Rectangular Monopole Antenna Design for ADS-B Application

Firdaus[1], Muhammad Amirul[2], Yulindon[3], Andi Ahmad Dahlan[4]

{firdaus@pnp.ac.id[1], mirulid@gmail.com[2], yulindon@pnp.ac.id[3], aadfuty@pnp.ac.id[4]}

Electrical Department Politeknik Negeri Padang, Indonesia[1,2,3]

Abstract In this paper, rectangular monopole antenna for ADS-B application is presented. The antenna was created by first examining the conventional RTL-SDR antenna using various measurements to identify the antenna's characteristics at 1090 MHz, which is the ADS-B operating frequency. Based on the measurement results, a rectangular monopole antenna was designed with FR-4 PCB substrate with a thickness of 1.6 mm to replace the convensional antenna. Antenna consisting of rectanguar patch radiator and a defected ground structure (DGS). A slot is etched on the radiation patch, and the patch's bottom size is reduced to perform tapered side. The final antena size is 100 × 125 × 1.6 mm. The antenna can operate in the frequency range 1036 - 2204 MHz, 2313 – 7504 MHz, and 8000 – 9451 MHz which is the first range is include 1090 MHz for ADS-B application. Antenna has 3.05 dB gain at 1090 MHz and has omnidirectional radiation pattern.

Keywords: RTL-SDR, ADS-B, Planar Monopole.

1 Introduction

In order to improve the safety of aviation services, the Directorate General of Civil Aviation (Ditjen Hubud) via press release Number: 30 /SP/KSIHU/II/2020, requires the installation of Automatic Dependent Surveillance-Broadcast (ADS-B) on all transport category aircraft in Indonesia. Automatic Dependent Surveillance-Broadcast (ADS-B) is a surveillance technology used in aviation. Aircraft equipped with ADS-B transponders periodically broadcast their precise GPS-derived position, altitude, velocity, and other data. This information is received by ground stations and other nearby aircraft, enhancing air traffic control and improving situational awareness for pilots. ADS-B is a key component of modern air traffic management systems, contributing to safer and more efficient aviation operations. ASB-S is usually mounted on aircraft or ground stations and is superior to radar[1].

Aircraft equipped with ADS-B via their transponder transmits information about altitude, position, velocity, direction and other information every two times per second to ground stations and other aircraft. This information is obtained from Global Positioning System (GPS) information or Flight Management System (FMS) backups on each aircraft [2]. With the presence of ADS-B. Air Traffic Control (ATC) is greatly assisted in controlling flights in an

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airspace and becomes a critical element in coordination between flight information regions. The information going to the ground station is called ADS-B Out which can be seen in the form of output like viewing air traffic screens in general. This information can also be transmitted to aircraft equipped with ADS-B and will be shown in the cockpit traffic display known as ADS-B In.

Even though aircraft are required to install ADS-B devices, not all airports are equipped with ADS-B devices. This causes the information emitted by the aircraft cannot be used by several airports to regulate aircraft traffic. For airports that do not have ADS-B devices, we can use software defined Radio RTL-SDR (Realtek-Software Defined Radio) devices which are the RTL2823U Chipset [3][4][5]. In combination with the virtual radar server application, information about the aircraft can be displayed visually in great detail.

The sensitivity of the RTL-RDR device depends on the type of antenna used for the receiver on the device. The RTL-SDR device uses an omnidirectional type Passive DVB-T Magnetic Antenna with a gain of 3 dBi. To improve the quality of the received signal, an omnidirectional antenna with a higher gain is needed. Planar antennas can be an excellent choice for RTL-SDR applications due to their compact form factor and ease of integration with PCB-based RTL-SDR dongles. Using of a patch antenna with PCB substrate material is able to obtain a gain greater than 3 dBi and an omnidirectional pattern [6][7]. On the costly Rogers RO3010 substrate, a Directional Flared Antenna with Slotted Ground for ADS-B Systems and GPR Applications is designed[8]. A blade antenna developed in [9] for UAV applications at 1.09 GHz and 3.5 GHz is suitable for future UAV-assisted 5G networks, as well as being fully compliant with upcoming ADS-B-based Detect-And-Avoid (DAA) technologies for Unmanned Aerial Traffic Control but lacking in omnidirectional pattern.

In this research, a stabil omnidirectional patch antenna is designed in cheap RF4 material with a working frequency of RTL-SDR with a gain higher than 3 dBi to increase the range of receiving information sent by ADS-B aircraft. As a result, ADS-B services from the airport will be more efficient. The advantage of this patch antenna is that it is smaller in size and can be combined with ADS-B devices without having to use an external antenna.

2 Research Methods

2.1 RTL-SDR Commercial Antenna Characteristic Measurement

The DVB-T+FM+DAB 820T2 & SDR device is a device that combines several features in one unit. The device integrates a DVB-T (Digital Video Broadcasting - Terrestrial) receiver, an FM (Frequency Modulation) radio receiver, a DAB (Digital Audio Broadcasting) receiver, and also functions as an SDR (Software Defined Radio) device using the Realtek RTL2832U chipset and the Rafael Micro tuner R820T2. It is a versatile device that allows users to carry out various types of radio reception with a single device.

Passive DVB-T Magnetic omnidirectional antenna is a type of antenna designed to receive signals with a 360 degree radiation pattern, meaning that it can receive signals from all directions without needing to be specifically directed. This is the type of antenna commonly used with DVB-T (Digital Video Broadcasting-Terrestrial) devices, used to receive digital television broadcasts and radio signals in the 24 MHz - 1.7 GHz range. Based on the author's understanding, no literature has been found which describes the characteristics of Passive DVB-T Magnetic omnidirectional antenna. For this reason, antenna testing is carried out.

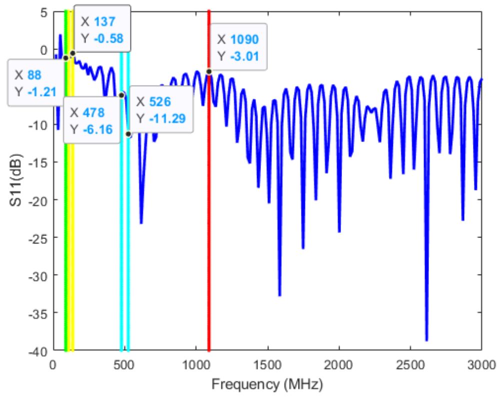


Fig. 1. S11 meausurement of The DVB-T+FM+DAB 820T2 & SDR antenna.

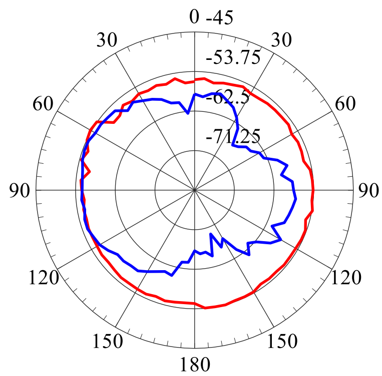
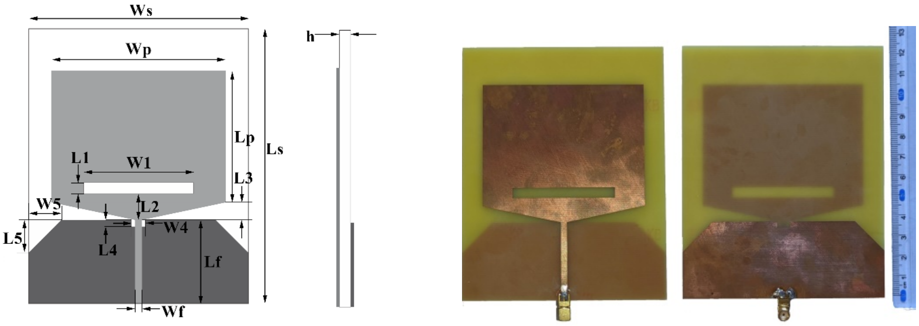


Fig. 2. Pattern measurement of The DVB-T+FM+DAB 820T2 & SDR antenna (E-plane= red, H-plane = blue).

Fig.1 shows the measurements of the The DVB-T+FM+DAB 820T2 & SDR antenna S11. markers are given to mark the FM frequency band, air band, dvb-t, and ADS-B. Fig.1 shows the measurements of the antenna S11. The antenna covers various radio frequency bands including the FM frequency band (88 – 137 MHz), air band (478 MHz), dvb-t (526 MHz), and ADS-B (1090 MHz) as indicated by the marker. S11 value needs to be increased lower than -10 dB for better system performance at each frequency. Fig.2 is a plot of radiation polarization measurements for the horizontal plane and the vertical plane. Antenna pattern shows a good omnidirectional pattern and will be a reference for antenna design.

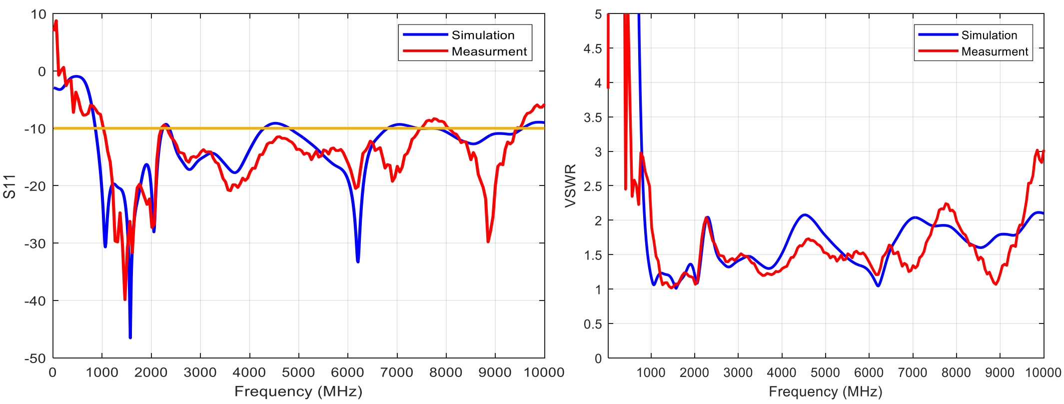
2.2 Wideband Rectangular Monopole Antenna Design

The geometry of the proposed planar antenna, as illustrated in Fig. 3, has a patch radiating element with a partial ground plane with defected ground structure (DGS). Planar monopole designs provide omni-directional radiation patterns in the azimuth plane, meaning they radiate or receive signals equally in all directions around the antenna's plane. a Defected Ground Structure (DGS) is a patterned modification of the ground plane in microstrip antenna design, used to achieve specific design goals, improve performance, or tailor the antenna's behavior at certain frequencies. The designed antenna is built on a dielectric FR4 material with $\varepsilon r = 4.4$, height = 1.6mm. The overall dimensions of the proposed Antenna are only 125 × 100 ×1.6mm. The proposed radiator is designed with tappered side on the bottom of radiator and a slot etching near bottom side. To attain broad-spectrum matching, the two upper-ground corners are trimmed into triangular shapes and positioned adjacent to each other as DGS. The optimized geometric parameters for the 1090 MHz antenna element are depicted in Fig. 1 are as follows: Ls = 125, Ws = 100, Lp = 60, Wp = 79.5, Lf = 38, Wf = 3.11, L1 = 5, W1 = 50, L2 = 12, W4 = 6.22, L3 = 8, W5 = 15, L4 = 3, h = 1.6, L5 = 15, all in mm.



(a) (b)

Fig. 3. Proposed Antenna. (a) Dimension, and (b) fabrication



(a) (b)

Fig. 4. Measured and simulated S-parameters and SWR for proposed Antenna. (a) S11 and (b) pattern.

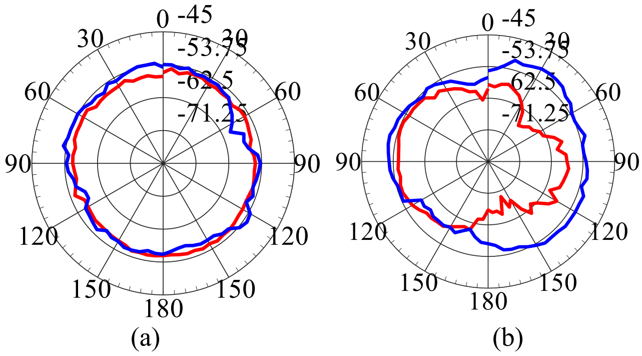


Fig. 5. Antenna radiation pattern . (a)Azimut (b)Elevation.(Red = RTL-SDR antenna, blue = small monopole)

3. Result and Discussion

The optimized antenna design is etched on an FR4 substrate as despicted in Figure 3 (b). The comparison between the measured and simulated S-parameters and SWR of the proposed antenna system, as illustrated in Figure 3, demonstrates a high degree of agreement. Notably, the fabricated antenna system exhibits a remarkable impedance bandwidth spanning from 1036 to 2204 MHz, 2313 to 7504 MHz, and 8000 to 9451 MHz, all of which maintain levels below -10 dB. This performance surpasses that of conventional antennas designed for the same frequency bands, indicating superior overall performance. the obtained 2D radiation patterns for both convensional and proposed antenna are shown in Figure 5. The antenna patterns are very close to omnidirectional at phi = 0 deg and 90 deg.

The proposed antenna fulfills ADS-B requirements for both working frequency and pattern. It further qualifies the proposed antenna for ADSB applications as well as a number of other implements in the three bands stated above.

4. Conclusion

This paper introduces a planar monopole antenna system designed for ADS-B applications. The antenna comprises a rectangular patch with a slot and DGS etching embedded within, which enhances its impedance bandwidth. A functional prototype of the antenna system has been constructed, and the measured results align closely with simulated data. The operational frequency range spans from 1036 to 2204 MHz, 2313 to 7504 MHz, and 8000 to 9451 MHz. The antenna showcased here offers ADS-B users a means to create compact, effective, and budget-friendly devices. In forthcoming research, one could assess the antenna's performance within a full ADS-B system.

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