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Triangular Microstrip Patch Antenna with Back-to-Back Structure to Obtain Bi-Directional Radiation Pattern

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ABSTRACT

In this research, a triangular patch microstrip antenna with a back-to-back structure technique has been designed to obtain Bidirectional radiation patterns operating at a frequency of ADSB 1090 MHz. The back-to-back structure technique using 2 substrate layers stacked together to form a single microstrip antenna component. As a result, the antenna has 2 patches on both sides of the microstrip, and the feedline is located between the 2 substrate layers. This antenna was designed using simulation software with an FR-4 substrate material. The parameter values obtained from the simulation at a frequency of 1090 MHz are: Return loss -15.4 dB, VSWR 1.4, Bandwidth 17.2 MHz, and Impedance 46.02 Ω.

Keywords: Triangular Patch, Gain, Bandwidth, ADS-B, Surveillance, Back-to-back structure.

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1. INTRODUCTION

An antenna is a crucial component in receiver equipment, as it functions to receive electromagnetic signals present in free space (Faizin & Wildan, 2022). Antennas come in various forms, such as wire antenna, reflector antenna, aperture antenna, and microstrip antenna (Balanis, 2005). One of the antennas that has relatively compact dimensions and is easy to fabricate is the microstrip antenna (Surjati, 2010). The microstrip antenna has three essential parts: Patch, Substrate, and Groundplane(Saputra et al., 2019). The square and flat shape of microstrip antennas gives rise to several drawbacks(Andhika et al., 2016). One of these drawbacks is that the radiation pattern of microstrip antennas tends to be directional, oriented towards a specific direction (Muhammad & Yusnita, 2017).

To generate a bi-directional radiation pattern, one approach is by using the back-to-back structure method. This method uses 2 layers of substrate, with patches placed in front of and behind the microstrip antenna components. While the feedline and ground plane are placed between the two substrates(Wei et al., 2017)(Reguna et al., 2016).

Research on microstrip antennas used as ADSB receiver antennas has been conducted by Abd. Rahman Abubar, et al (Abubar et al., 2020). They produced a design for a Left Handed Metamaterial (LHM) microstrip antenna that operates at the ADSB receiver frequency of 1090 MHz, with specifications a return loss value -16.09 dB, VSWR 1.38, bandwidth 92.7 MHz, and directional radiation pattern. Research on the back-to-back method in microstrip antennas has been carried out by Hisao Iwasaki (Iwasaki, 1998). This resulted in the design of a microstrip antenna capable of omnidirectional radiation patterns at a working frequency of 1897 MHz.

In this study, microstrip antennas were designed to obtain return loss < 10 dB, VSWR < 2, bandwidth < 30 MHz, and bi-directional radiation patterns. The patch design is configured in an equilateral triangle shape, and the substrate material employed is FR-4 with a thickness of 1.6 mm. Differences in dielectric materials can have an impact on antenna parameters (Saiful Islam et al., 2015). FR-4 was chosen as the substrate material due to its cost-effectiveness and easy availability in the market (ICAO, 2020).

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2. RESEARCH METHOD

In this study, the author employed an experimental method, which aims to test the influence of one variable on another variable (Ramdhan, 2021). The study utilized simulation software for antenna design and simulation to assess antenna performance. This software also provides insights into the values of Return Loss, VSWR, Bandwidth, and the radiation pattern shape of an antenna. The initial antenna design used a single-layer PCB, followed by a design with a stacked two-layer PCB, observing differences in parameter values between the two antenna designs.

3. RESULTS AND DISCUSSION

Before proceeding with the design, antenna dimensions are calculated. The calculated dimensions are then optimized to achieve optimal results in accordance with the desired operating frequency. Here is the calculation of the equilateral triangle-shaped patch dimensions (Nur Tri Yuliarto & Wagyana, 2021) :

$$a = \frac{2c}{3f\sqrt{\varepsilon_r}} = \frac{2 \times 3 \times 10^8}{3\ \times 1090 \times 10^6\sqrt{4{,}3}} = 0{,}0884\ m = 88{,}4\ mm$$

Next, the calculation for the feedline. The feedline used is a 50 Ω transmission line that connects the patch to the connector. To find the width of the 50 Ω feedline, use the following equation (He et al., 2014):

$$B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}} = \frac{60(3{,}14)^2}{50\sqrt{4{,}3}} = 5{,}70570$$

The width of the feedline can be calculated using the following equation:

$$W_f = \frac{2h}{\pi}\left\{B - 1 - In(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[In(2B-1)0{,}39 - \frac{0{,}61}{\varepsilon_r}\right]\right\}$$

$$W_f = \frac{2(1{,}6)}{3{,}14}\left\{5{,}7057 - 1 - In(2(5{,}7057)-1) + \frac{4{,}3-1}{2(4{,}3)}\left[In(2(5{,}7057)-1)0{,}39 - \frac{0{,}61}{4{,}3}\right]\right\}$$

$$W_f = 3{,}11\ mm$$

Next, the calculation for the ground plane. To determine the dimensions of the ground plane, you can use the following equation (Nur Tri Yuliarto & Wagyana, 2021):

Width:

$$W_g = 2 \times r = 102\ mm$$

Length:

$$L_g = 2 \times r = 102\ mm$$

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A. Single Patch Mikrostrip Antenna

The design of the single patch microstrip can be seen in Figure 1. The antenna dimensions obtained from the calculation results are then optimized. The antenna dimension values can be found in Table 1.

Fig 1. Single patch antenna design

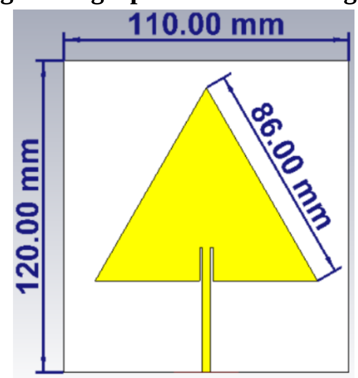
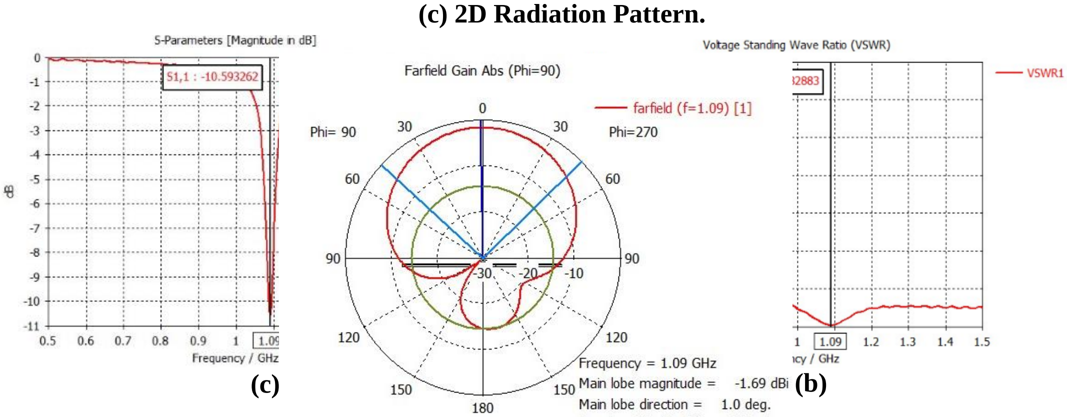


Table 1. The dimensions of the single patch antenna design

Description	Symbol	Before optimization (mm)	After optimization (mm)
Triangle side length	a	88,4	86
Width of Feedline	Wf	3,11	3
Length of Feedline	Lf	38,1	35,1
Width of Insert Feedline	Wif	1	1
Length of Insert Feedline	Lif	13	13
Width of Groundplane	Wg	102	110
Length of Groundplane	Lg	102	120
thick of Patch	T	0,035	0,035
thick of Substrate	h	1,6	1,6

The simulation results of this design meet the minimum standard values for antenna parameters. The return loss value is -10.59 dB, VSWR is 1.83, bandwidth is 3.1 MHz, and the antenna exhibits a directional radiation pattern. Below is the simulation result image of the triangular single-patch microstrip antenna:

Fig 2. The simulation results of the antenna design (a) Return Loss, (b) VSWR, (c) 2D Radiation Pattern.



B. Single Patch With Back To Back Structure Mikrostrip Antenna

The design of the single patch with back to back structure mikrostrip antenna can be seen in Figure 3. The antenna dimensions obtained from the calculation results are then optimized. The antenna dimension values can be found in Table 2.

Fig 3. Single patch antenna design with With Back To Back Structure

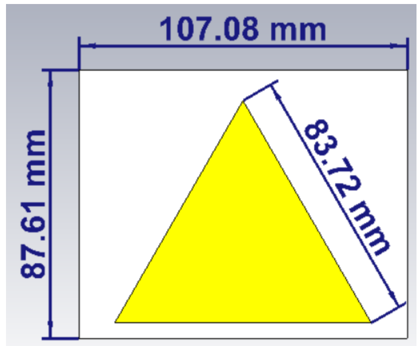
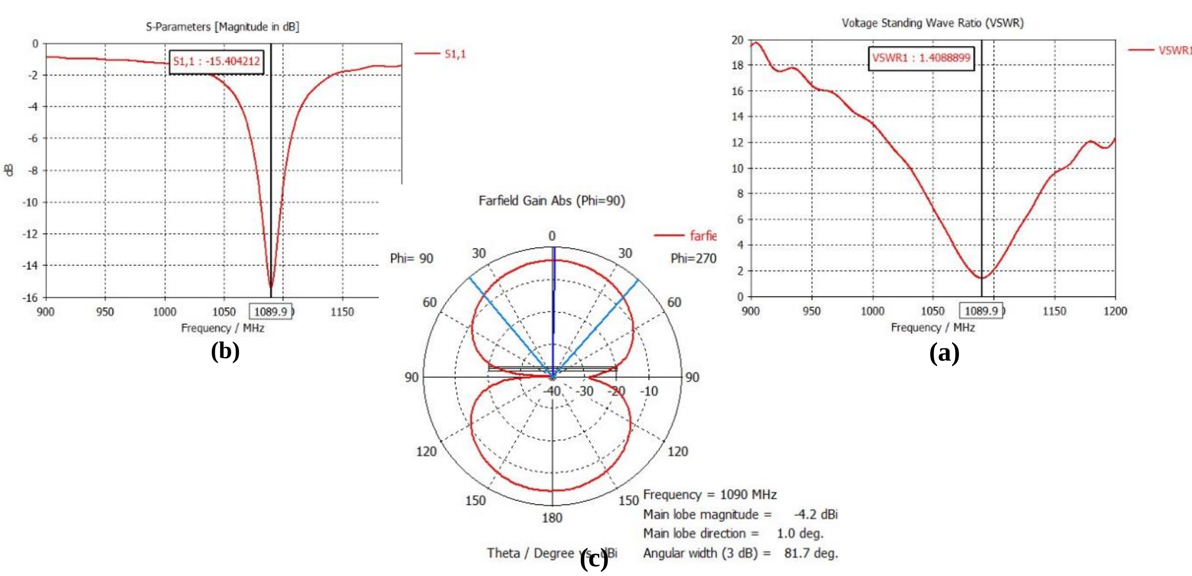


Table 2. The dimensions of the single patch with With Back To Back Structure

Description	Symbol	Dimension (mm)
Triangle side length	a	83,72
Width of Feedline	Wf	2,73
Length of Feedline	Lf	29,2
Width of Substrate	Ws	107
Length of Substrate	Ls	87,6
thick of Patch	T	0,035
thick of Substrate	h	1,6

The simulation results of this design show an improvement in antenna parameters compared to the previous design. The return loss value is -15.40 dB, VSWR is 1.4, bandwidth is 17.2 MHz, and the antenna exhibits a bi-directional radiation pattern. Below is the simulation result image of the triangular single-patch microstrip antenna with a back-to-back structure:

Fig 4 The simulation results of the antenna design (a) Return Loss, (b) VSWR, (c) 2D Radiation Pattern.



C. Comparison between Single Patch Design and Single Patch Back-to-Back Structure

The simulation results of the single patch microstrip design and the single patch back-to-back structure design exhibit significant differences. Not only the radiation pattern but also other parameters like Return Loss, VSWR, and Bandwidth have improved. Below is a table showing the differences between the single patch design and the single patch back-to-back structure design.

Table 3. Comparison of result values between single patch design and single patch back-to-back structure

Description	Single patch	Single patch back to back structure
Return loss	-10,59	-15,40 dB
VSWR	1,83	1,4
Bandwidth	3,1 MHz	17,2 MHz
Impedance	48,44 Ω	46,02 Ω
radiation pattern	Directional	Bi-Directional

4. CONCLUSION

Based on the description of the results of the research and discussion that has been carried out, it is concluded that :

1. The utilization of the back-to-back method on the microstrip antenna has successfully operated at the ADSB receiver frequency of 1090 MHz, achieving parameter values as expected.
2. The utilization of the back-to-back method can enhance the parameter values of the microstrip antenna compared to the single-patch antenna design with a 1 layer substrate. The achieved parameter values include a Return Loss of -15.40 dB, VSWR of 1.4, Bandwidth of 17.2 MHz, and a resulting bi-directional radiation pattern.

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