Design and Analysis of a 1x2 Triangular Patch Array Microstrip Antenna with Low Gain at a Frequency of 1,09 GHz for ADS-B Applications

Dhuha Rais[a]

[a] Telecommunication Engineering, Politeknik Negeri Padang, Padang, 20362, Indonesia

Corresponding author: dhuhagaul30@gmail.com

***Abstract*— Microstrip antennas are one of the popular technologies for wireless communication applications due to their compact dimensions and ability to operate at high frequencies. In this research, we designed and analyzed a 1x2 triangular patch array microstrip antenna operating at a frequency of 1,09 GHz, which is used in ADS-B systems. ADS-B is a communication system used in aviation to transmit aircraft position to ground-based receivers. The array antenna is designed to enhance the gain and directivity required in ADS-B applications. This antenna consists of two triangular patch elements symmetrically arranged on an FR4 dielectric substrate with a dielectric constant of 4,4 and a thickness of 1,6 mm. This design uses software simulation methods with CST Studio Suite 2019 to optimize antenna parameters such as input impedance, VSWR, gain, axial ratio, and radiation pattern. By applying the appropriate design techniques, this 1x2 triangular microstrip array antenna can achieve good performance in communication applications at a frequency of 1.09 GHz. Simulation results show that the antenna can operate within a frequency range of 0,5 GHz to 1,5 GHz, with a center frequency of 1,09 GHz, a return loss of less than -17 dB, and a bandwidth of 60 MHz. The gain produced is 0,67 dB. The radiation polarization generated is unidirectional. This research presents the success of the design and simulation of a 1x2 triangular microstrip patch antenna array operating at a frequency of 1,09 GHz.**

***Keywords*— CST Studio Suite 2019, ADS-B , 1,09 GHz, Triangular Patch**

Manuscript received 21 Sept. 2024; revised 30 Oct. 2024; accepted 6 Jan. 2025. Date of publication 2 Mei. 2025.

I. INTRODUCTION

The ADS-B (Automatic Dependent Surveillance-Broadcast) system is a surveillance system used by aircraft to transmit flight information such as position, altitude, and speed. This system operates at a frequency of 1.09 GHz and requires an antenna designed to transmit signals efficiently. Although high-gain antennas are often desired for long-distance communication, in some applications such as very dense areas or constrained conditions, low-gain antennas can offer advantages, such as avoiding interference and maintaining communication at closer and more controlled distances.This research aims to design and analyze a 1x2 triangular patch array microstrip antenna with low gain at a frequency of 1.09 GHz.

The antenna design will be analyzed in terms of return loss, VSWR, gain, bandwidth, and radiation pattern to ensure its performance meets the requirements of the ADS-B system, despite the low gain.

Microstrip antennas are known for their advantages in compact size and relatively low cost. The triangular patch antenna offers a more efficient structure in terms of space utilization compared to the rectangular patch, especially for high-frequency applications. Previous research has largely focused on antennas with high gain, but there is little literature discussing low-gain antennas for short-range applications in ADS-B.

Additionally, microstrip antennas produce low gain, so array antenna techniques are required. The design of microstrip antenna arrays has successfully improved gain and directivity through the more optimal arrangement of antenna elements.

Their research results indicate that an array with a specific configuration can lead to a significant improvement in antenna performance. (Smith dan Johnson, 2018). The influence of slot size on the bandwidth of a triangular patch microstrip antenna. In this study, they found that increasing the slot size can expand the antenna's bandwidth, making the antenna more effective over a wider frequency range. (Rahman et al., 2020). The Triangular Array 1x2 Microstrip Antenna is a type of microstrip antenna that consists of a series of triangular antenna elements arranged in 1 row and 2 columns. This antenna is designed to operate at a frequency of 1.09 GHz. This type of antenna is commonly used in wireless communication applications and wireless networks to transmit and receive signals at specific frequencies.The advantages of a 1x2 triangular array microstrip antenna include its relatively small size, ease of manufacturing, and its ability to produce the desired radiation pattern according to the needs of communication applications.

The purpose of this research is to design and analyze the characteristics of a 1x2 triangular patch array antenna at a frequency of 1.09 GHz, including key parameters such as return loss, bandwidth, gain, and radiation pattern. The results of this study are expected to contribute to the development of microstrip antennas.The design and optimization of this antenna involve selecting the appropriate geometric dimensions for each triangular element, choosing the dielectric substrate, and arranging the spacing between elements to achieve the desired performance at the specified operating frequency. Thus, the 1x2 Triangular Array Microstrip Antenna can be a good choice for communication systems at a frequency of 1.09 GHz.

II. METHOD

A. Triangular Patch Microstrip Antenna

A triangular patch microstrip antenna composed of three parts. The microstrip antenna consists of a ground plane serving as a reflector of electromagnetic waves, a substrate containing dielectric material as a conduit for electromagnetic waves, and a patch as the radiating element.

B. Array Antenna

In general, antennas with a single patch element produce low gain, resulting in a wider radiation pattern. Some applications require designing antennas with characteristics that have high directivity.the arrangement of several antenna elements connected together to form a single large structure. The purpose of using an antenna array is to enhance the performance of the antenna in terms of gain, directivity, and controllable radiation patterns. By using an array, signals can be amplified in specific directions, allowing for greater communication range or better reception in the desired direction.

C. Antenna Gain

Antenna gain is one of the important parameters that measures how well energy is radiated in a specific direction. Antennas with low gain are typically used in short-range applications to avoid interference with other devices or for communication in more confined areas. In a 1x2 array, although the gain increases with the addition of elements, this design is specifically tailored to keep the gain low through optimization of the spacing between elements and appropriate feed network design.

D. Antenna Design Flowchart

In this research, a triangular-shaped microstrip patch antenna will be designed and arranged in a 1×2 array with a frequency of 1.09 GHz. The design process begins by determining the specifications and shape of the antenna to be designed. Then, calculations were performed using the equations obtained from various references, which were then designed using CST software. After the design, the antenna was simulated and reviewed to see if it met the desired parameters. The parameters observed during testing are the resonant frequency of the antenna, return loss, bandwidth, radiation pattern, gain, and VSWR. These parameters will first be tested through simulation. Here is the flowchart for the simulation process of a 1x2 triangular array microstrip antenna at a frequency of 1.09 GHz. The flowchart in the antenna design can be seen in Figure 1.

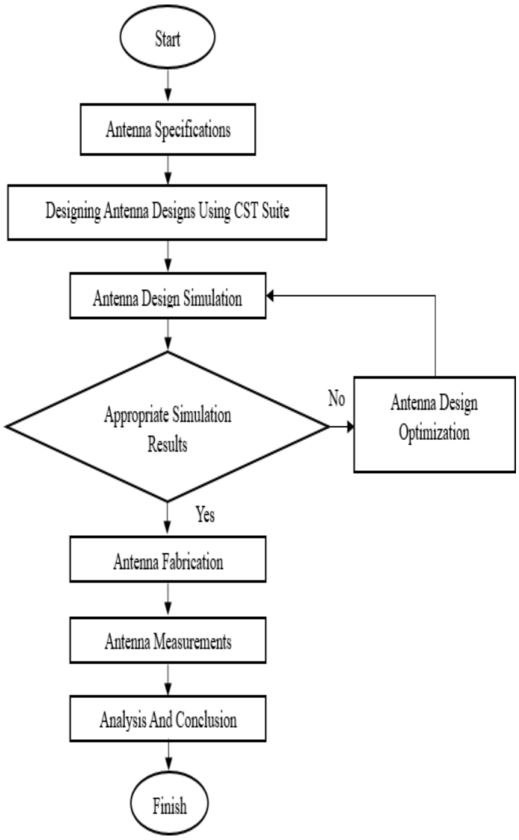


Figure 1. Antenna Design Flowchart

The first stage is the literature review stage, where a study is conducted on the 1x2 Triangular Patch Array Microstrip Antenna, as well as an examination of the antenna parameters and necessary literature sourced from final projects, journals, books, and articles available online. The second stage involves determining the dimensions of the antenna, as well as the parameters of the 1x2 Triangular Patch Array Microstrip Antenna obtained from the literature review found on the internet. The third stage, which focuses on the design planning of the 1x2 Triangular Patch Array Microstrip Antenna, begins with establishing the operating frequency of the antenna, the length of the antenna elements, and the distance between elements, culminating in the final design of the 1x2 Triangular Patch Array Microstrip Antenna based on the literature review obtained. In the fourth stage of the simulation phase, if the desired simulation outcome is achieved, the antenna manufacturing process continues. However, if the simulation results do not meet the target, antenna design optimization is carried out. The fifth stage is the manufacturing stage, where the design and fabrication process of the antenna using CST Studio Suite software is carried out before production. The design results from CST Studio Suite are first transferred using Corel Draw software, and during this process, the expected parameter results are also obtained using that software. The sixth stage is the measurement stage, which takes place after the design and fabrication processes are completed. The purpose of the measurement is to determine the parameters of the produced antenna, as a comparison between the manufactured antenna and the antenna simulation in CST Studio Suite. The seventh stage involves data analysis, where the analysis of the antenna measurement data obtained is carried out.

E. Antenna Dimensions

The dimensions of the antenna used are mm2 with a substrate thickness of 1.6 mm. The type of substrate used is FR-4, which has a dielectric constant of 4.4 and a loss tangent of 0.02. These dimensions are related to the operating frequency of the antenna, as the size of the antenna is typically chosen as a fraction or multiple of the wavelength of the radio signal being used. These dimensions also affect the radiation characteristics, gain, bandwidth, and efficiency of the antenna.The design shape of the antenna can be seen in Figure 2.

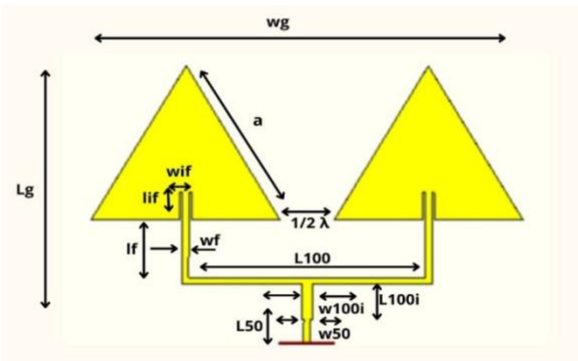


Figure 2. Design of a 1x2 Triangular Patch Array Microstrip Antenna

Table 1. Parameter Value

Variable	Dimension (mm)	Description
a	49,1	Pacth
h	1,6	Subsrat
L50	13,9	Supply line length(1)
L100	109,6	Channel length
L100i	16,8	Length of supply line
lf	30,65	Length of feeding
lg	145	Ground length
lif	13	Panjang insert feeding
t	0,035	Thick ground
w50	3	Supply LineWidth(1)
W100	3	Channel width
W100i	5	Outlet channel width
Wf	3	Lebar feeding
Wg	227,8	Lebar ground
wif	1	Lebar insert feeding

This antenna uses an SMA connector. Figure 3 shows the results of the antenna construction

Figure. 3 Antenna Fabrication.

F. Antenna Fabrication and Measurement

After getting the optimization results on an antenna and by the expected specifications, then carry out the manufacturing process and take measurements.

III. RESULT AND DISCUSSION

The results of the antenna simulation using a rectangular patch arranged in a 1×2 array have been analyzed. The parameters used for analysis include return loss (S11), bandwidth, VSWR, axial ratio to determine the type of polarization, and gain to understand the radiation pattern

A. Analysis of Bandwidth Changes

Bandwidth is the range of frequencies limited by a certain return loss value (S11). In this study, the return loss threshold used is -17 dB. Return loss is a parameter used to determine how much power is lost due to reflections from the transmission line, preventing it from being fully radiated by the antenna. The results of the return loss graph from the simulation can be seen in Figure 4.

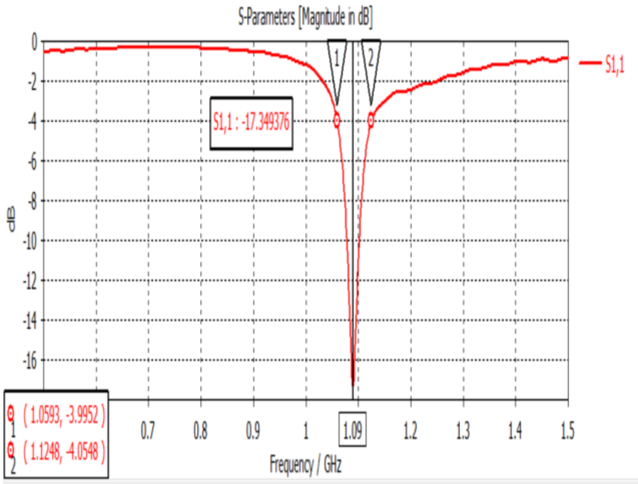


Figure 4. Results of the Return Loss/ Bandwidth Change Simulation

Figure 4 shows the simulation results of the return loss using a triangular patch arranged in a 1×2 array. From the curve, it is obtained that the return loss for the antenna reaches a value of -17 dB at a frequency range of 1.09 GHz. Based on the return loss simulation results, the bandwidth of this antenna is 65 MHz.

B. Analysis of Gain Changes

Gain is the ratio of the intensity of power in a specific direction to the intensity of power obtained from a reference antenna that radiates power isotropically. The measurement of gain relates to how directional the antenna is in radiating in a particular direction. The higher the gain of the antenna, the more focused the radiation direction of the antenna becomes towards the desired angle.

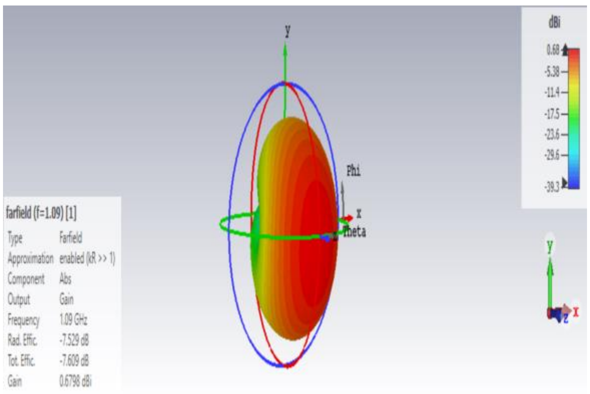


Figure 5. Gain farfield Triangular Patch Array 1x2

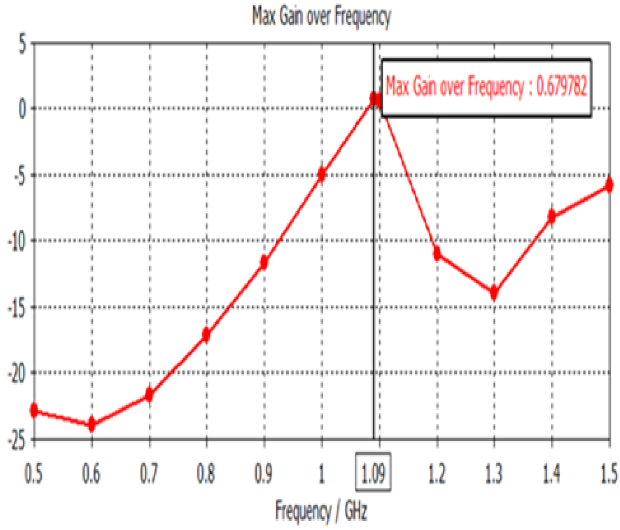
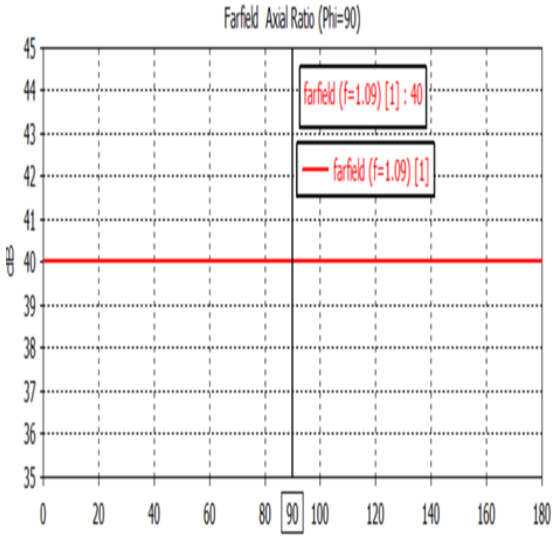


Figure 6. Gain Triangular Patch Array

Figures 5 and 6 show the simulation results of the maximum gain value using a triangular patch antenna arranged in a 1×2 array. The maximum gain of the antenna is 0.67 dB at a working frequency of 1.09 GHz. This antenna has a low gain because the size of the triangular microstrip patch element is smaller compared to square or rectangular patches, which reduces the effective radiation area and, ultimately, the gain.

C. Analysis of Axial Ratio Changes

The axial ratio is the ratio between the major axis and the minor axis in the electric field plane of an antenna, expressed in dB. The axial ratio can serve as a reference for determining the type of polarization of an antenna. An axial ratio within the range of 3 dB to 40 dB indicates that the antenna has elliptical polarization, while an axial ratio greater than 40 dB indicates that the antenna is linearly polarized. The axial ratio value can be seen in Figure 7.



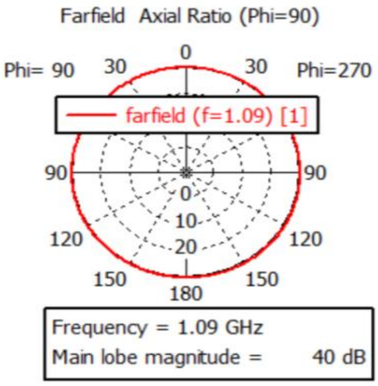


Figure 7. Results of the Axial Ratio of the 1×2 Triangular Patch Array

Figure 6 shows the simulation results of the axial ratio using a triangular patch arranged in a 1×2 array. From the curve, at the condition of the main radiation direction, which is at $\varphi = 0°$ (the antenna pointing forward), the axial ratio of the antenna is obtained to be 40 dB.

D. Analysis of VSWR Changes

VSWR is an indication of the degree of mismatch between the antenna and the feed line that connects them. This is also known as the Standing Wave Ratio. (SWR). The range of VSWR values is from 1 to ∞. In the image below, the simulation value of VSWR for the 1x2 triangular microstrip antenna is obtained at 1.3 dB.

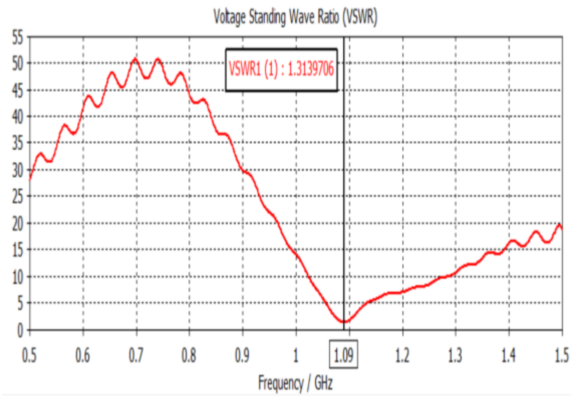


Figure 8. VSWR values of the 1×2 Triangular Patch Array.

E. Analysis of Radiation Pattern Changes

The radiation pattern is a two-dimensional graphical representation that illustrates the emission characteristics of an antenna. There are two aspects in the review of radiation patterns, namely in elevation represented as theta (θ) and in azimuth represented as phi (φ). In Figure 10, the two-dimensional shape of the Radiation Pattern can be seen. The radiation pattern of this antenna is unidirectional, which is also evidenced by the more dominant emission direction towards the top.

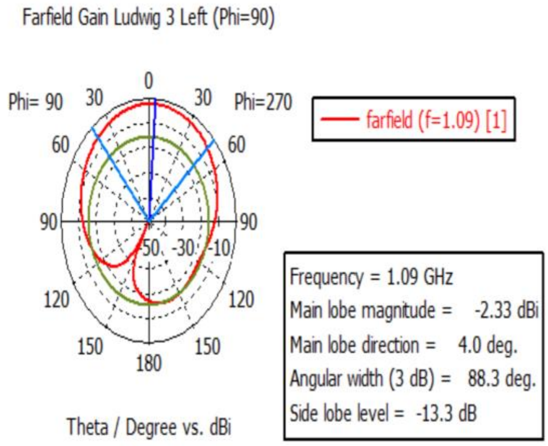


Figure 9. Radiation Pattern of a 1×2 Triangular Patch Array

Table 2. results of antenna design parameter values

Parameter	Specifications
Middle Frequency	1,09 GHz
Working Frequency	0.5 GHz – 1.5 GHz
Return Loss	≤ -17 dB
Bandwidth	65 MHz
Gain	≥ 0.67 dB
VSWR	1,3 dB
Axial Ratio	40 dB
Radiation patterns	Unidirectional

F. analysis of return loss (S11) changes after fabrication

In the measurement after fabrication, the return loss value is -20 dB. Return loss is a parameter used to determine how much power is lost due to reflections from the transmission line, preventing it from being fully radiated by the antenna. The results of the return loss graph from the simulation can be seen in Figure 10.

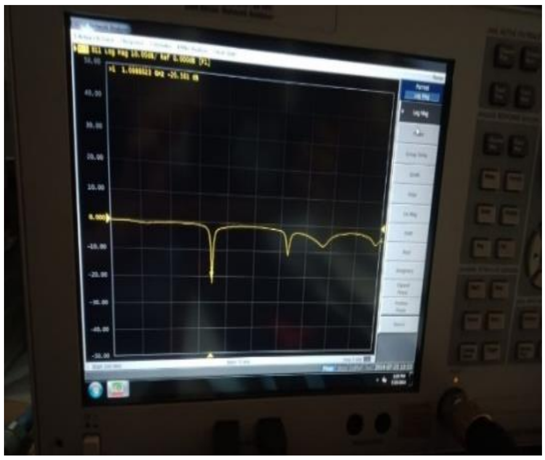


Figure 10. Results of Return Loss Measurement After Fabrication

G. *Analysis of VSWR changes after fabrication*.

Bandwidth width is less than 7.5 GHz, but the working frequency is in theUWB frequency range. The frequency range for UWB is 3.1 to 10.6 GHz so the bandwidth width is 7.5 GHz.

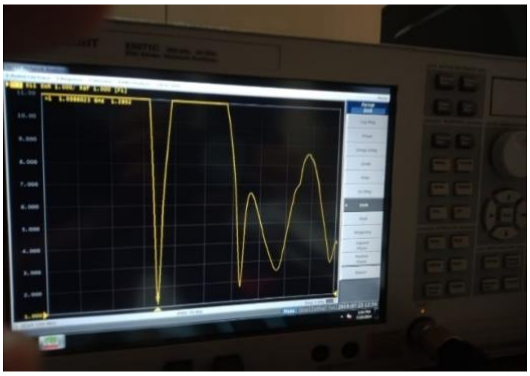


Figure 11. Results of Return Loss Measurement After Fabrication

Table 3. Antenna Specifications After Fabrication

Parameter	Specifications
Return Loss	-20 dB
VSWR	-1,28 dB

IV CONCLUSION

A. *Conclusion*

Conclusion Based on the results of the design and analysis that have been conducted, several conclusions can be drawn, namely:

1. Microstrip Array Antenna Design: This journal successfully developed a microstrip array antenna with a triangular patch configuration. The antenna operates at a frequency of 1.09 GHz, the standard frequency for ADS-B applications. (Automatic Dependent Surveillance-Broadcast). This design was chosen because it allows for a more compact size compared to square patches.
2. Low Gain Performance: Although the antenna design was created with ADS-B applications in mind, the simulation and measurement results indicate that the antenna gain is relatively low. This may be due to several factors such as the size of the patch and the distance between elements in the array.
3. Antenna Parameter Analysis: The analyzed antenna parameters include VSWR (Voltage Standing Wave Ratio) with a value of 1.3 dB, return loss, gain with a value of -17 dB, and a bandwidth of 65 MHz. Although the gain is low, the VSWR and return loss parameters meet the specifications for ADS-B applications, indicating that the antenna can operate at the specified frequency with adequate efficiency. The measurement results of the designed antenna after fabrication show a return loss value of -20 dB. This indicates that the return loss value is better in the fabricated results compared to the simulation results obtained from CST software. Additionally, the measured VSWR value matches the simulation results from CST, with a VSWR of 1.3 dB, which meets the specifications for the antenna parameters.
4. Optimization Potential: From this research, it is recommended to conduct further optimization on the patch design, such as increasing the distance between elements or modifying the shape of the patch, to enhance the gain and overall performance of the antenna. More complex array techniques can also be considered to enhance directivity and radiation efficiency.
5. ADS-B Applications: Overall, the proposed antenna has the potential to be used in ADS-B applications despite its low gain performance, and with further optimization, this design could yield more optimal performance.

B. *Suggestions*

Based on the design and data analysis that has been conducted, the suggestions provided by the author are as follows:

1. It is hoped that the creation of the 1x2 ADS-B Triangular Patch Array Microstrip antenna can further modify the antenna to function over a wider frequency range.
2. For the fabrication of the 1x2 ADS-B Triangular Patch Array Microstrip antenna, it is expected that fabrication can be carried out to see how the 1x2 ADS-B Triangular Patch Array Microstrip antenna performs in real life.
3. For the next design, it is hoped that an antenna with more than 2 elements can be designed for the 1x2 ADS-B Triangular Patch Array Microstrip antenna.

REFERENCE

[1] Balanis, C. A. (2005). Antena Theory Analysis and Design 3nd Edition. USA: WileyInterscience

[2] Errifi , H., Baghdad, A., Badri, A., & Sahel, A. (2010). Design and Simulation of Microstrip Patch Array Antenna with High Directivity for 10 GHz Applications.

[3] International Symposium on Signal Image Video and Communications (hal. 19-21). Marrakech, Maroc: ISIVC.

[4] Singh, I., & Tripathi, V. (2011). Micro strip Patch Antenna and its Applications: a Survey

[5] International Journal of Computer Techonlogy and Applications, 1595–1599.

[6] https://ojs.uma.ac.id/index.php/jite/article/view/4927

[7] Wiyanto, E., Alam, S., & Harsono, B. (2018).Realisasi dan Pengujian Antena Mikrostrip Array 4 Elemen dengan Polarisasi Melingkar untuk Aplikasi 4G/LTE.

[8] ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika, 244-258.

[9] Balanis, C.A., Antenna Theory: Analysis and Design, 4th Edition, Wiley, 2016.

[10] Garg, R., Bhartia, P., Microstrip Antenna Design Handbook, Artech House, 2001.

[11] Khandelwal, M.K., et al., Design and Analysis of Low Gain Microstrip Patch Antenna, IEEE Transactions on Antennas and Propagation, 2017.

[12] Pozar, D.M., Microwave Engineering, 4th Edition, Wiley, 2011.

[13] Handika, D. M. (2022). Rancang Bangun Antena Mikostrip Patch Circular Untuk Aplikasi 5G . Data Sci. Indones, 9-12.

[14] Y. K. Gultom, S. A. (2022). Microstrip Antenna Reflection Coefficient with X Slot Addition Method for 5G Connection . J. Informatics Telekommun. Eng, 532- 544.

[15] Abdurrahman. (2018). Desain Antena Microstrip Rectangular Untuk WIFI Pada Frekuensi 2,462 GHz dan 5,52 Ghz , 1-38.