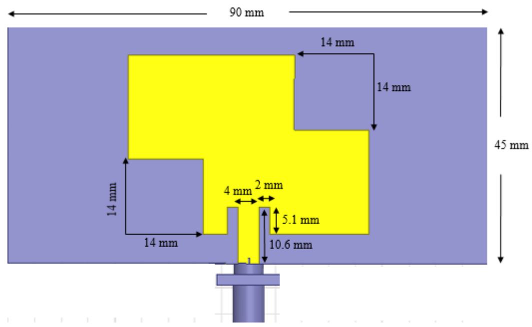

Figure 6. Microstrip truncated single element antenna

carried out and optimized on the cut corner of the patch in order to increase the gain and bandwidth according to the desired standard. It can be seen in Figure 6 that the antenna has been optimized at the edge of the patch. So that the best size obtained is with a length and width of 14 mm.

The size of the 14 mm truncated corner was in accordance with the expected parameters. The return loss was -23.024 dB, VSWR was 1.151, while the gain and bandwidth were not in accordance with the expected parameters where the gain is 1.832 dB, and the bandwidth was 170 MHz.

In Figure 7, the design of a 2×1 truncated corner microstrip antenna with a substrate, an inset feed line transmission line, a t-junction channel, the patch distance has been optimized while the truncated corner size was still the same as the previous size. So that this method results are in accordance with the desired parameter standards for return loss ≤ -10 dB, VSWR ≤ 1.5, gain > 2 dB and bandwidth > 200 MHz in simulation.

After optimizing the 2×1 truncated corner microstrip antenna, the parameters obtained are return loss of -18.171 dB, VSWR of 1.281, gain of 3.963 dB, and bandwidth of 283 MHz.

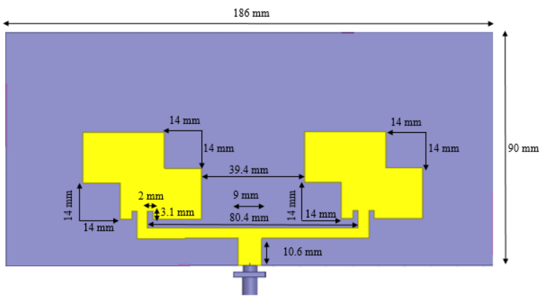

Figure 7. Microstrip antenna array 2×1 truncated corner

TABLE 3
COMPARISON OF SIMULATION RESULTS OF MICROSTRIP ANTENNAS FROM DIFFERENT MODELS

Microstrip antenna model	Rectangular single element microstrip antenna	2×1 truncated corner array mikrostrip antenna
Frequency (GHz)	2.3	2.3
S_{11} (dB)	-11.628	-18.171
VSWR	1.489	1.281
Gain (dB)	1.142	3.963
Bandwidth (MHz)	109	283

The comparison between the simulation results of a single element rectangular microstrip antenna and a 2×1 truncated corner microstrip array antenna can be seen in Table 3. There was an effect on the results of the return loss, VSWR, gain, and bandwidth parameters after using the truncated corner method. This is because the changes in the edge of the patch cause the VSWR to decrease. This is because the value of the reflection coefficient (Γ) is getting smaller so that the VSWR value decreases. The same thing happens with the return loss value, if the return loss is smaller, the reflection coefficient (Γ) is also getting smaller resulting in a change in the value of the VSWR.

Changes in the length and width of the truncated corner on the gain and bandwidth also show an increase. The increase in gain occurs when the directivity value is greater, both gain and directivity are related to each other in determining the ratio between the radiation intensity in a certain direction and the radiation intensity from an isotropic antenna. This can be proven from the gain and directivity formulas in (11) and (12), while the bandwidth parameter is extracted from the VSWR graph from the VSWR 1.5 point obtained with a wide bandwidth of 283 MHz. The effect of changing the truncated corner on the gain if the antenna is optimized is that the value is obtained according to the desired standard.

A. Radiation Pattern

After taking measurements to determine the value of S11, VSWR, gain, and bandwidth in a simulation, the next step is to take measurements to see the direction of the radiation pattern on the antenna in a simulation. It can be seen in Figure 8 that the radiation pattern on the rectangular single element microstrip antenna is directional which leads to the theta angle. The angle used is 90 deg, while in Figure 9 and 10 the single element truncated corner microstrip antenna and the 2×1 truncated corner array produce a bidirectional radiation pattern with an angle of 90 degree.

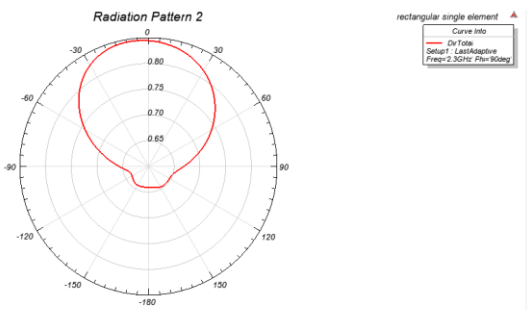

Figure 8. The radiation pattern of a single element rectangular antenna

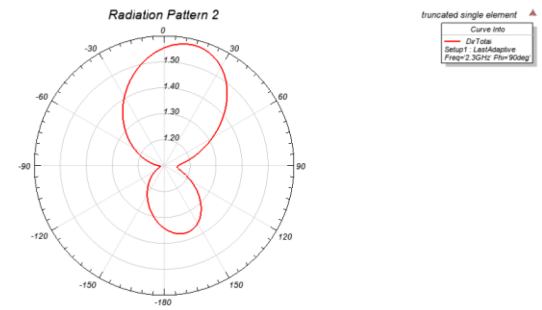

Figure 9. The radiation pattern of truncated corner single element antenna

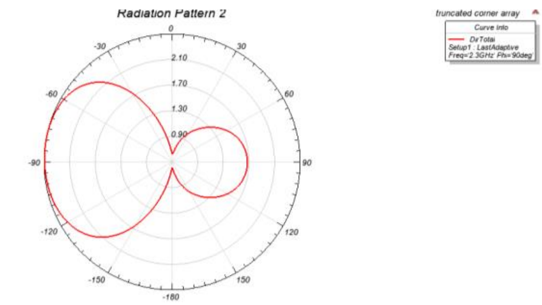

Figure 10. The radiation pattern of 2×1 truncated corner array antenna

B. Microstrip Antenna Realization

After doing the simulation using software and proceeding with analyzing the simulation, the value was obtained according to the desired parameter standard. Then the next step is to realize the microstrip antenna

Figure 11. Realization results of 2×1 truncated corner microstrip array antenna (front view)

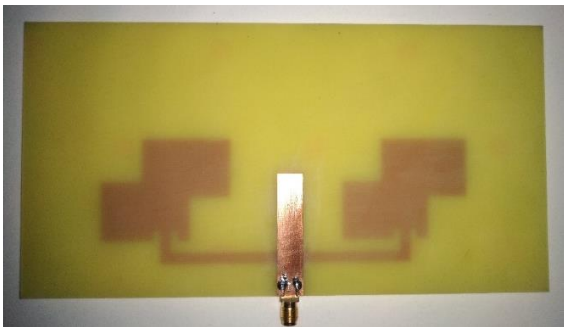

Figure 12. Results of the realization of a 2×1 truncated corner microstrip array antenna (back view)

with the help of vector graphics editor software to create a negative film layout.

The material used on the PCB was FR4 with a thickness of 1.6 mm in accordance with the desired specifications. PCB printing results can be seen in Figure 11 and Figure 12.

C. Microstrip Antenna Measurement

After the microstrip antenna was realized, the next step was to measure the antenna. Measurements were carried out to determine whether the parameters of the resulting antenna were in accordance with the desired parameters or not. The results of this measurement become a reference for the success of the 2×1 truncated corner microstrip array antenna that has been realized.

Figure 13 shows a microstrip antenna measurement scheme that has been realized. The equipment used in measuring the antenna include:

1. Vector Network Analyzer (VNA) AV3672 with a frequency range of 0 GHz to 13 GHz.
2. Connector cable.
3. Microstrip antenna.

Before measuring the VNA measuring instrument, calibration was carried out. After calibration, the connector cable was connected from the VNA port to the microstrip antenna port where the parameters measured include return loss and VSWR. For the gain parameter, measurements were not carried out due to the limited

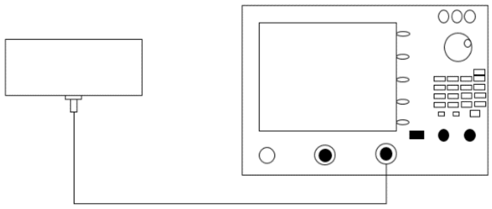

Figure 13. Schematic of measuring microstrip antenna

ability of the measuring instrument, and measurements were carried out at the Electrical Engineering Laboratory Unjani.

D. Comparative Analysis of Simulation and Measurement Results

After the microstrip antenna has gone through the simulation stage and optimization of the parts of the antenna was carried out until it was realized, measurements are carried out to determine the value of the microstrip antenna parameter. Measurements were made at the Electrical Engineering Laboratory Unjani, the parameters measured included return loss and VSWR.

Figure 14 and 15 show a comparison of the measurement and simulation results with the return loss and VSWR parameters. In the graphs of Figures 14 and 15, it can be seen that the simulation results of return loss

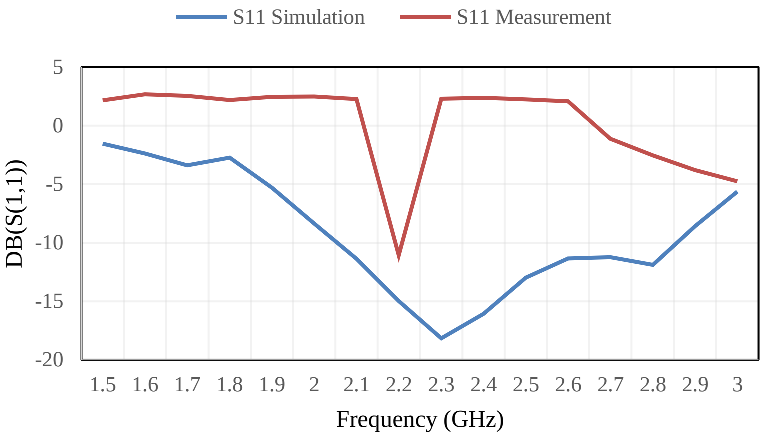

Figure 14. Comparison graph of S11 measurement and simulation results.

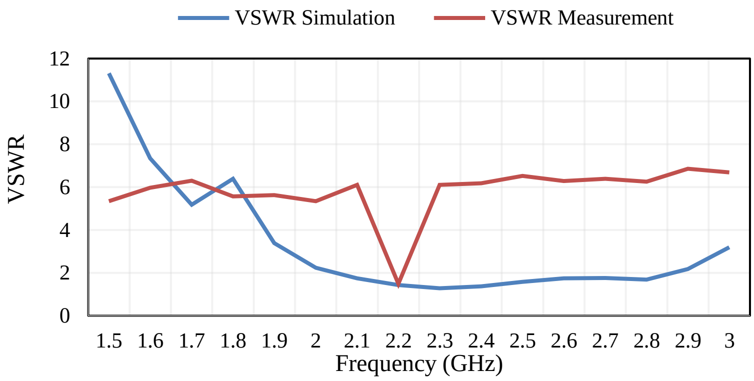

Figure 15. Comparison graph of measurement and simulation VSWR results.

and VSWR are better than the measurement results. For the simulation of the antenna working at a frequency of 2.3 GHz, the return loss value of the simulation results was -18.171 dB and VSWR 1.281. While the measurement results work at a frequency of 2.2 GHz with a return loss of -11.07 dB and VSWR of 1.49. This was due to several factors that could affect the measurement results including: (1) the size when manufacturing the antenna was less precise so that the size did not match the simulation, (2) the soldering process of the connector to the patch antenna that was not good so that the measurement results are less accurate, (3) losses in the coaxial cable, and also (4) the addition connector cable used during the measurement process. This causes the results of the return loss and VSWR parameters in the measurement to be greater than the simulation results, then when the measurements are not carried out in a conducive room, these factors also cause the working frequency to shift in the measurement results. We recommend that the measurement process was carried out in a more conducive room, for example in the anechoic chamber.

Meanwhile, from the measurement results of return loss and VSWR in Figures 14 and 15, it can be seen that the resonance condition is shown by the presence of a valley curve at a frequency of 2.2 GHz. This change occurs because the antenna is in a condition matching the 2.2 GHz frequency, causing a deeper valley than other frequencies.

However, the difference in the values obtained was not very significant, as proven by the return loss results that can be said to be quite good, namely $\leq$ -10 dB which was still in accordance with the desired standard. Likewise, in term of VSWR, the results are still in accordance with the expected standard, which is $\leq$ 1.5.

Gain measurement cannot be carried out due to limitations in the measurement tool so that only return loss and VSWR are measured.

V. CONCLUSION

From the results of the measurements, it can be concluded that the antenna works at a frequency of 2.2 GHz with a return loss value of -11.07 dB and a VSWR of 1.49. While the antenna simulation works at a frequency of 2.3 GHz with a return loss value of -18.171 dB, VSWR of 1.281, a gain of 3.963 dB, and a bandwidth of 283 MHz. This shows that there are differences in the results of antenna parameters in simulation and measurement, but the results are still in accordance with the desired standard, namely with return loss $\leq$ -10 dB and VSWR $\leq$ 1.5. The difference in parameter results and frequency shift in measurements was caused by the lack of precision in the dimensions of the antenna during the manufacturing process, poor soldering process, and the addition of a connector cable during measurement.

In the simulation results, it can be concluded that the microstrip antenna using the 2×1 truncated corner array method has better results than the single element rectangular microstrip antenna. For the microstrip antenna with the 2×1 truncated corner array method, the return loss value is -18.171, VSWR is 1.281, a gain is 3.963, and bandwidth is 283 MHz, while the rectangular single element microstrip antenna has a return loss value of -11.628, VSWR of 1.489, gain of 1.142, and bandwidth of 109 MHz. It proves that the truncated corner can improve the parameters, especially the most significant of those are the gain and bandwidth parameters according to the theory.

DECLARATIONS

Conflict of Interest

The authors have declared that no competing interests exist.

CRediT Authorship Contribution

Ahmad Heri Ilyasah: Resources, Data Curation, Writing - Original Draft, Visualization; M. Reza Hidayat: Conceptualization, Methodology, Software, Validation; Salita Ulitia Prini: Writing - Review and Editing.

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