Design Of Multiband Microstrp Antenna On Cubesat For Ads-B Communication

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Abstract*— Automatic Dependent Surveillance-Broadcast (ADS-B) is a new technology in aircraft observation that uses the global positioning system (GPS) to track the position, speed, wind direction and altitude of the aircraft. The research aims to compare the results of application simulations and the results of field measurements. ADSB simulation results return loss -21.13 dB, VSWR 1.2181, gain 0.5 dBi, and axial ratio 3.06. S-Band antenna simulation, return loss of -15.35 dB, VSWR of 3.89, gain of 3.88 dBi, and axial ratio of 9.7 dB. The measurement results obtained for the ADS-B antenna return loss -19.376 dB, VSWR 1.25, gain 2.67 dBi, and axial ratio 1.341 dB. Measurement of the S-Band antenna return loss is -15.36 dB, VSWR is 1.35, gain is 0.62 dBi and axial ratio is 1.33 dB. In the simulation and measurement of the ADS-B antenna, a close value is obtained. In the simulation and measurement of the S-Band antenna, there are differences in the measurement frequency from 300 MHz to 2700 MHz, while in the simulation it is 2400 MHz. The factor that affects the difference in results is the material used is not the same as the material used in the simulation.

Keywords: ADS-B, S-Band, Microstrip Antenna, CubeSat

I. INTRODUCTION

Telecommunications technology is developing very rapidly and covers many fields including aviation. Satellite-based Communication Navigation Surveillance/Air Traffic Management (CNS/ATM) technology has been agreed upon and has become an international standard in air space management in every country in the 10 Air Navigation Conferences held in Montreal in 1991 to anticipate high aviation growth without compromising aspects of safety and operation [1].

Automatic dependent surveillance-broadcast (ADS-B) is a surveillance technology that allows aircraft to broadcast identification, status and position information to neighboring aircraft and nearby ground stations. ADS-B is an important composition of CNS/ATM and a surveillance method recommended by the International Civil Aviation Organization (ICAO) in the next generation of air traffic management (ATM) [2].

In ADS-B Space-based aircraft data broadcasts are received on satellites which then the signal is then forwarded to the earth station, which will then provide data to the air navigation service provider. The satellite requires several components to be able to receive and transmit ADS-B data. Antenna is one of the important components so that the satellite can receive and send data properly.

Microstrip antenna is an antenna that has small and thin dimensions, an affordable price to realize [3]. Microstrip antenna was chosen because it has a simple material (low profile), lightweight structure, easy to integrate with other systems, making it suitable for nano satellite communication systems, namely CubeSat [4]. The microstrip antenna which is designed as a receiver component has circular polarization and omnidirectional radiation pattern because the CubeSat does not have control, antennas are needed from all directions. To obtain ADS-B frequency coverage, a microstrip antenna with a wide bandwidth is designed.

The term CubeSat is used to describe a small satellite whose basic unit form is a 10 cm edge cube, namely 1U. CubeSat units can be put together to form bigger artifacts, like 2U, 3U, 6U, and so forth. CubeSats must follow the standards defined by the CubeSat Design Specification, which includes compliance with flight safety guidelines. Compact antenna required to support protocol on CubeSat. Microstrip antenna is one of the antennas several types of antennas for CubeSats that are easy to build, easy to make, and small in size. Microstrip antenna can easy to place on a variety of surfaces, making it relatively easy to install on CubeSat [5].

Based on previous research. From the measurement results on the microstrip antenna, it can be seen that the antenna has a wide bandwidth and can work at a frequency of 1090 MHz with a VSWR value of 2, return loss - 10 dB, and a minimum gain of 3 dB. However, the system that has been built cannot use 2 frequencies [6].

Based on this research, this research will use the title "Design of Multiband Microstrips Antenna on CubeSat for ADS-B Communication". This antenna will work on the ADS-B frequency of 1.09 GHz to receive ADS-B data from the aircraft and in the 2.4 GHz s-band to send ADS-B data to ground. The s-band frequency was chosen because it supports the amount of data sent from the satellite to the ground and the need for high-speed communication for ADS-B.

II. BASIC CONCEPT

A. Automatic Dependent Surveillance Broadcast (ADS-B)

Automatic Dependent Surveillance Broadcast (ADS-B) is an air surveillance system that is used to determine aircraft position, aircraft code, altitude, and other data. ADS-B periodically transmits information and other data on other aircraft, satellites, and ground stations. The ADS-B system is located on aircraft operating using satellites [3]. ADS-B has 2 types, namely ADS-B in and ADS-B out. The two systems have different functions. ADS-B serves to receive information between aircraft and send information to ground stations or ATC (Air Traffic Control) at the airport. ADS-B works to provide route information, the arrival of each aircraft, and provide aircraft identity information, altitude, speed, and position of the aircraft [7]

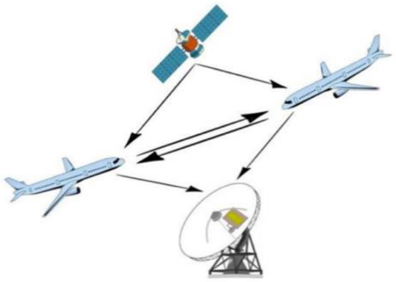

FIGURE 1
System ADS-B

B. Cubesat

CubeSat has a mass of 1 liter of water with standard dimensions per 1U (Unit) which is 10 x 10 x 10 cm. The dimensions of the CubeSat can not only be 1U but can be 2U, 3U, 6U, 12U, 16U, and 27U. Figure 2 is an illustration of the class of the CubeSat currently available. CubeSat usually orbits at an altitude between ± 500 - 1500 km above sea level or commonly known as Low Earth Orbit (LEO) [8]. Standardization of the CubeSat size was made by Stanford and California Polytechnic State Universities in 1999, and the standard specification used for the 1U CubeSat is 1000cm3 (10cm x 10cm x 10cm). for a 3U CubeSat, the factor is similar to three 1U arranged into one part [9]. The mass of the 3U satellite is around 10 kg.

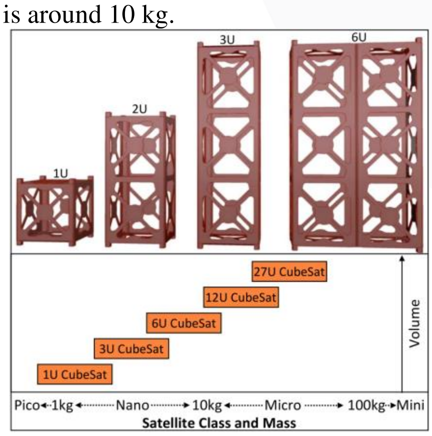

FIGURE 2
Cubesat grouping base on class and mass

III. METHOD

A. System Design

Design and realization of microstrip printed collinear dipole array antennas for ADS-B receiver applications that can work at a frequency of 1090 MHz using CST Microwave Studio (CST MWS) is software that can be used to design and analyze all types of antenna systems. These tools are very helpful for an antenna designer to analyze antenna parameters, calculate S Parameters, calculate VSWR, Gain, polarization and radiation polarization or study antennas in 3D, based on polar and Cartesian coordinates. The features presented in this software make it easier for electromagnetic analysis. The design of this software is almost accurate to the original, making it easier to manufacture antennas. After designing the desired antenna and knowing the output size, then the manufacture of the antenna will be more convincing.

B. Antenna Specifications

Designing an antenna requires knowing the specifications of the antenna to be made, such as working frequency, VSWR, Return Loss, impedance, radiation polarity and gain. The antenna design specifications in this final project proposal are:

Desired antenna specifications:

Substrate Material	: FR4 Epoxy
Method	: Microstrip
Working frequency	: 1090 MHz and 2.4 GHz
Gain 1.09 GHz	: 1 dBi
Gain 2.4 GHz	: 3 dBi
Bandwidth	: 20 MHz
VSWR	: < 2
Return Loss	: < -10
Impedance	: 50 ohms
Polarization	: 1090 MHz Circular and 2.4 GHz

Linier Using microstrip type

Using CST Studio Suite 2019 software for design and the simulation. Designing an antenna must use a substrate, this substrate affects the design and calculations in making the antenna, so in this final project proposal the substrate that will be used in the design of this antenna is FR4, has the following substrate specifications:

Dielectric permittivity of the material (εr): 4.3

Thickness: 1.6 mm per layer

C. Selection of Substrate, Ground plane and Patch Materials

The patch dimension width

$$Wp = \frac{C}{2f_r\sqrt{\frac{\varepsilon_{r+1}}{2}}} = \frac{3 \times 10^8}{2 \times 2.4\sqrt{\frac{4.3+1}{2}}}$$
$$= 0.0383\ m$$
$$= 38.3\ mm$$

The patch dimension length

Before calculate the length of the patch dimension, first to calculate ε_{eff} and ΔL to get Lp value.

$$\varepsilon_{eff} = \frac{\varepsilon_{r+1}}{2} + \left[\frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12\,\frac{h}{Wp}}}\right)\right]$$
$$= \frac{4.3 + 1}{2} + \left[\frac{4.3 - 1}{2}\left(\frac{1}{\sqrt{1 + 12\frac{1.6 \times 10^{-3}}{0.0383}}}\right)\right]$$
$$= \frac{4.3 + 1}{2} + \left[\frac{4.3 - 1}{2} 0.8161\right]$$
$$= 2.65 + 1.346 = 3.996$$

$$\Delta L = 0.42 \times h \frac{(\varepsilon_{eff} + 0.3)\,(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)\,(\frac{W}{h} + 0.8)}$$
$$= 0.42 \times 1.6 \times 10^{-3} \times \frac{(3.996 + 0.3)(\frac{0.0383}{1.6 \times 10^{-3}} + 0.264)}{(3.996 - 0.258)(\frac{0.0383}{1.6 \times 10^{-3}} + 0.8)}$$
$$= 0.000672 \frac{4.296 \times 24.201}{3.738 \times 24.737}$$
$$= 0.000672 \frac{103.967}{92.466} = 0.000755\, m$$
$$= 0.755\, mm$$

$$Lp = \frac{c}{2 \times f \times \sqrt{\varepsilon_{eff}}} - (2 \times \Delta L)$$
$$= \frac{3 \times 10^8}{2 \times 2.4 \times 10^9 \times \sqrt{3.996}} - (2 \times 0.755) = \frac{3 \times 10^8}{9.595 \times 10^9} - 1.55$$
$$= 0.02977\, m = 29.77 mm$$

Ground plane design

Ideally the ground plane can be calculated as follows:

$$Wg = 6h + W = 6 \times 1.6 \times 10^{-3} + 0.0383 = 39{,}2\, mm$$
$$Lg = 6h + L = 6 \times 1.6 \times 10^{-3} + 0.0297 = 39.3\, mm$$

From the results above, the ideal ground plane is 39.3 mm x 39.2 mm. However, in this study the limitation of the ground plane used is in accordance with the 3U CubeSat size of 219.45 mm x 83 mm. From the calculations and simulations, the microstrip antenna design is obtained, Figure 3, Figure 4, and Figure 5.

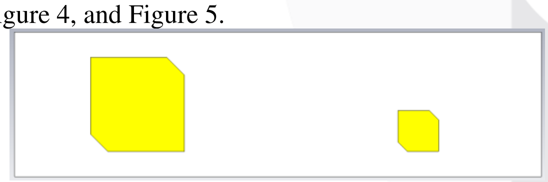

FIGURE 3
Antenna design

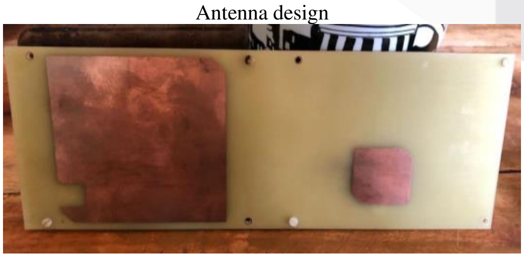

FIGURE 4
Front view fabricated antenna

FIGURE 5
Rear view fabricated antenna

D. Flowchart diagram design

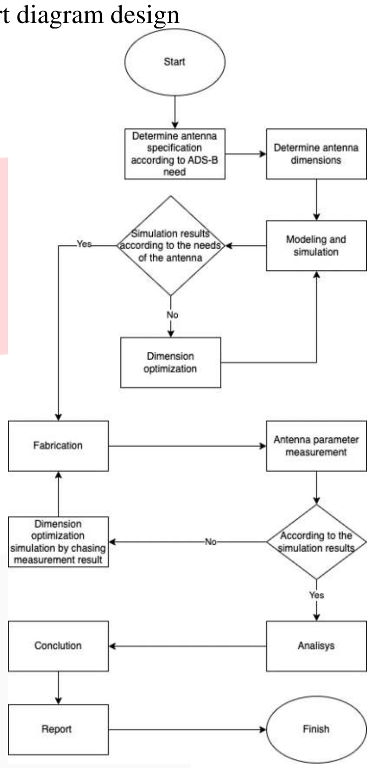

FIGURE 6
Antenna manufacturing

IV. RESULT AND DISCUSSION

A. Comparison of simulation and measurement results

Return loss

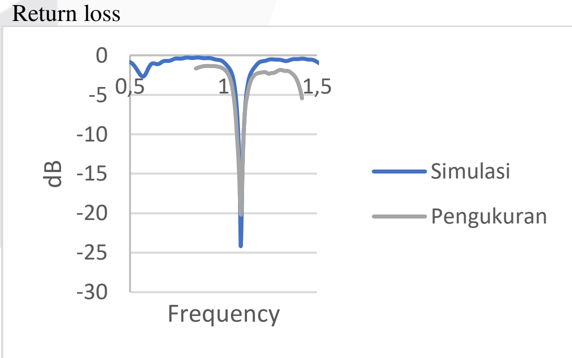

FIGURE 7
ADS-B antenna measurement results of S-Parameters

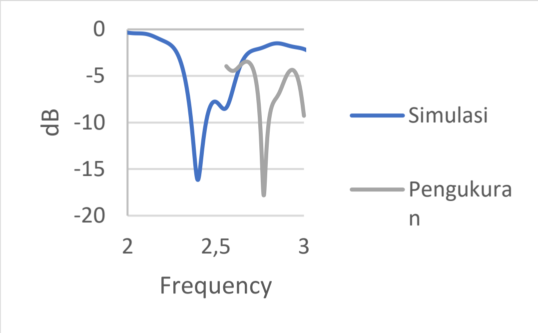

FIGURE 8
S-Parameter measurement result of the S-Band antenna

The graphs of Figure 7 and Figure 8 are the results of a comparison of the ADS-B frequency graphs between the measurements and the simulations that have been carried out. The simulation and measurement results show different results between the prototype measurement results and the software simulation results. Based on these results, on frequency. The ADS-B measurement results are in accordance with the simulation results, which means that the antenna can work at the ADS-B frequency of 1.09 GHz. However, at the S-Band frequency of 2.4 GHz, there is a frequency shift to 2.76 GHz which in the simulation is appropriate at 2.4 GHz. This can occur due to several factors, such as constraints during measurement, the influence of tools, or other factors that occur when measuring.

1. VSWR

Based on the results of the comparison of the CST Studio simulation test with field testing, the graph in Figure 9 is obtained where the ADS-B antenna uses a frequency of 1090 MHz to produce an orange graph which is the VSWR value in the simulation which has a value of 1.2181 and the yellow graph is the result of field testing which has a value of 1, 25.

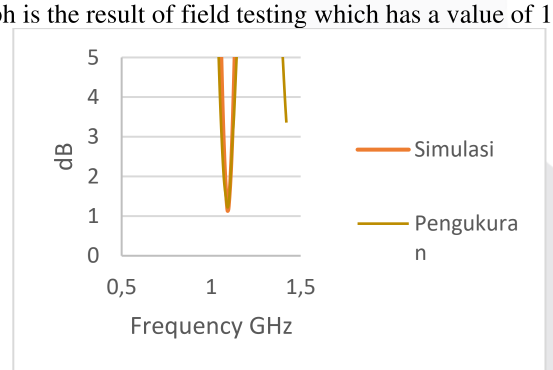

FIGURE 9
VSWR comparison on ADS-B antenna

Based on the simulation results and field testing on the S-Band antenna, the graphic data is obtained in Figure 10 where the frequency used is 2400 MHz, the orange graph is the result of the simulation to get a result of 1.3689 and the yellow graph is the measurement result to get a result of 1.35.

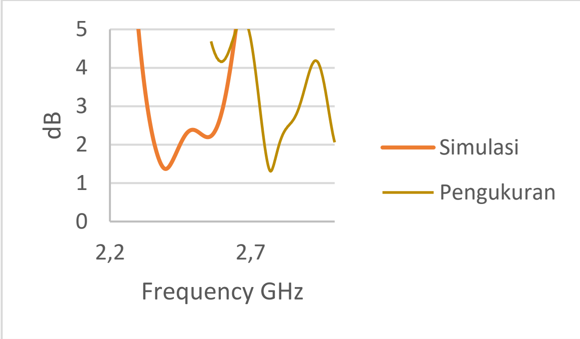

FIGURE 10
VSWR comparison on S-Band antenna

2. Gain and pola radiation

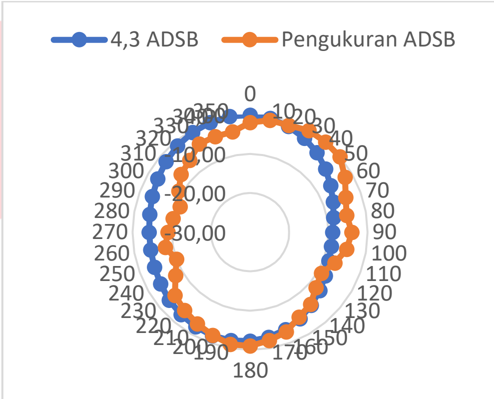

FIGURE 11
Pola Radiation of ADS-B antenna

The results of the ADS-B antenna polarization measurement data in Figure 11 based on the comparison chart of the two graphs have almost the same shape, namely circular. The shape of the radiation pattern in a vertical direction shows that the maximum power beam is at all beam angles. Thus, the position of the antenna can be placed at all angles in the elevation direction.

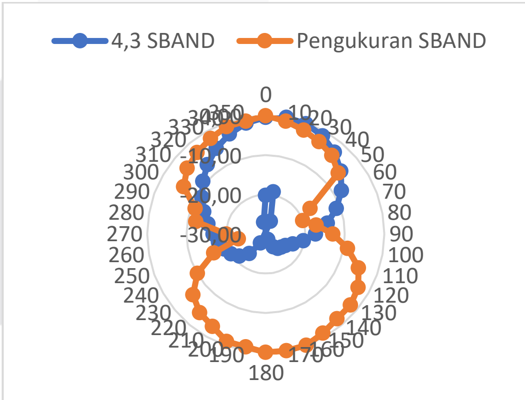

FIGURE 12
Pola Radiation Of S-Band Antenna

Meanwhile, the polarization of the S-Band antenna is shown in Figure 12 between simulation and measurement. The measurement results have the form of a radiation pattern with a vertical direction which indicates that the maximum power scatter is at an angle of 0 degrees and 180 degrees. Thus, the position of the antenna can perform maximum power transfer at that angle in the azimuth direction. The shape of the radiation pattern that has been obtained can determine the orientation of the antenna so that the power emitted from electromagnetic waves can be transmitted with the maximum. Based on these results, there is a difference in the radiation polarization between the measurement and the simulation. In the simulation results, the radiation polarization obtained is directional towards the front of the antenna, while the measurements obtained are bidirectional towards the front and back of the antenna. This can happen because the measurement process is not optimal and the condition of the measuring tool or room is not proper so that the results obtained are less accurate.

3. Axial ratio

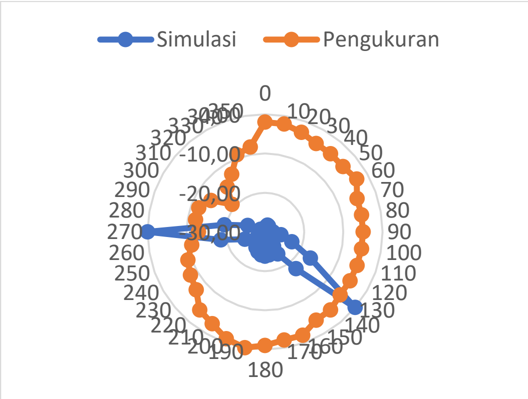

FIGURE 13
Polarization on ADS-B antenna

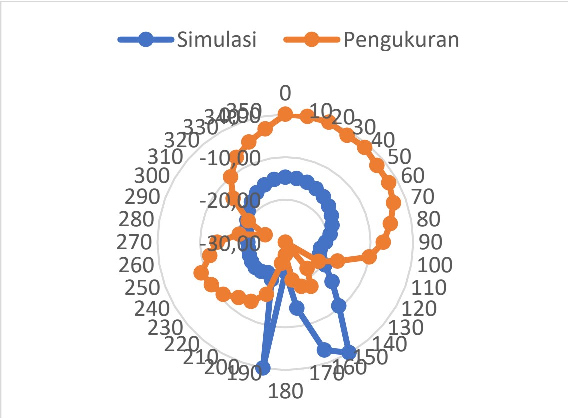

FIGURE 14
Polarization on S-Band antenna

At the S-Band frequency of 2.4 GHz, the polarization measurement results are different from the simulation results. In measuring the axial ratio value, the value is 1.33, which means that the antenna polarization from the measurement results is a circular polarization. Meanwhile, from the simulation results the obtained axial ratio is 9.9 dB which shows elliptical polarization.

Based on the results of the comparison of the axial ratio values at the ADS-B and S-Band frequencies, it shows the difference between the simulation and measurement results. This could be due to several factors at the time of measurement. Due to the design of the antenna between ADS-B and this S-Band on one piece of material, this might be the cause of interference that occurs during measurements. So that it causes the received signal at the time of measurement of one antenna to be influenced by another antenna so that the polarization obtained on the two antennas is almost the same, namely circular.

B. Comparative analysis of optimized measurement and simulation results

1. Return loss

In Figure 15 is a comparison of the return loss value between the measurement results and the simulation results which have been optimized by changing the value of the dielectric constant. In the graph, the return loss value at the ADS-B frequency also shifts to 1.2 GHz, which should be 1.09. In the previous measurement, the resulting return loss on the ADS-B antenna was -20.8457 dB at a frequency of 1.09 GHz. In the optimized simulation results, the resulting return loss was -20.06 db. This could be because changing the dielectric constant to 3.2. At the frequency of 1.09 GHz and 1.2 GHz the value of return loss is the same, this shows that changes in the dielectric constant do not affect the quality of the return loss, it only shifts the working frequency from the previous one.

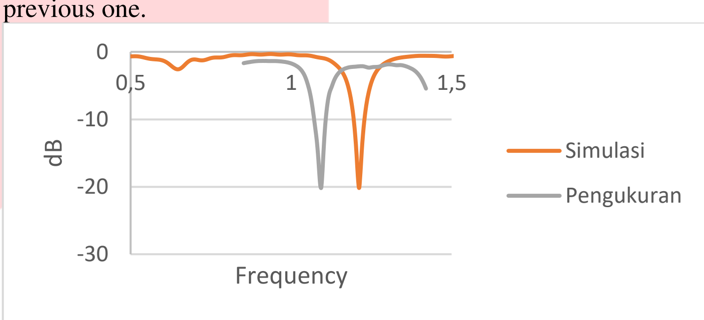

FIGURE 15
S-Parameter on ADS-B antenna

Previously, in Figure 8, there was a shift in frequency from 2.4 GHz to 2.76 GHz. This proves that the material used in the antenna has a dielectric constant that is different from what was simulated at the beginning. Then, in Figure 16, there is a graph that explains the difference in the results of the S-Band antenna Return Loss measurements and the SBAND antenna simulation. The measurement results obtained were -17.851 db. Then, in the simulation of the S-Band antenna, the return loss was -14.36 db. In the optimized simulation results, the S-Band frequency has been successfully shifted according to the measurement results to 2.76 GHz by changing the dielectric constant value to 3.2. There is a difference of 3.491 dB between the two. This is due to several factors at the time of measurement, such as cable loss, loss on the antenna port and port on the Network Analyzer, and so on.

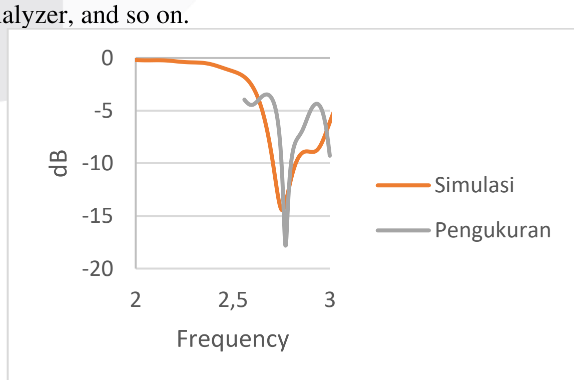

FIGURE 16
S-Parameter on S-Band antenna

2. VSWR

The VSWR measurement results on the ADS-B antenna are shown in Figure 17. The graph shows that the VSWR value through measurement is 1.218 and, in the simulation, the VSWR obtained is 1.268, between the two there is a difference of 0.05. However, when compared to Figure 9, there is a difference in frequency, previously 1090 MHz changed to 1.2 GHz. This is due to a change in the dielectric constant to 3.2.

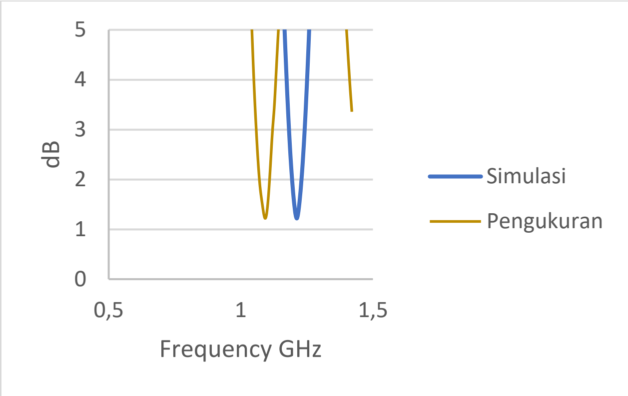

FIGURE 17
VSWR on ADS-B antenna

Because there is a frequency shift in the S-Band antenna, from 2.4 GHz to 2.76 GHz, this VSWR chart is a comparison between the measurement results and the simulation results which have been optimized by changing the dielectric constant value to 3.2. Changing the value of this dielectric constant is proven to be able to shift the frequency in the simulation to 2.76 GHz to match the measurements. Represented in Figure 18.

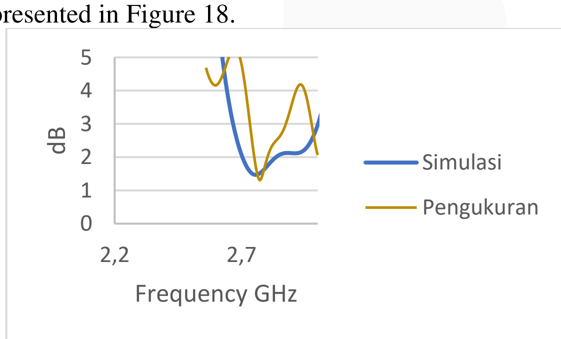

FIGURE 18
VSWR on S-Band antenna

3. Gain and pola radiation

In the ADS-B antenna, the polarization between measurement and simulation has been optimized the same, namely omnidirectional. This shows that the measurement results are in accordance with the simulation results that have been optimized. However, the gain obtained from the optimized simulation results is quite decreased, with a value of -5.5 dBi while from the simulation results the gain obtained by the antenna at the ADS-B frequency is 0.267 dBi.

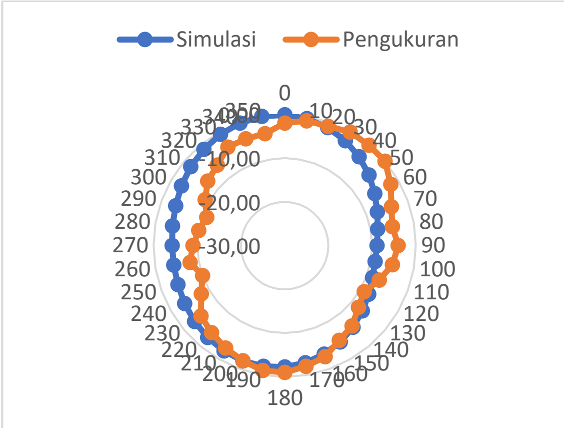

FIGURE 19
Pola radiation on ADS-B antenna

At the S-band frequencies, there are differences in the polarization of the antenna. In the polarization measurements obtained bidirectional towards the front and back of the antenna while in the simulation that has been optimized the radiation polarization obtained is directional towards the front of the antenna. The gain obtained from the optimized simulation results also does not match the gain measured results. The gain from the simulation results is -4.8 dBi while the measurement results are 0.62 dBi.

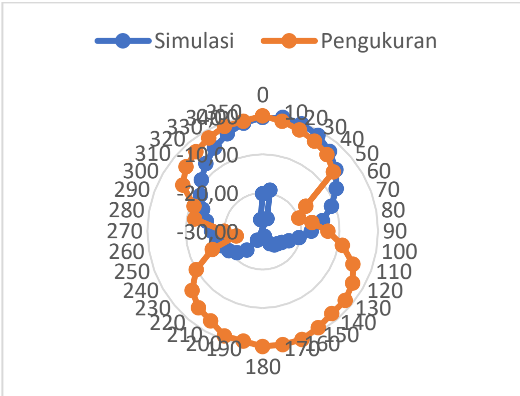

FIGURE 20
Pola radiation on S-Band antenna

V. Conclusions

A. Conclusion

Based on the research that has been done, it can be concluded that the results of the research are as follows: Testing at the ADS-B frequency, the results obtained are in accordance with the results of the simulation. And testing to receive the ADS-B signal from the aircraft can work properly. The results of the return loss test for the S-Band antenna show a frequency shift of 300 MHz to 2.7 GHz, which was previously 2.4 GHz in the simulation results. This is due to FR-4 fibrillation errors when measuring the room not being sterile, and lots of metal material when measuring.

B. Suggestion

In order to get better performance, there are several things that can be considered, namely: Use design references or other patch shapes to get better results. Using the same FR4 material as the CST Studio Suite 2019 software. Ensure the room is in a stable condition and there is no metal material in the room.

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