JET paper 414

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<< Paper ID : (diisi oleh redaktur)>>

Franklin Collinear Antenna 2 Levels Different Sides using Array Method 4 Stacking Units 360º with Integrated Reflector and Power Combiner for ADS-B S-Receiver Mode

Abstract

In this study an antenna system was created that could cover the 360º detection area using the microstrip method. The antenna design used uses the franklin collinear method with the addition of an array of arms to the left and right of the antenna and the addition of reflectors as a gain enhancer. The four antenna array units are combined using a power divider (combiner) as a unifying antenna. Antenna design with end fire radiation pattern cannot be used in receiving the ADS-B antenna system, because it works only in certain sectors with certain beamwidth, so it needs to be modified by adding an array of 4 units that make up 360º radiation of directional diagrams. The addition of the reflector is done by testing the optimum width. The most optimum width is obtained by the width of the side addition on the side of the antenna aperture cross section width of 80 mm. Based on the results of experiments that have been carried out for the design of receiver antennas for ADS-B applications that are required in the form of a radiation pattern in all directions using the reflector technique for the most appropriate gain increase is to use a phase difference for the antennas that are closest both left and right by 90º in ¼ λ conditions in the integration process using a 4 way power combiner. For a value of -23,222309 dB with a bandwidth limit of return loss of -15 dB of 33.8 MHz. From a frequency of 1.0752 GHz - 1.109 GHz, a gain of 7,586 dBi, this antenna design is very suitable for use in the ADS-B application.

Keywords : *ADS-B, antenna, microstrip, array, franklin, collinear, power combiner, reflector*

I. Introduction

Automatic Dependent Surveillance - Broadcast (ADS-B) is one of the important technologies in aviation, namely the technology for receiving information from aircraft. ADS-B technology is included in the S-Mode reception group which has the code number 17 [1]. In this research, Arhanud TNI - AD collaborated with PT. Radar Telekomunikasi Indonesia has developed a radar-based Surveillance Technology, IFF and Mode S receiver. The system is designed to be able to detect aircraft, both civilian and military. For S-Mode reception civil aircraft work at a frequency of 1090 MHz. The S-Mode reception works by using an antenna system that works 360º with a minimum gain of 3 dB, and a working frequency of 15 MHz. In receiving Mode-S, there are three links that can be used as a physical layer, namely 1090 MHz Mode-S Extended Squitter (1090 MHz ES), Universal Access Transceiver (UAT) and VHL Data Link (VDL) Mode 4. In receiving Mode-S, there are three links that can be used as a physical layer, namely 1090 MHz Mode-S Extended Squitter (1090 MHz ES), Universal Access Transceiver (UAT) and VHL Data Link (VDL) Mode 4. ADS-B is a system that uses 1090 MHz ES as the data delivery protocol. Examined from the name of the ADS-B, this is also meant as a broadcast system automatic surveillance and dependent. It is called automatic because no interrogation is required to initiate data or squitter from the transponder. It is called dependent because the data depends on the navigation system and aircraft capabilities.

In this research, an antenna system that can cover a detection area of 360º using the microstrip method is created. The design of the antenna used to use franklin method collinear with the addition of an array of arms on the left and right as well as the addition of a reflector antenna as an enhancer gain. The four antenna arrays are combined using a power divider (combiner) to unite the antenna.

II. Background

A. ADS-B Overview

ADS-B is located on an aircraft using an on board navigation system to obtain information. Every 1 second, the aircraft broadcasts position, altitude, and other data to the nearest aircraft equipped with ADS-B technology and to earth stations, airports. Antennas on satellites are useful for locating aircraft and knowing the position of the aircraft. After the position of the aircraft has been obtained, the transponder provides an information signal to the ground station. After the data is received by the ground station, the data is processed and broadcast [3]. In the Regulation of the Director General of Civil Aviation number KP 103 of 2015 concerning Technical Standards for Aviation Telecommunication Facilities, there are ADS-B technical specifications. The technical specifications on the ADS-B are given in Table 1.

Table 1. ADB Technical Specification Regulations and Standards, Directorate General of Civil Aviation

No.	ADS-B Technical Specifications	Information
1.	Detection Range	250 NM at 290 FL
2.	Target *Capacity*	± 250 aircraft targets at the same time
3.	Process capability	DO 260, DO260A, DO260B
4.	*Update rate*	*1 second*<rate <5 *seconds as operationally required*
5.	Target Type	Mode ES, Mode A/C, Mode S
6.	*Time Synchronization*	*GPS Network Time Server*
7.	*Receiving signal*	*Extended Squitter* ADS-B, Mode S 1090 MHz, GPS.
8.	*Network Latency*	95% <2 *seconds of G/S output*
9.	*Reliability 1*	*2 autonomous groundstation including antenna, each providing data, no common point of failure*
10.	*Reliability* 2 - MTBF	*Each groundstation including antenna to*

		have MTBF> 10.000 hrs
11.	Communication link	*Completely duplicated, no common point of failure.*
12.	Availability	99,999 %
13.	*Integrity - Groundstation*	*Site Monitor*, GPS RAIM, *monitored item by* RCMS, *at least :* *Status Reporting ; Buffer Overflows; Processor Overloads; Target Overloads;*
14.	*Integrity - Data communication And Processing*	All *system up to* ATM *system errors <* 1xlOE-6
15.	*Data Transmission Mode*	*Asterix Category* 21 *edition*: 0.23, 0.26, 1.6, 2.1 *orlatest edition*
16.	Grounding system	Sesuai dengan standar PUIL2000 atau PUIL terbaru
17.	*Recording* dan *playback*	30 hari atau lebih
18.	*Backup power supply*	Redundant UPS dengan kemampuan backup tiap unit masing-masing 5 jam

B. Antenna

In general, Antenna is a device that can emit and receive electromagnetic waves and can be defined as a transducer, because it converts an alternating electric current into electromagnetic waves. In its propagation from a transmitter to a distant receiver, electromagnetic waves experience a reduction in energy, so that when received by the receiver, the signal strength has decreased. In order to be received properly by the receiver, it is necessary to pay attention to the parameters that are the basis of the antenna such as gain, radiation pattern, polarization, and directivity [4]. Wireless communication systems or communications that do not use antenna cables are very important. It is to radiate and receive electromagnetic waves. Antenna is transitional device between transmission lines and free space. Because it is a transitional device between the cable and free space, the antenna must have properties in accordance with the cable media feeder.

The radiation field of a radiating antenna is characterized by the Poynting complex vector E x H where E is the electric field vector and H is the magnetic field vector. The closer to the antenna, the imaginary (reactive) and (E, H) Poynting vector decreases much more drastically with respect to 1 / r, meanwhile when the Poynting vector is real (radiating) and (E, H) decreases in proportion to 1 / r it means the further away with the antenna [4].

C. Microstrip Antenna

Microstrip antenna is a type of antenna that is in the form of a thin board and is able to work at very high frequencies. Microstrip antenna is made using a substrate that has three layers of structure from the substrate. These layers are [5], Trace or conductor, this trace is also called patch, is the top layer of the substrate, this layer is usually made of conductors. Conductors are generally made of copper, aluminum, or gold. In this layer, it will be formed into a certain shape to get a radiation pattern as desired. Dielectric, the middle part of the substrate, is used in this layer dielectric material. A dielectric with a thickness h has a relative permittivity (εr) in the range of 2.2 to 10. The dielectric constant is kept low to increase the overflow field which is useful in radiation. The lowest layer of the substrate is called the groundplane, which has a simple geometric shape, for example a circle, rectangle, triangle or other shape that functions as a reflector to reflect unwanted signals [6].

D. Power Combiner

Microwave power divider (combiner), such as the Wilkinson divider can be realized in microstrip or strip line technology, generally using the ¼ λ transformation, where this transformation is used to convert the input impedance, which is generally 50 ohms to the output impedance represented by a parallel combination of multiple outputs. The type of microwave power divider (combiner) accomplished in this study has 2 input / output inputs and 1 input / output, with a value of s12, which has the same characteristics as the s-parameter in s21, s31 [7].

III. SYSTEM DESIGN

The antenna is designed using an array system in a 360 ° array using the antenna array method. The antenna designed is an antenna with the franklin collinear type applied to the microstrip material used adapted from the dipole antenna, by irradiating using a long field, with a length of 1 / 2λ. The franklin antenna is commonly used for radio communications, such as HF and VHF and is made of metal wires and pipes. In this study, the length of the antenna is multiplied with the aim of seeing the maximum gain results from the antenna design that will be used. In this research, the microstrip antenna will be fed with the microstrip line feed feeding technique. Coaxial feed or probe feed is a technique that is carried out by connecting the inner conductor of the coaxial cable connected to the radiating conductor, and the outer conductor of the coaxial cable connected to the ground, using the antenna feed using a female SMA connector. The advantage of this feeder is that it can be placed at any location in the radiation area or the desired transmission line to obtain impedance matching from the antenna. The antenna is integrated using a FR4 reflector and integrated using a 4-way Wilkinson power divider.

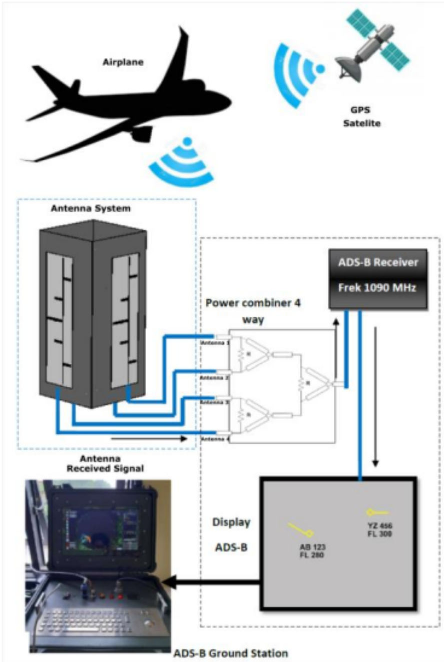


Figure 1. Antenna Design for ADS-B Receiver System

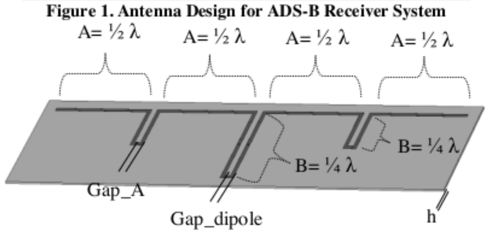


Figure 2. Initial Franklin Colinear Design on Microstrip

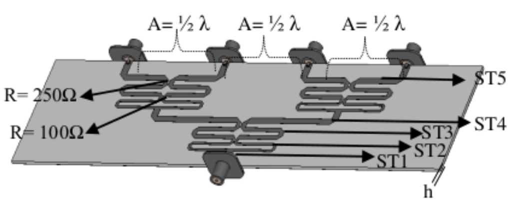


Figure 3. Initial Design of Power Combiner on Microstrip

The choice of material, namely FR4, with a value of εr = 4.4, h = 1.6 mm, then the value of λ based on the calculation results is 131.21 mm. So that the length of the antenna arm A is obtained = 65.605 mm and arm B = 32.8 mm and a width of 3.05 mm. Figure 1 is the overall design of the ADS-B antenna system designed, using 4 franklin collinear array antennas with a side difference with a placement of 360°. The antenna is integrated using a 4-way power combiner and attached to the insides of the ADS-B system. For the antenna system design, it can be seen in Figure 2. Figure 3 is the design of the 4-way power combiner. 4-way power combinerused uses the Wilkinson method, where this method uses a resistor to increase the isolation value between the branch ports.

The stages in designing a 4-way power combiner are to do a 2-way design first, then combine it into 4 ways with the same structure as 2 way, but there is a multilevel process as can be seen in Figure 3. In the 4-way power combiner integration, the resistor placed on each transmission line has 2 stages. The first stage is 100 Ω, obtained from the sum of the impedance of the radio frequency (RF) transmission line, which is 50 Ω. For the value of the second stage resistor, that is, at least increasing 2 times from the first resistor, in this case the value of the second stage resistor becomes 250 Ω. ST1 is a transmission line connected directly to a connector with an impedance of 50 Ω. For ST2 it is parallel to the source impedance, with a value of 50 times. In theory, the value of ST2 and ST3 has the same value, that is 70.71 Ω, using a transformer, so that the cleaning is smoother. The purification process uses the following equation = 59.5 Ω for the ST3 value. For ST4 and ST5 values have the same value, because they are the main transmission line, which is worth 50Ω. To see detailed sizes in Table 2 and 3.

Table 2. Value of Size from Antenna Calculation Results

No.	Variabel	Value
1.	A	65,605 mm
2.	B	32,8 mm
3.	**Gap A**	3 mm
4.	Gap Dipole	3 mm
5.	Substrate Distance	10 mm
6.	h	1,6 mm
7.	Copper	0,035 mm

Table 3. The Size Value of the Power Combiner Calculation Results

No.	Variabel	Value
1.	A, ST4_ Length	65,605 mm
2.	ST1, ST4, ST5_ Width (50 Ω)	3,05 mm
3.	ST1, ST5_ Length (50 Ω)	38,39 mm
4.	ST2_ Width (70,71 Ω)	1,595 mm
5.	ST2_ Length (70,71 Ω)	39,22 mm
6.	ST2_ Width (59,5 Ω)	2,25 mm
7.	ST2_ Length (59,5 Ω)	38,8 mm
8.	Substrate Distance	10 mm
9.	h	1,6 mm
10.	Copper	0,035 mm

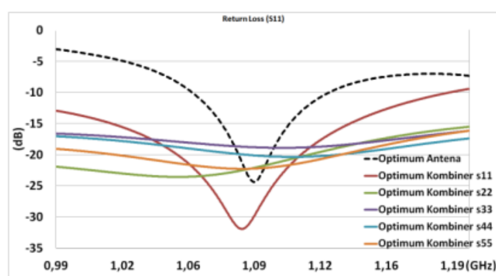


Figure 4. Simulation Results of Optimum Return Loss Antenna Franklin Collinear and Combiner Wilkinson 4 Way on Microstrip

The optimum simulation results of the return loss parameters are obtained with the franklin collinear antenna design of -24.315434 dB. The bandwidth obtained from this design has a limit of -15 dB at 34.8 MHz, from a frequency of 1.0741 GHz to 1.1089 GHz, which is in accordance with the specifications for ADS-B bandwidth requirements ranging from 15-30 MHz. In Figure 3 there is also a graph of the results of the optimization of the 4-way Wilkinson combiner, with the results of the return loss for each connector, for the port 1 arrangement colored red line, with the name return loss s11. Port 1 is the result of the combination of the other 4 branch ports, which in other words there is no isolation effect from the other ports, port 1 produces a return loss value of -30.294135 dB, with a bandwidth of 121.5 MHz, with a frequency limit 1.0181 MHz to 1.1396 MHz. For the branching port, the power obtained from port 2, port 3, port 4 and port 5 produces different return loss values, but is still within the specification limit range of the required value, which is below -15 dB. The difference that occurs is due to the influence of the position of the port distance placement, so that the length of the transmission line arm connected to each branch port produces a different length. Apart from the outcome of the transmission line, the effect that occurs is also due to the coupling effect between the connectors. For the port 2 graphic with a green line called s22 with a return loss value of -22.179718 dB, for port 3 of -18.811352 dB, Port 4 of -20.115187 dB, and port 5 of -22.259935 dB .

In the use of a power combiner using Wilkinson as a separator or combining power from the antenna, careful design and calculation is required regarding the loss that will occur when the power flows through each transmission line on the power combiner. The loss that occurs will result in the performance of a power combiner that can work optimally or even attenuation occurs when powering the amplitude of the signal passed, the loss parameter in the power combiner is called insertion loss. Figure 5 is a graph of the results of insertion loss obtained in the process of optimizing the dimensions of the power combiner. Theorytically, the insertion loss calculation is obtained by performing a logarithmic calculation of the number of branch ports to be designed. The calculation for the 4-way power combiner is 10 log 4 = 6,0206 dB. In fact, the use of a power combiner, the limit of the insertion loss value is 6,0206 dB, which becomes the benchmark for the resulting loss limit. In Figure 5, there are 4 loss streams that can be observed, namely from port 1 to port 2 with the naming on the black graph S12 and vice versa S21 of -6.2434861 dB, the values of S12 and S21 mean that the loss occurs during the flow process the electromagnetic wave is ~0.2 dB. In a radio frequency (RF) circuit, the loss process that occurs should not be ~3 dB, which means there will be a decrease or loss of ½ of the power in the amplitude of the signal that flows. In the results, the loss that occurs for S12 and S21 is still very far from 3 dB, which means it is very effective, which is able to pass nearly 98% power. Likewise for insertion loss that occurs on port 1 to 3 and vice versa with a red graphic with S13 and S31 values of -6.5361844 dB, with a loss value of ~0.53 dB. For ports 1 to 4 and vice versa 4 to 1 of -6.4032417 dB, with a loss of ~0.403 dB. Finally, for ports 1 to 5 and 5 to 1 of -6.198204, with a loss value of ~0.198 dB. Overall, the loss value obtained is far from 3 dB, with a maximum value of ~0.53. The difference in value at each port occurs at the difference in the distance at each port placement for the branch, as well as, as already explained, on the effect of the length of the transmission line, especially at the end of the port that is connected to the arm at 2-way to 4-way branching.

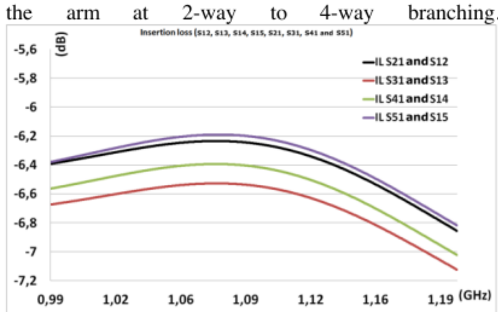


Figure 5. Siulation Result of Insertion Loss Optimum Combiner Wilkinson 4-Way Microstrip

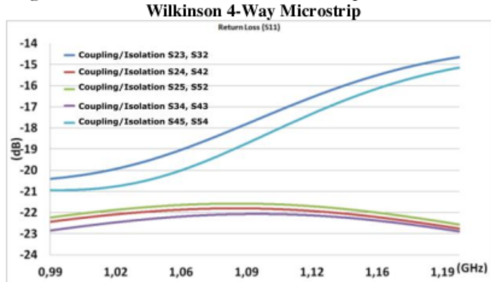


Figure 6. Simulation Result of 4-Way Wilkinson Combiner Coupling/Isolation on Microstrip

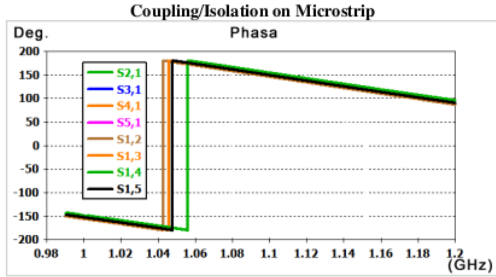


Figure 7. Simulation Result of the Wilkinson 4-Way Combiner Optimum Phase on Microstrip

One of the important parameters in a power combiner is the value of isolation or mutual coupling between branch ports and the resulting phase value between branch ports to and from a single port. The isolation graph obtained from the dimensional optimization process can be seen in Figure 6. The theoretical isolation value process in the antenna requirement circuit is -15 dB, where each antenna has a small effect on one another. In Figure 6 it can be seen that 2 to 3, vice versa and port 4 to 5 and vice versa produce different values with 2 to 4, 2 to 5 and 4 to 3, this is because the positions of ports 2 and 5 are at the end of the power combiner. Then the distance obtained is shorter than the distance between the ports in the middle position, and the ports at the end are affected by the transmission line that was previously, so the resulting isolation value is quite large. In addition, the effect of isolation is obtained from the use of the 100 Ω and 250 Ω resistors in the 4-way power combiner. Figure 7 shows the results of the phases obtained during the process of streaming electromagnetic waves on each transmission line from a single port to each branch port. The difference in the obtained phase values must not more than 5◦, this is because, if there is a large enough phase difference it will result in the phase of each port originating from the merging of the antenna experiencing a difference, so that it will influence the multiplication process diagram on the antenna and change the shape of the radiation pattern that occurs, and affects the gain value obtained. Therefore, the phases obtained must be as much the same as possible, both from ports 1 to 2, 1 to 3, 1 to 4 and 1 to 5.For details on the parameters obtained in the combiner, you can see in Table 4.

Tabel 4. *Power Combiner* Parameters at 1,09 GHz

No.	Parameter	Value
1.	VSWR Port 1	1,0630685
2.	VSWR Port 2	1,1687415
3.	VSWR Port 3	1,2590329
4.	VSWR Port 4	1,2189742
5.	VSWR Port 5	1,1670607
6.	Phasa s21/s12	151,9◦
7.	Phasa s31/s13	153,7◦
8.	Phasa s41/s14	159,9◦
9.	Phasa s51/s15	154,9◦

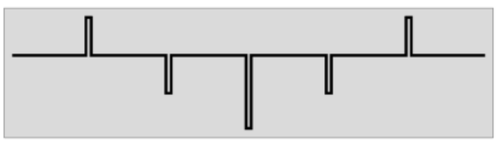


Figure 8. Design of Franklin Collinear Optimum Antenna with Additional Arm on Different Sides of Arm B

Table 5. Results of Parameter Optimization of Franklin Collinear Antenna Dimensions

No.	Parameter	Different side
1.	VSWR	1,1196432
2.	Return Loss	-24,967498 dB
3.	Impedance	52,571082 + J5,257902 Ω
4.	Bandwidth	130,4 MHz
5.	Frequency Limit	1,0277 GHz – 1,1581 GHz
6.	Gain	4,204 dBi
7.	3 dB Angel (HPBW)	28,2◦
8.	Direktivity	5 dBi

The next research process is to add 1 pair of arms B to see the increase that occurs in the Franklin Colinear antenna before adding a reflector. Arm enhancement is done by adding arm A to the left and right of the antenna, and arm B to the left and right of the antenna. The arrangement of arm B which is carried out with different side directions, for the design that has been done, can be seen in Figure 8. The results of the return loss from the side difference antenna are -25.425379 dB with a bandwidth of -15 dB return loss limit of 78.7 MHz. From a frequency of 1.0532 GHz - 1.1319 GHz, an antenna with an extra arm design produces a greater bandwidth than the original design antenna, this is in line with the theory that the sloping return loss, the greater the resulting bandwidth, and the sharper the return loss, the resulting bandwidth will be smaller. Grafik *return loss* dan VSWR hasil antena dapat dilihat pada gambar 9, VSWR dengan garis biru, dan *return loss* garis hitam. Graph of return loss and VSWR from antenna can be seen in Figure 9, VSWR with blue line, and return loss with black line.

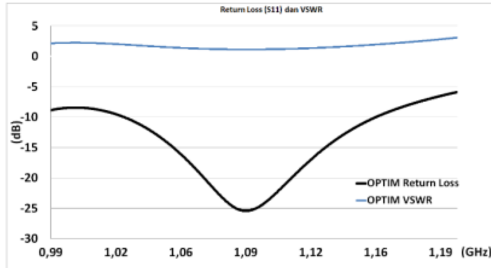


Figure 9. Franklin Collinear Optimum VSWR and Return Loss Value with Additional Arm

In order to increase the antenna gain, a reflector is added to one side of the antenna cross section. The reflector material used is FR 4 double layer copper, with h = 1.6 mm. The use of a reflector that is expected to increase the gain 2 times from an antenna without a reflector, in theory the addition of a reflector is like the principle of reflection, with an increase in the direction diagram on the side of the radiation surface adjacent to the reflector and changing the direction of the emissive axis, so that the opposite axis increases 2 times. However, the process of adding a reflector will change the type of directional diagram produced. In the initial antenna design, the resulting direction diagram or radiation pattern is omni directional, whereas when using a reflector, the resulting radiation pattern becomes uni-directional, or end fire radiation pattern, in other words the antenna with the maximum main emission in the direction parallel to the main plane where the antenna is located. An antenna design with an end fire radiation pattern cannot be used in the reception of the ADS-B antenna system, because it works only in certain sectors with a certain beamwidth, so it is necessary to modify it by adding an array of 4 units which form 360 ◦ of radiation from the direction of the radiating diagram. The addition of a reflector is done by testing the optimum width, the most optimum width is obtained by adding the width of the side addition of the antenna aperture cross-sectional width of 80 mm. The geometry design of the antenna system design using the addition of a reflector can be seen in Figure 10.The optimization results of the franklin collinear antenna with the addition of an arm and a return loss reflector and VSWR are in Figure 11.

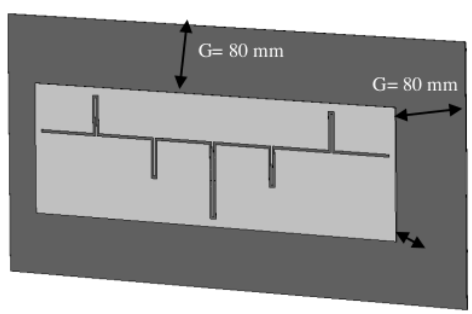


Figure 10. Franklin Collinear Geometry with Additional Arms and Reflectors

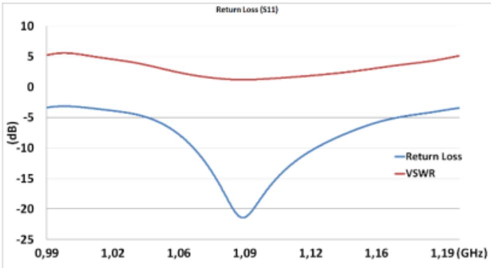


Figure 11. Franklin Collinear Optimum Smulation Results with Additional Arm and Reflectors

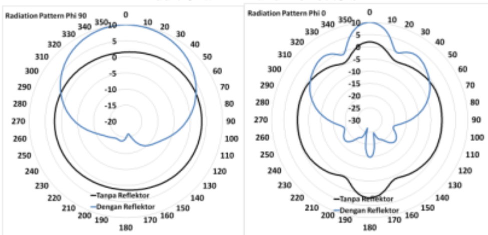
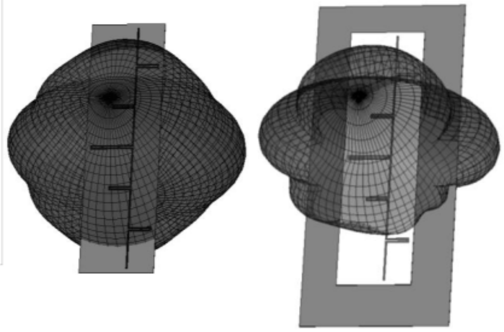


Figure 12. Antenna Radiation Pattern with and Without Reflectors a). φ = 90˚ b). φ = 0˚

From the simulation results obtained, the VSWR value obtained in the optimization process at a frequency of 1.09 GHz is 1.1854007 shown a red line in Figure 11. For the return loss value of -21.42839 dB is shown a blue line. The bandwidth obtained with a return loss limit of -15 dB from a frequency of 1.0761 GHz to 1.107 GHz, in which the amount of bandwidth is in accordance with the specifications for ADS-B bandwidth requirements ranging from 15-30 MHz. Antenna design using a reflector produces a very significant difference in the resulting gain and direction diagram. The gain of the antenna without reflector is 4.204 dBi with a deriktevity of 5 dBi. For the antenna using an additional reflector produces a gain of 10 dBi, with a directivity of 11.55 dBi. From the result of dissimilarity in gain and directivity, it can be seen that the addition of a reflector gives an increase in gain and changes the shape of the radiation pattern. The difference in polarity can be seen in Figure 12. The graphic image from the results of the polar or 2-dimensional direction diagram shows a significant difference, that the antenna without a reflector shown at φ = 90˚ with a black graph is the result of omni directional radiation, with values on all theta axes having almost uniform values. In contrast to the blue graph which shows the radiation pattern towards a certain theta angle which shows the reflection of the addition of a reflector. Similarly for the diagram φ = 0˚, showing different results for an antenna without a reflector and an antenna with a reflector. The shape of the 3-dimensional polarity produced by the Franklin Collinear Antenna using a reflector and without a reflector can be observed in Figure 13.



(a) (b)

Figure 13. Antenna Radiation Pattern with and Without Reflector of 3 Dimensional Shape (a). Tanpa Reflector (b). With Reflector

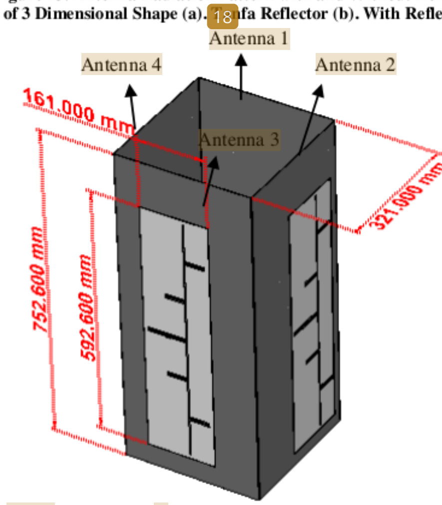


Figure 14. Antenna of ADS-B Receiver System Using Reflector with 4 Units Arrangement.

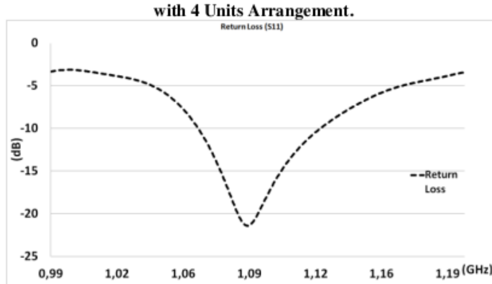


Figure 15. Franklin Collinear Optimum Return Loss Value for the Final Design

Figure 14 is the final design of the Franklin Collinear Antenna design with the addition of an array and a reflector and is arranged in a square to get a 360° radiation pattern with integration using a 4 way power combiner. For Figure 15, the return loss results from the side difference antenna are -23.2222309 dB with a bandwidth of -15 dB return loss limit of 33.8 MHz. From a frequency of 1.0752 GHz - 1.109 GHz.

IV. PHASE ANALUSIS 4 ANTENA

One of the important parameters in carrying out the integration of 4 antennas on a 4 way power combiner is the phase used in connecting, because the phase setting will greatly affect the process of multiplying the diagram between each antenna, by default the arrangement is arranged with the same phase, or called uniform, however, with the same phase conditions and the conditions of contact radiation patterns, each other will cancel each other out, and the gain value decreases. The gain value obtained when the phase is the same, in the conditions S11, S22, S33 and S44 with a phase value of 0° of 6.34 dBi, for directivity of 7.9 dBi. Whereas for the 60° phase difference with the position of 2 different phase antennas that are directly connected, phase 0° antenna 4 and 2, 60° for 1 and 3 produces a gain of 7,233 dBi. With a directivity value of 8.8 dBi. Further testing by changing the phases 0° antenna 4 and 2, 90° for 1 and 3 produces a gain of 7.586 dBi. With a directivity value of 9.159 dBi. The 4th test changes the phase 0° of antenna 4 and 2, 150° for 1 and 3 resulting in a gain of 6.73 dBi. With a directivity value of 8,293 dBi. Next, the 0 phase of antenna 4 and 2, 210° for 1 and 3 produces a gain of 6.743 dBi. With a directivity value of 8.306 dBi. And the last phase change test is with the phase 0° antenna 4 and 2, 240° for 1 and 3 produces a gain of 7,430 dBi. With a directivity value of 9.009 dBi. From the results of these phase differences, the most optimum difference is in the 90° phase, this is because the phase difference is equivalent to ¼ λ, which means that for the value ¼ λ is the most effective transformer commonly used in radio frequency circuits, so it is suitable also adapted in the array of ADS-B signal receiving antenna systems. For a graph of the form of polarity generated from various experiments with different phases of each antenna, it can be seen in Figure 15. it will be different, if the phase used is λ, which means that one position is in the line, then there will be no reduction from the multiplication of the diagram, but mutually reinforcing one another. If the differentiated phases are ½ λ then the positions in the same lamda (λ) are on parallel lines, and will affect each other for the resulting direction diagram.

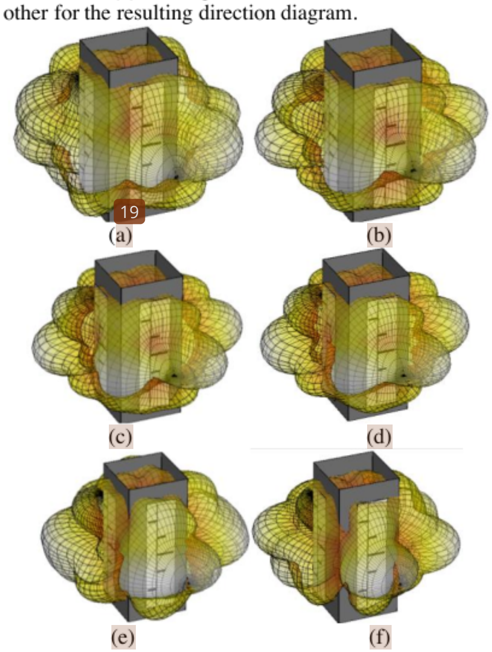


Figure 16. Results of Phase Difference Antenna, (a) Same Phase 0 Phase, (b) Phase antenna 1 and 3 60° and Antenna 2 and 4 0°, (c) Phase Antenna 1 and 3 90° and Antenna 2 and 4 0°,) Phase Antenna Antenna 1 and 3 150 and Antenna 2 and 4 0 e, (e) Phase Antenna Antenna 1 and 3 210° and Antenna 2 and 4 0°, (f) Phase Antenna Antenna 1 and 3 240 ° and Antenna 2 and 4 0°.

V. CONCLUSION

Based on the results of experiments that have been carried out for the design of the receiving antenna for ADS-B applications which are required to be in the form of a radiation pattern in all directions using the reflector technique to increase the gain, the most appropriate is to use a phase difference for the antenna that is on the closest side both left and right of 90° or in conditions ¼ λ in the integration process using a 4 way power combiner. For a value of -23.222309 dB with a bandwidth of -15 dB return loss limit of 33.8 MHz. From a frequency of 1.0752 GHz - 1.109 GHz, a gain of 7.586 dBi, this antenna design is very suitable for use in these ADS-B applications..

ACKNOWLEDGMENT

Our gratitude goes to PT. Radar Telekomunikasi Indonesia and Arhanud TNI AD who have involved the author in research making Radar and ADS-B for Air aviation.

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