Modification of 2.2 GHz S-Band Rectangular Patch Microstrip Antenna using Truncated Corner Method for Satellite Applications

Farid Armin[1], Astriany Noer[2], Kamirul[3], Suisbiyanto Prasetya [4]
LAPAN Biak Office
Indonesian National Institute of Aeronautics and Space
Biak, Indonesia
farid.armin@lapan.go.id [1], astriany.noer@lapan.go.id [2], kamirul@lapan.go.id[3], suisbiyanto.prasetya@lapan.go.id [4]

***Abstract*—This study aims to develop a rectangular patch microstrip antenna design that can work at a resonant frequency of 2.2 GHz to obtain circular polarization. The modification method used is truncated corner with a single microstrip feed channel, which cuts the patch's top and bottom edges as far as 45 degrees. The design and simulation of the microstrip rectangular patch antenna and the truncated corner antenna were carried out using Ansys HFSS v15 software, and the material used was FR4-Epoxy with a material thickness of h = 1.6 mm and a dielectric constant of 4.4. The simulation results of the two antennas' design can resonate well at a frequency of 2.2 GHz. The return loss of rectangular patch microstrip antenna is -28,377 dB, VSWR is 1.0778, bandwidth is ±150 MHz, and the axial ratio is 53.4022 with linear polarization. In comparison, the values of return loss, VSWR, bandwidth and the axial ratio of truncated corner antennas are -20.3793 dB, 1.2117, ± 150 MHz and 0.7934 dB with LHCP circular polarization, respectively.**

Keywords— Microstrip rectangular patch, microstrip antenna, truncated corner, circular polarization, satellite application

I. INTRODUCTION

Along with developing communication technology, antenna technology as an essential component of communication systems is also growing. Various innovations have been made to get an antenna that is simple but effective in its use. One of such innovations is the use of microstrip antennas. Microstrip antenna has a simple design because of its small shape and is very easy to be formed so that it does not require high costs in the manufacturing process. In addition, this microstrip antenna can also be easily integrated with other systems [1-4]. According to these advantages, microstrip antennas have been widely implemented in cellular technology, aircraft and satellite technology [5-6].

A microstrip antenna is a type of antenna in the form of a thin conductor plate with three main parts, namely the radiation element (patch) and the ground element. The two elements are separated by a dielectric material called a substrate. The patch antenna works as a radiating element that resonates according to its working frequency, while the ground plane serves as a grounding element for the microstrip antenna system. Meanwhile, the substrate is a dielectric material that affects the antenna size based on its material dielectric constant [7].

A microstrip antenna works well at the intended working frequency if it meets the parameter values, including the return loss ⩽ -10 dB, Voltage Standing Wave Ratio (VSWR) ⩽ 2 [7]. However, polarization also needs to be considered. In general, the polarization of microstrip antennas is linear [8]. This type of polarization has limitations including discontinuity of the radiation signal caused by direction shifting of the polarization from vertical to horizontal polarization or vice versa [9]. Meanwhile, in satellite communication, a continuous and stable signal level is required because they are continually moving. Therefore, circular polarization is a suitable polarization for satellite communication.

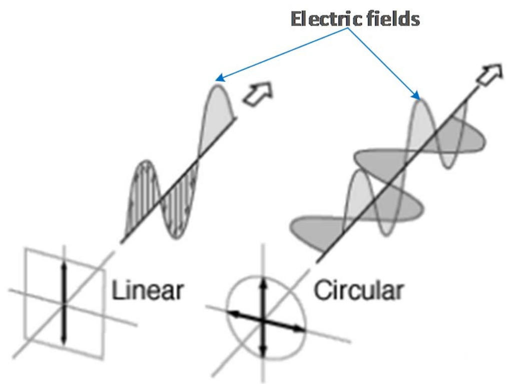


Fig. 1. Linear Polarization and Circular Polarization [10]

In the process of transmitting a signal, the antenna radiates electromagnetic waves with an electric field vector that varies with time. The antenna can produce circular polarization if the electric field vectors are perpendicular to each other with the same amplitude and the phase difference is an odd multiple of 90 degrees. Communication systems are generally well suited to using antennas that can operate with circular polarization. This is because the end path of the electric field vector rotates around the propagation axis as a function of time. As with ground station antennas and satellite antennas, circular polarization can provide signal continuity and removes the need to continuously align the two apertures, which would otherwise be required to maximize the received power. Also, circular polarization signals are not subject to the Faraday rotation effect [11].

Several studies have been carried out to obtain circular polarization in antennas by specific methods. The method commonly used is the truncated corner method using a single feed with aperture coupled and probe-feed feeding techniques. In the truncated corner, a 45-degree corner of the rectangular patch is cut. The most extensive current will flow at the patch angle of the microstrip antenna. However, due to the patch antenna angle cutting, there is a shift in the working frequency resulting in circular polarization [9]. To find out that the microstrip antenna design has circular polarization, it can be seen at the axial ratio value ⩽ 3 dB [12-13]

In this paper, a rectangular patch microstrip antenna resonating at 2.2 GHz (S-Band frequency range) has been designed for satellite communication applications. Since LAPAN-A2 / LAPAN-ORARI satellite has a downlink frequency of 2.2 GHz, the antenna can be used to communicate with the satellite in acquiring mission data. The antenna design is expected to have a return loss value ⩽ -10 dB, VSWR ⩽ 2, and a gain value ⩽ 10 dB. Furthermore, the patch antenna was modified with the truncated corner method using a single feed and microstrip line feeding technique by cutting the edge of the patch with a slope of 45 degrees to obtain circular polarization, which was indicated by the axial ratio value ⩽ 3 dB.

II. Antenna Design

A. Rectangular Patch Microstrip Antenna Design

The proposed microstrip antenna was designed with a rectangular patch and a resonant frequency of 2.2 GHz, which can work in the S-Band frequency range for satellite communication applications. The substrate material used is FR-4 Epoxy with a dielectric constant (Ɛr) = 4.4, dielectric loss tangent (•) = 0.002 and material thickness (h) = 1.6 mm. The size of the patch length (L) and patch width (W) of the antenna is obtained through the following calculations [7].

$$L = \frac{c}{2f_r\sqrt{\varepsilon_r}} \quad (1)$$

$$W = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (2)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{W}}}\right) \quad (3)$$

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}} \quad (4)$$

$$W_f = \frac{2h}{\pi}\left\{B - 1 - \ln(2B-1) + \frac{\varepsilon_r-1}{2\varepsilon_r}\left[\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\} \quad (5)$$

The supply line used in this antenna design is a microstrip line with an input impedance (Z_0) of 50 Ω. By using the equations (1), (2), (3) and (4) above and employing the speed of light constant (c = 3x108 m/s), the patch length (L), patch width (W), feed line width (Wf), and feed line length (Lf) are obtained as shown in Table I.

TABLE I. Summary of Dimension of Rectangular Patch Microstrip Antenna

No.	Parameter	Units
1.	Patch length (L)	32.12 mm
2.	Patch width (W)	41.12 mm
3.	Substrate length (X)	48 mm
4.	Substrate width (Y)	50 mm
5.	Substrate thickness (h)	1.6 mm
6.	Feed line width (W_f)	3 mm
7.	Feed line length (L_f)	9.2 mm

Fig. 2 shows the microstrip antenna design model with the specifications based on Table I. This model will be used for the simulation in order to obtain the return loss, VSWR and gain values at the resonant frequency of 2.2 GHz. Moreover, this simulation is also conducted to obtain the axial ratio value indicating the type of polarization of antenna design.

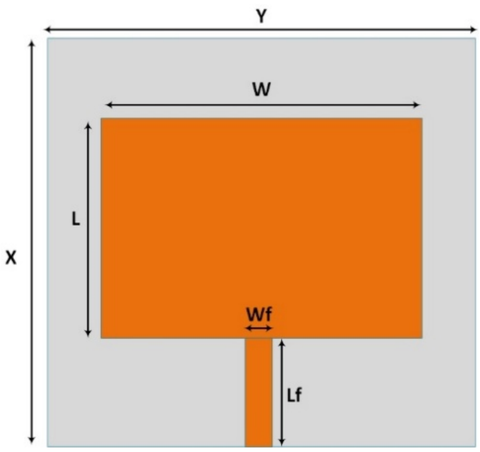


Fig. 2. Rectangular Patch Microstrip Antenna Design

B. Truncated Corner Method Antenna Design

One of the methods that can be used to obtain circular polarization in the rectangular patch microstrip antenna design is the truncated corner. In the truncated corner method, the patch's corner is cut to produce two resonant frequencies caused by two different diagonal lengths with a phase difference of 90 degrees between them [14]. Thus, circular polarization is obtained. The size of the cut angle on the patch can be calculated using (5) with a cutting angle of 45 degrees to the edge [9].

$$\Delta L = \frac{1}{8} x\, L \quad (5)$$

By cutting the top and bottom edges of the antenna patch, the diagonal of cut dimensions are 7.73 mm through calculations using (5). The antenna dimensions after the edges cut are shown in Table II.

TABLE II. Summary of Dimensions of Truncated Corner Microstrip Antenna

No	Parameter	Units
1.	Patch length (L)	31.6 mm
2.	Patch width (W)	31.6 mm
3.	Substrate length (X)	48 mm
4.	Substrate width (Y)	50 mm
5.	Substrate thickness (h)	1.6 mm
6.	Feed line width (W_f)	3 mm
7.	Feed line length (L_f)	9.2 mm
8.	Edge cut length (ΔL)	7.73 mm

Moreover, in Fig. 3, the antenna design model after cutting the top and bottom edges of the patch is shown. For the purpose of analysis, the simulation has been conducted by using two antenna designs to obtain the comparison of resulted return loss, VSWR, gain, and axial ratio values.

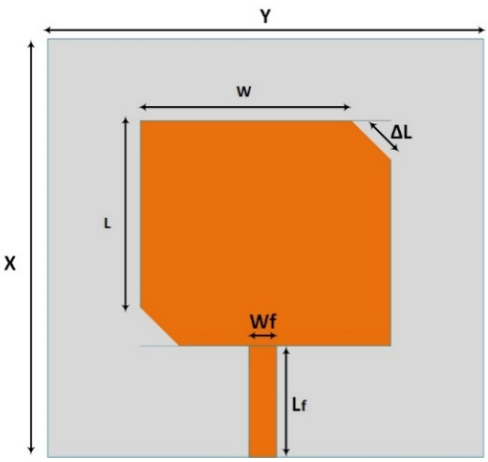


Fig. 3. Truncated Corner Microstrip Antenna Design

III. RESULT AND DISCUSSION

To obtain the return loss, VSWR, gain, and axial ratio values, a simulation using two antennas was conducted. The simulation was performed using Ansys HFSS v15 software. The comparison of return loss, VSWR, gain, and axial ratio resulted by the rectangular patch and truncated corner antenna designs are respectively shown in Fig.4., Fig.5, Fig.6, and Fig. 7. Moreover, the comparison of the simulation results as a whole is summarized in Table III.

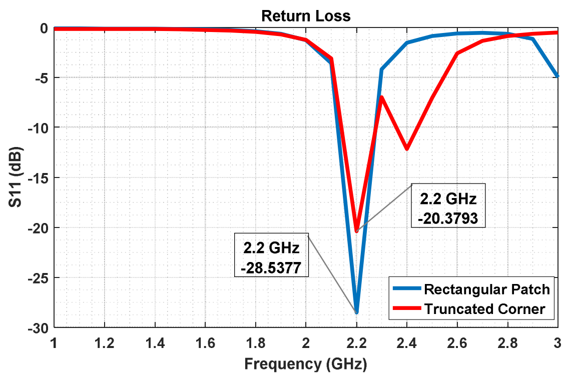


Fig. 4. Return Loss of Rectangular Patch & Truncated Corner

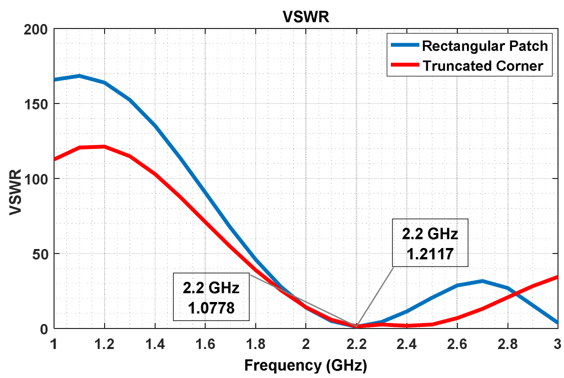


Fig. 5. VSWR of Rectangular Patch & Truncated Corner

Fig. 4 shows the trend return loss value of two antenna designs. It can be seen that both antennas resonate well at a frequency of 2.2 GHz with respective return loss values of -28.5377 and -20.3793, less than -10 dB. It is also shown that the return loss value on the truncated corner antenna has decreased compared to the rectangular one. This phenomenon happens since the edge of the patch is cut with a slope of 45 degrees, reducing the dimension of wave reflection and consequently decreasing the return loss value compared to the other antenna design. However, the resulted return loss value is still in the acceptable range since this value did not cross -10 dB. Moreover, based on VSWR values shown Fig. 5, the two designs are also ideal with the values of 1.0778 and 1.2117, in which is less than 2. The two antenna designs also have similar bandwidth, ± 150 MHz.

Fig. 6 shows the total gain value of the two antenna designs of 3.85 dB and 3.67 dB. This value is still considered to be implemented in satellite communication, but it is sufficient to meet the standard of microstrip antenna gain in general, i.e., ⩾ 3 dB.

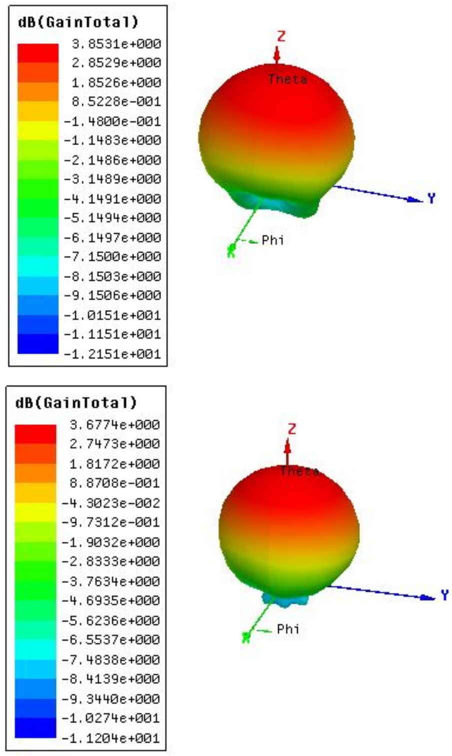


Fig. 6. Gain of Rectangular Patch & Truncated Corner

Fig. 7 shows the axial ratio value of the rectangular patch antenna, 53.4022 dB at 2.2. GHz. This value indicates that the antenna polarization is linear. In comparison, the axial ratio value of the truncated corner antenna is 0.7934 dB. This value is ⩽ 3 dB, which means that the polarization is circular polarization.

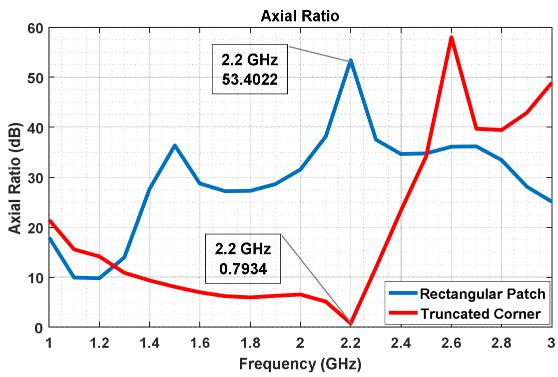


Fig. 7. Axial Ratio of Rectangular Patch & Truncated Corner

According to Table III, both of antenna designs have almost the same parameter values. However, there is a striking difference in the axial ratio value. Rectangular patch antennas do not have circular polarization, while truncated corner antennas have circular polarization. This is indicated by the axial ratio value ⩽ 3 dB, namely 0.7934 and the AR bandwidth value of 706 MHz, as shown in Fig. 8.

TABLE III. SIMULATION RESULTS OF THE TWO ANTENNAS

Parameter	Rectangular Patch Antenna	Truncated Corner Antenna
Return Loss	-28.5377 dB	-20.3793 dB
Bandwidth	± 150 MHz	± 150 MHz
VSWR	1.0778	1.2117
Gain	3.85 dB	3.67 dB
Axial Ratio	53.4022 dB	0.7934 dB

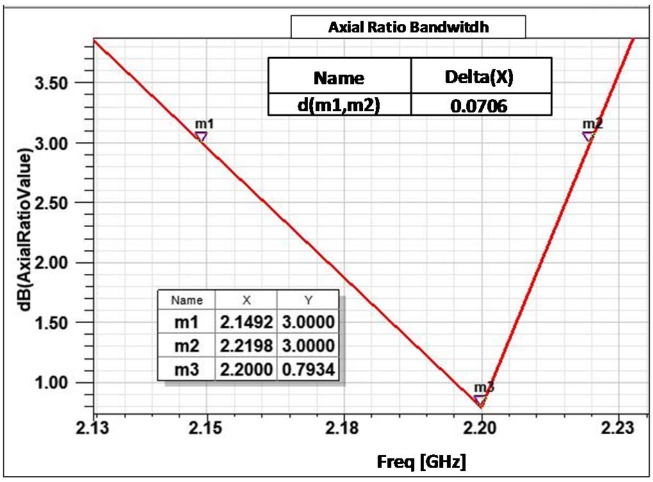
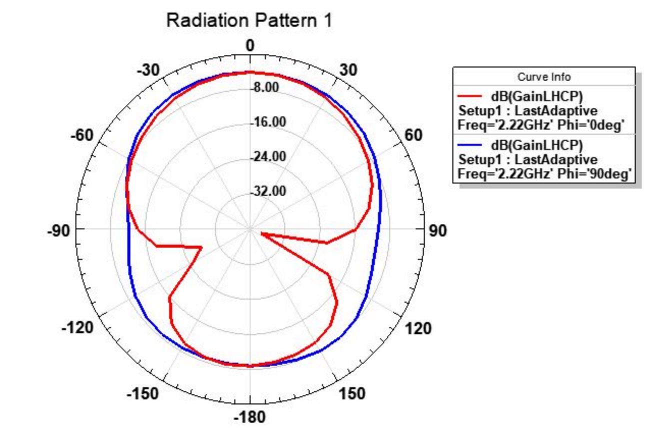
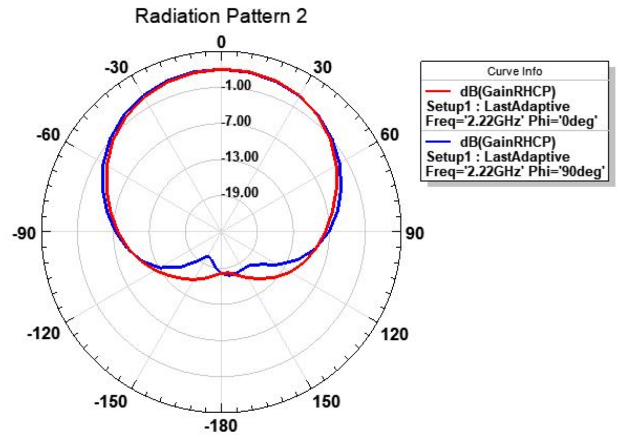


Fig. 8. Bandwidth Axial Ratio of Truncated Corner Antenna

With circular polarization on a truncated corner antenna, there are two types of polarization that occur, Left Handed Circular Polarization (LHCP) and Right Handed Circular Polarization (RHCP). The LHCP and RHCP gain values can be obtained from the simulation results as shown in Fig. 9.



(a)



(b)

Fig. 9. (a) LHCP and (b) RHCP Gain of Antena Truncated Corner

Fig. 9 shows the LHCP and RHCP gain of the truncated corner antenna with Φ = 0 degrees and 90 degrees at the resonant frequency of 2.2 GHz. The LHCP gain value at θ = 0 degrees is 4.082 dB, while the RHCP gain value at θ = 0 degrees is 2.01 dB. This shows that the antenna is more likely to work on LHCP. Thus the truncated corner antenna that has been designed can be implemented for satellite communications with the LHCP polarization tendency.

IV. CONCLUSION

The design and simulation of a rectangular patch microstrip antenna that can work at a resonant frequency of 2.2 GHz for satellite communication applications have been carried out. Based on the simulation results, the antenna can work well with a return loss value of -28.5377 dB, VSWR 1.0778 and a bandwidth of ±150 MHz. However, the polarization is still linear, so it is modified using the truncated corner method to get circular polarization. The truncated corner antenna simulation results show that the antenna can have circular polarization with an axial ratio value of 0.7934 dB and an LHCP polarization tendency. Meanwhile, the return loss, VSWR, and bandwidth values are not much different from the previous antenna simulation results with a return loss of -20.3793 dB, VSWR of 1.2117 and a bandwidth of ±1500 MHz.

Future work on this research is the antenna gain will be increased using the antenna array method as well as fabrication to verify the simulation data that has been done.

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