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Featuring Software Defined Radio in Airports for Finding Automatic Descendants Surveillance

Ardian Arief Epti Nur Putra[1], Wahyu Pamungkas[1]*, and Agung Wicaksono[2]
[1]The University Center of Excellence for Sustainability Cities, Village and Food Security, Telkom University, Purwokerto, 53147, Indonesia
[2]Telkom University, Purwokerto, 53147, Indonesia
*e-mail: wahyupa@telkomuniversity.ac.id

***Abstract*—As air traffic becomes more complicated, more effective monitoring systems are required to assure aviation safety and security. Automatic dependent surveillance-broadcast (ADS-B) technology has become the international standard for real-time airplane tracking, however typical ADS-B receivers used in airports are expensive and frequently unavailable. This study assesses the dependability and efficiency of software defined radio (RTL-SDR) as a low-cost option for receiving ADS-B signals. The study uses an experimental method focusing on developing a 1090 MHz PCB antenna coupled to an RTL-SDR device, with data processed using RTL1090 software and visualized using virtual radar server. Testing took place at two airports: Yogyakarta International Airport (YIA) and Wirasaba Airport. The results show that the system can identify aircraft within a range of up to 400 km at YIA and 250 km at Wirasaba, with the received data providing precise information on aircraft position, altitude, and speed. The system spotted four airplanes in Wirasaba and nine at YIA, indicating that the latter location has broader coverage. These findings show that RTL-SDR is a dependable and cost-effective option for ADS-B signal reception, with the potential to replace more expensive conventional receivers used in airports.**

Keywords: ***ads-b, rtl-1090, software defined radio, virtual radar***

I. Introduction

Increasing air traffic requires effective control for the safety and security of aviation. Advanced air traffic monitoring and flight navigation systems play a crucial role in preventing aviation incidents. Without good aircraft navigation, the aircraft could lose its predetermined flight path, causing the possibility of colliding with other aircraft or encountering unpredictable weather conditions that could result in a very dangerous situation and increase the risk of accidents [1]. Additionally, if aircraft traffic is irregular or too congested, there can be confusion and conflict in the air. Ineffective air traffic management systems can cause aircraft to be late for landing or takeoff, increasing the likelihood of runway incidents [2].

Therefore, sophisticated navigation and navigation technology is crucial to prevent these incidents [3]. Automated systems and *real-time* data integration enable air traffic control to identify potential conflicts, provide instructions to pilots, and ensure air traffic flows run safely and efficiently. Thus, this system helps to create a safer and more orderly flight environment [4].

Automatic dependent surveillance-broadcast (ADS-B) is a technology that allows aircraft to provide real-time information about their position and has become international standard in-flight surveillance systems [5]. ADS-B plays an important role in improving safety and efficiency in air traffic management [6].

ADS-B is a system that relies on cooperation between aircraft and ground stations that requires aircraft to share information, including the position, altitude, direction, speed, and destination of the aircraft [7]. ADS-B signals operate at a frequency of 1090 MHz and have a maximum distance of up to 200 NM (370 km) for transmission to ground stations. Aircraft are equipped with electronic devices used in flight to relay additional information to air traffic monitoring systems [8]. With this device, the aircraft can transmit flight data at a frequency of 2 Hz, which means that there are two transmissions per second or the equivalent of sending data twice in one second. Flight data transmitted by the aircraft is obtained from the global navigation satellite system (GNSS) navigation satellite system which helps find the aircraft's accurate position [9].

Software defined radio (SDR) is a technology that allows electronic devices to transmit and receive radio signals using software that can be configured as needed [10]. SDRs are useful in a variety of applications, including wireless communications, radar, and frequency monitoring. As a flexible and effective solution, SDRs make it easy to build easily configurable receivers for evolving communication systems [11]. Thanks to its ability to be configured at a variety of frequencies, including an ADS-B frequency of 1090 MHz, SDRs can be used as ADS-B signal receivers. This provides a more affordable alternative to aircraft navigation and tracking systems compared to conventional ADS-B receiver systems at airports [12].

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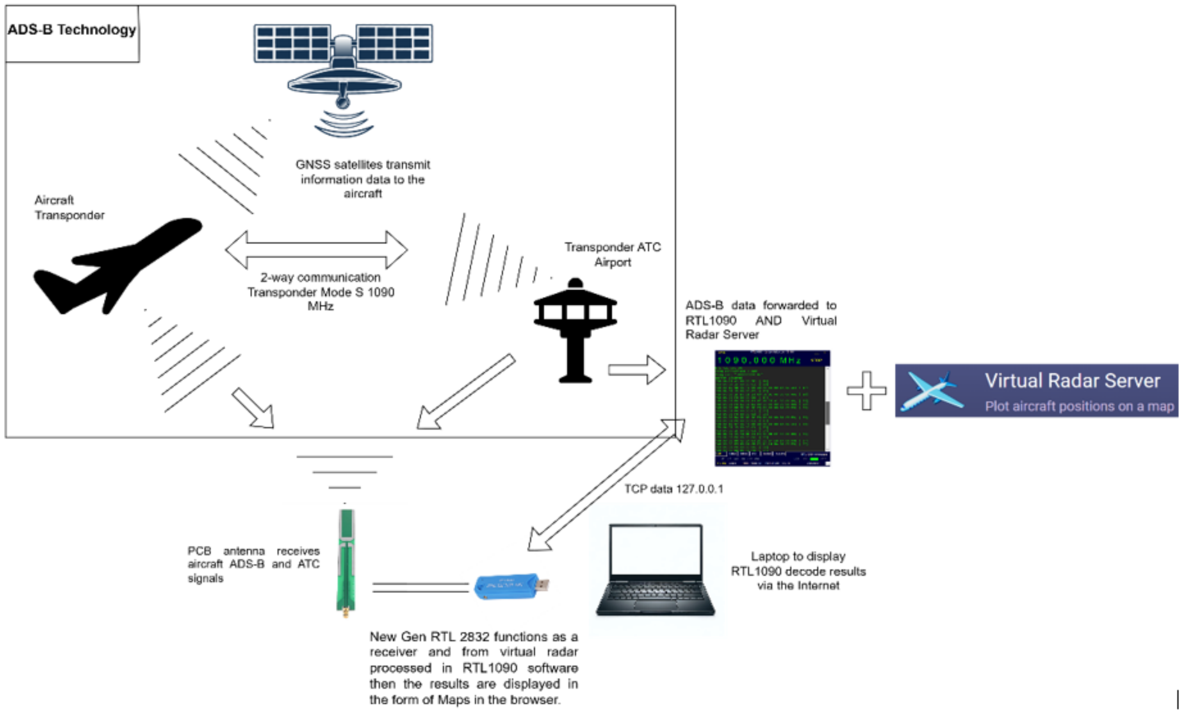

Figure 1. System design

ADS-B signals that are operated at airports usually require expensive receiving equipment. However, SDR technology offers the ability to replace this expensive receiver equipment, allowing for easier and more economical use in performing the functions and roles of the receiver at airports, making it an economical choice for aircraft navigation and tracking systems [13].

To capture ADS-B signals, SDR devices must be connected to a PCB antenna specifically designed for the 1,090 MHz frequency which is the operational frequency of ADS-B [14]. The signal capture process begins when the PCB antenna is microstriped, which has a gain characteristic with a range of 2 to 6 dBi [15]. This antenna picks up radio waves at these frequencies emitted by the aircraft. Then this signal is passed to the SDR device. Within SDR, the signal is processed by software configured to decipher ADS-B data, including information such as aircraft position, altitude, and speed [16]. Thus, SDRs play an important role in converting the received radio signals into useful and analyzable data for aircraft navigation and tracking systems [17].

The ADS-B signal received by the SDR device will be decoded using RTL1090 software. In this software, information from the signal, such as altitude, speed, and other parameters, will be revealed, After obtaining the information, the data will be visualized through a virtual radar server so that the author can analyze the location of the aircraft in the form of a two-dimensional image on a world map [18,19].

II. Method

The use of ADS-B technology in-flight monitoring has become an important aspect in the aviation industry due to its contribution to improving efficiency and safety. The ADS-B system facilitates the continuous transmission of information from the aircraft regarding the aircraft's position, speed, and identity, both to monitoring stations on the ground and to other aircraft within the operational radius. To ensure an efficient and effective implementation of ADS-B, it is important to have a detailed and accurate design of a virtual radar system. This involves using a PCB antenna to optimally capture ADS-B signals and using virtual radar as a platform to process and display that data.

Figure 1 shows an overview of the system design that is the core of this study, where it will show in detail the configuration and function of each component in the flight monitoring system, and illustrate how they integrate to achieve real-time data collection and analysis.

Figure 1 shows the design of an air traffic monitoring system. The system is designed to collect and display aircraft data through a webserver. Figure 2 shows the block diagram broadcast system. This process begins with the use of ADS-B signals emitted by aircraft, where the aircraft's transponder acts as an information transmitter. This signal contains data on the aircraft's identity, altitude, and speed, which are received by stations on the ground.

Figure 3 shows the Decoding Output System ADS-B. The radio frequency (RF) signal transmitted by the ADS-B transponder on the aircraft used to convey flight information has been specially regulated by the 1090 MHz Antenna. The Narrow Band-Pass Filter functions to filter RF signals and ensure signals in the 1090 MHz frequency range used to reduce noise and interference. SDR has several mechanisms including the RF Amplifier which functions to amplify the received RF signal, the RF Tuner which functions to adjust the frequency of the RF signal so that it can be processed by the digital processor, the analog

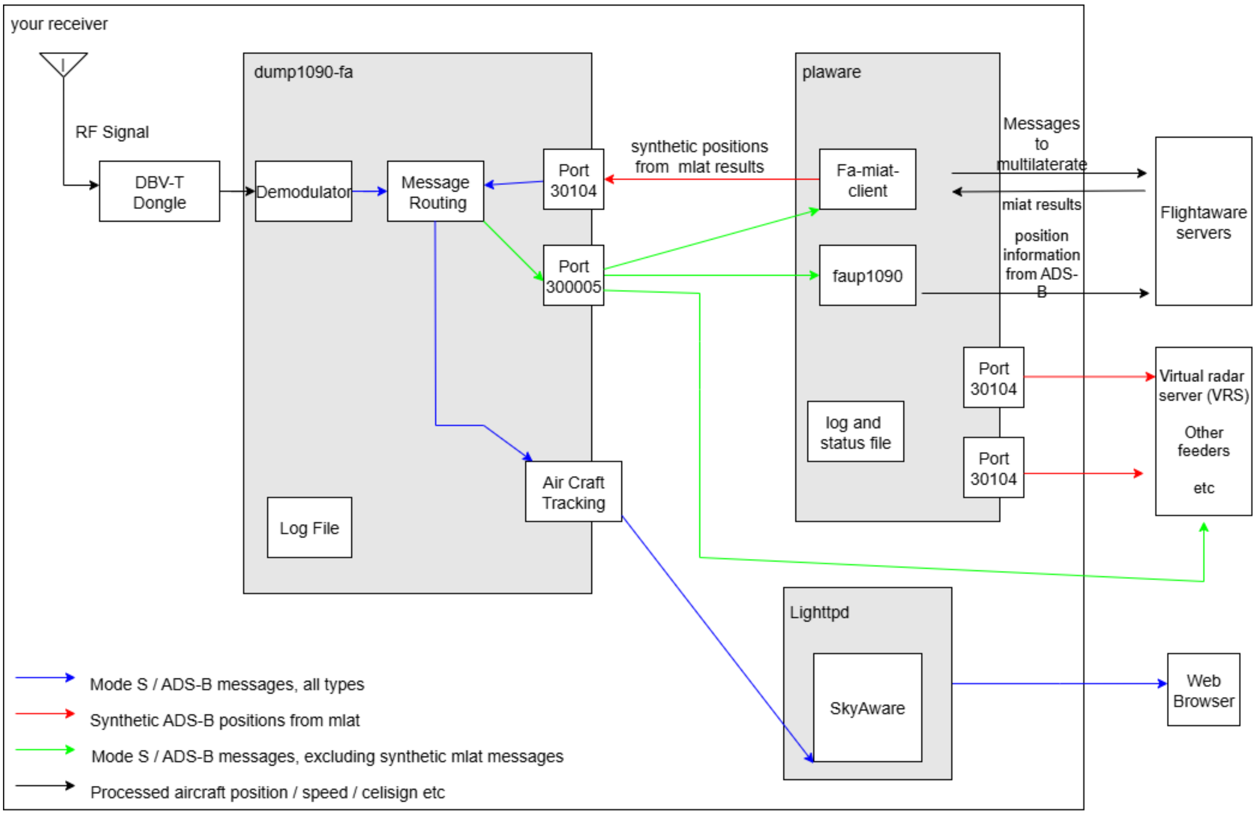

Figure 2. Block diagram broadcast system

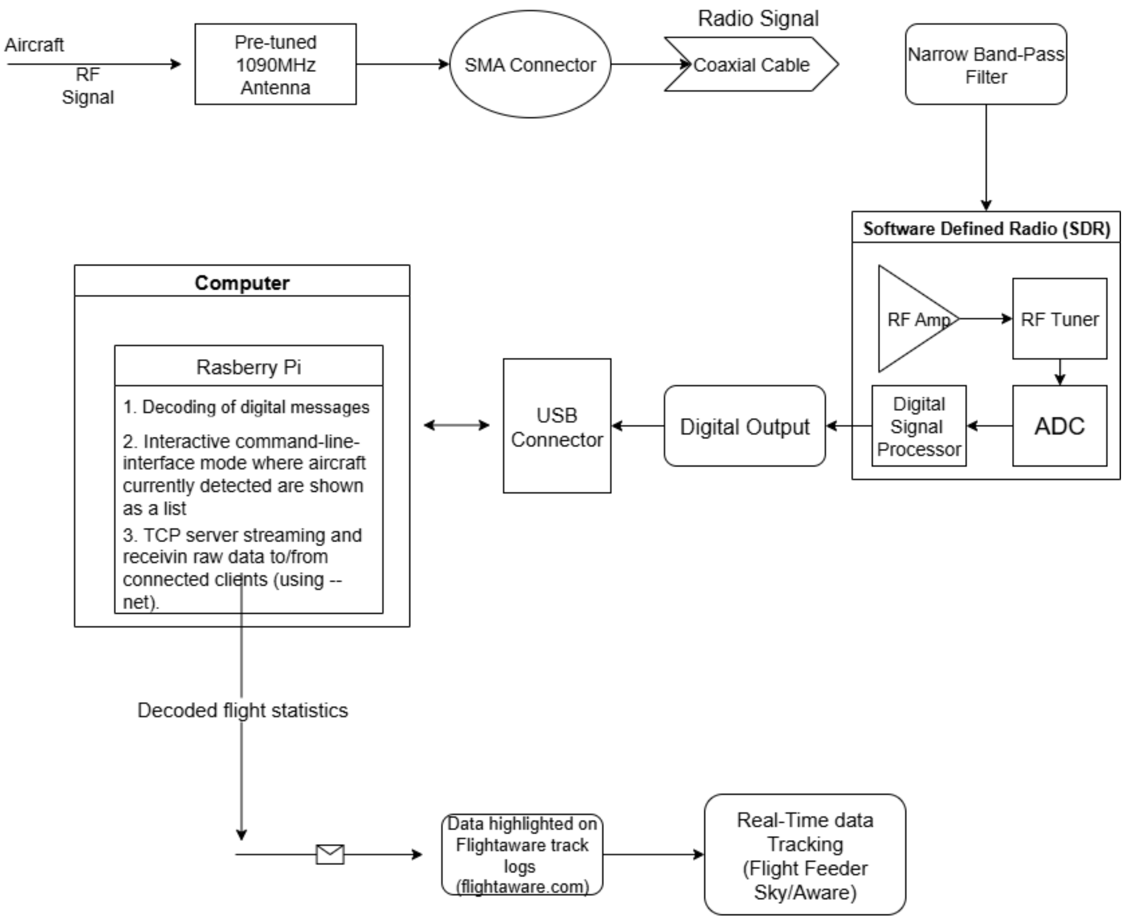

Figure 3. Block diagram decoding output system

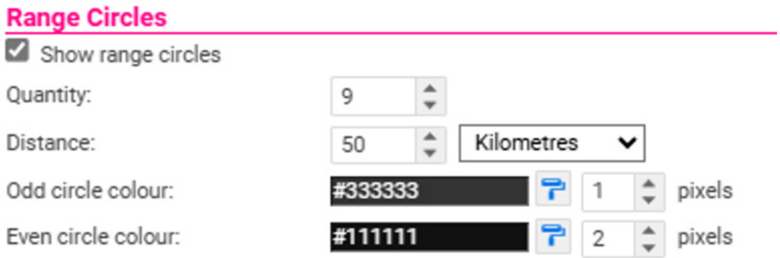

Figure 4. Setup range circles

Table 1. Hardware used

Device Name	Function
NEW GEN. RTL2832	As a receiver of DVB-T and DAB signals and this device is in charge of receiving television and radio signals.
Laptop	As a carrier of interface displays through the internet or web browser.
Kabel Extender RG174	It serves to place the antenna in a more optimal location, such as outdoors or in a higher place, to get a better signal.
1090MHz PCB Antenna	The 1090MHz PCB antenna serves to receive or transmit radio signals efficiently at the 1090MHz frequency, specifically for ADS-B signals used in air traffic monitoring.

to digital converter (ADC) which functions to convert analog signals to digital, and the digital signal processor (DSP) which functions to convert digital signals into the required information. Processing on the Raspberry Pi as a computer includes decoding digital messages which functions to translate data from the SDR into information that can be known, the interactive command-line interface which functions to display a list of detected aircraft, and the TCP server streaming which functions to send and receive data connected via the network. The decoding results include decoded flight statistics which function to obtain processed flight data, and real-time data tracking which functions to visualize real-time flight tracking.

Two-way communication between the aircraft transponder and the airport ATC transponder plays an important role in this system. Airport transponders, especially in control towers, are in charge of receiving and transmitting signals for air traffic navigation and monitoring. The system also involves a PCB antenna that is capable of detecting ADS-B signals from multiple directions and allowing for more extensive and accurate data collection.

Finally, the data received by ATC is processed by the Virtual Radar Server. This server converts the data into a visualization of the aircraft's position on an interactive map that can be accessed online. The process of transmitting and receiving data uses the TCP/IP protocol with an IP address of 127.0.0.1 which is commonly used for local network testing. NEW GEN RTL2832 is a receiver of RTL-SDR signals and virtual radar as well as a laptop that functions as a device and allows the author to view air traffic data in real-time.

Table 2. Hardware used

Software Name	Function
RTL-SDR Driver 2832	Driver installation
Zadig Ver 2.4	Installation of USB driver settings
RTL1090 Ver 3.0.4	Decoder, displaying raw data
Virtual Radar Server Ver.2.4.4	Decoder, Map viewer

Hardware and software used is featuring software defined radio in airports for finding automatic descendants surveillance as described in Table 1 and Table 2 respectively.

III. Results and Discussion

Virtual radar allows the author to view flights in real-time on a web-based map. Virtual radar receives ADS-B data from devices such as RTL-SDR dongles that run with software such as RTL 1090 and then display the data visually. The following is a display of the addition of the range circle to the virtual radar in Figure 2.

Figure 4 above shows the "range circles" setting on the Virtual Radar Server, which allows the researcher to display the distance circles on the map, helping to visualize the distance from the central point of receiving the ADS-B signal. The researcher chose to display 9 distance circles with a distance of 50 kilometers between the circles, as shown in Figure 4 This setup is important to provide a visual reference to the coverage of the signal reception range and to understand the extent of the aircraft's data reception. Odd circles are colored #333333 with a dark black line thickness, while even circles are colored #111111 with a light black line thickness, providing a clear contrast.

The results of measuring the distance of receiving ADS-B signals in two different locations between Wirasaba Airport and YIA Airport. Measurements were made to determine the range and quality of ADS-B signal reception using RTL-SDR devices at both locations.

Figure 5 shows the results of measuring the distance of receiving ADS-B signals at Wirasaba Airport. The distance measured reaches 350 meters from the ATC to the receiver, marked with a yellow line. Measurements are made in open areas such as large fields for optimal signal reception, using the yellow ruler feature on Google Earth to ensure data accuracy.

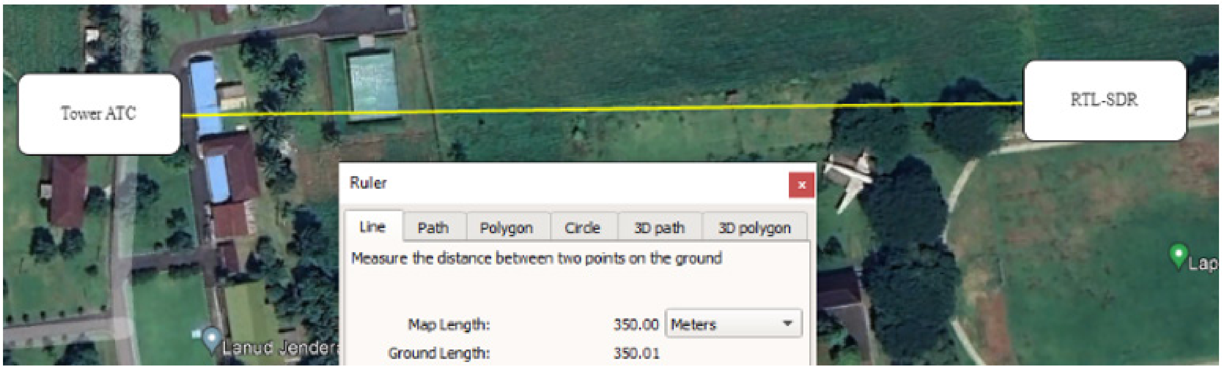

Figure 5. Measurement distance in Wirasaba

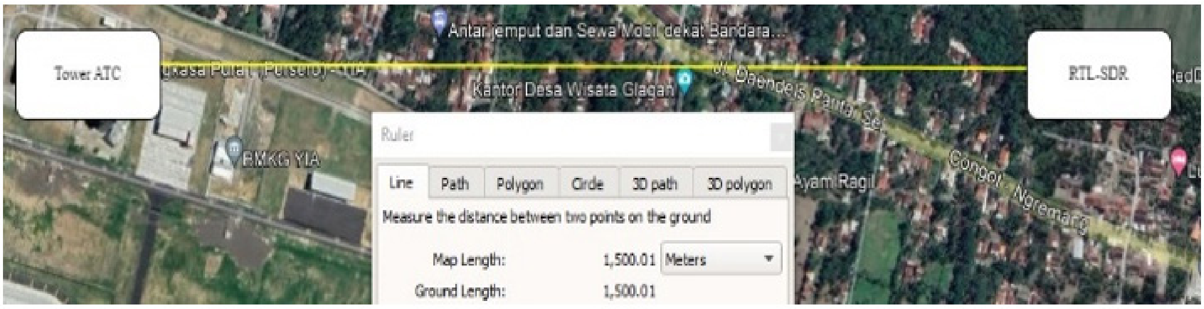

Figure 6. Measurement distance in YIA

Table 3. Difference in measurement distance between the two airports

Location	Distance (meters)	Jerk (kilometers)
Wirasaba	350	0.35
YIA	1500	1.5

The measurement results at YIA shown in Figure 6 show the results of measuring the ADS-B signal reception distance at YIA Airport. Unlike Wirasaba Airport, measurements are carried out in a large area of rice fields. The distance measured reached 1500 meters from the ATC to the receiver, marked with a yellow line. The following is Table 3 of the differences between the distance between Wirasaba Airport and YIA Airport.

Table 3 shows the difference in the distance of ADS-B signal reception in two locations, namely Wirasaba Airport and YIA Airport. At Wirasaba Airport, the signal reception distance is 350 meters, while at YIA Airport, the distance reaches 1500 meters. This comparison shows that YIA Airport has a wider range of reception compared to Wirasaba Airport.

The researcher will show the starting point of aircraft detection by the ADS-B monitoring system using RTL-SDR on the virtual radar application with an additional 9 range circle circles 50 km away at Wirasaba Airport and YIA Airport. The purpose of this initial detection is to understand how the system initiates aircraft tracking and determine the effective range of ADS-B signal reception.

Figure 7 shows the starting point of aircraft detection by the ADS-B monitoring system using RTL-SDR at Wirasaba Airport. In this image, 4 aircraft are detected within different distance circle radii, clearly depicting the signal reception range of the system. These measurements demonstrate that the ADS-B system is capable of capturing aircraft signals within a certain range, effectively illustrating its ability to monitor aircraft movements in the vicinity. The varying distances at which the aircraft are detected highlight the system's sensitivity and accuracy in different scenarios, providing valuable data on the coverage area and potential limitations of the signal reception. This visualization underscores the effectiveness of the ADS-B system in maintaining situational awareness and ensuring reliable tracking of aircraft in the monitored airspace.

Figure 8 below shows information data on one of the four aircraft captured by RTL-SDR, offering a detailed view of the aircraft's position, altitude, and speed as recorded by the monitoring system, further illustrating the system's capability in tracking specific flight parameters in real-time. The information provided in this figure is crucial for understanding the real-time operational status of the aircraft, enabling precise monitoring and decision-making processes in air traffic management.

In addition to the position of the aircraft, the RTL-SDR also managed to capture aircraft information data at Wirasaba Airport, as shown in Figure 9. In the image, the researcher took information data of one of the aircraft, namely the Garuda Indonesia aircraft, which was marked in yellow on the virtual radar. The aircraft was detected at a distance of 150 km from the receiver, with an initial tracking time of 30 seconds and a distance of 147.29 kilometers from the receiver.

Figure 9 shows the starting point where the aircraft was first detected by the ADS-B monitoring system using the RTL-SDR device at YIA. Unlike Wirasaba Airport which only detects 4 aircraft, YIA Airport is able to detect 9 aircraft. The initial detection of the aircraft at YIA is

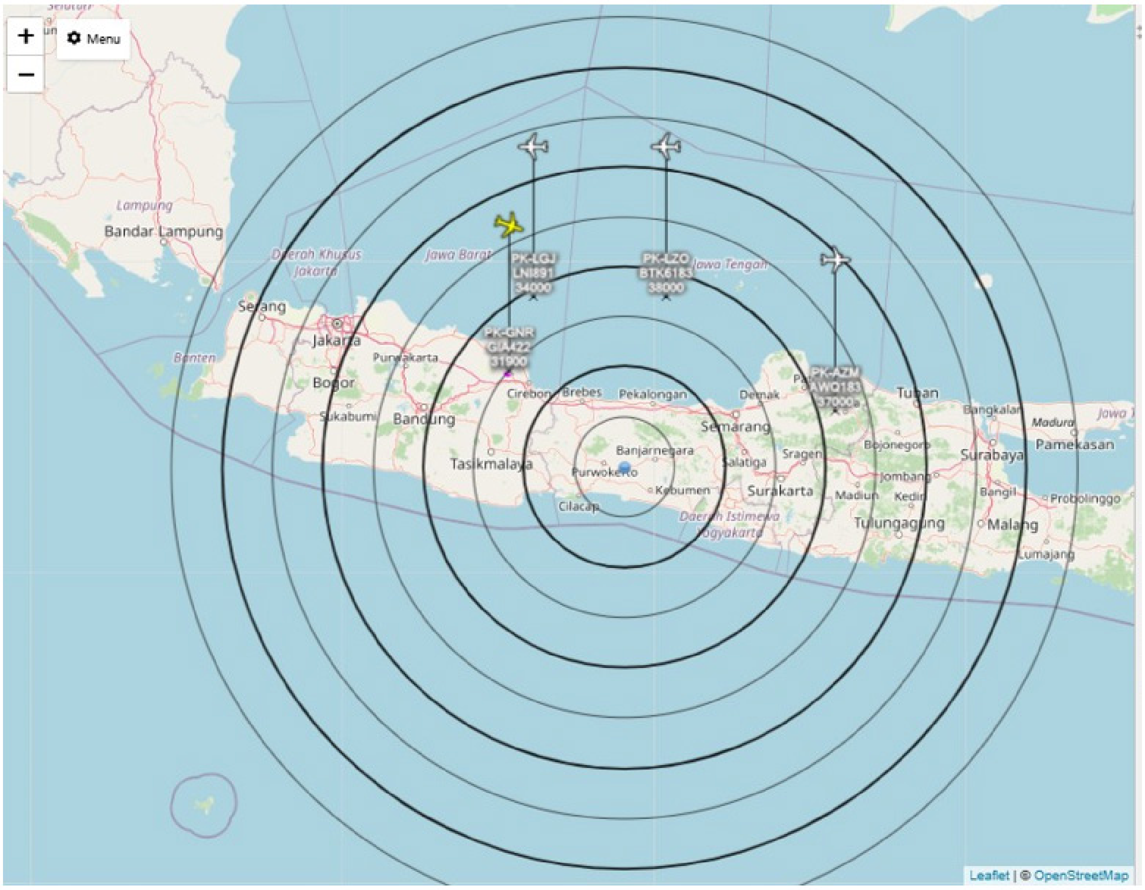

Figure 7. The beginning of aircraft detection in wirasaba

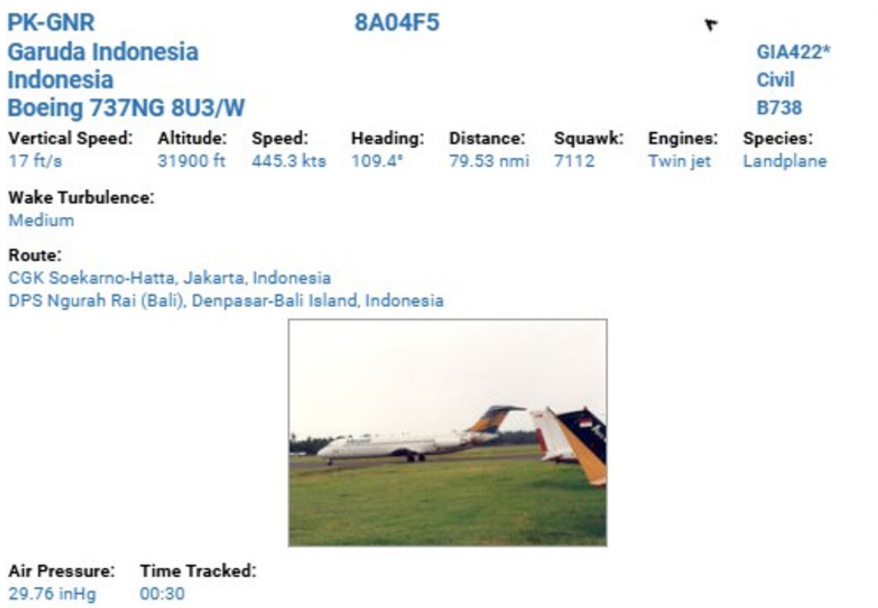

Figure 8. One of the initial aircraft information data was detected in Wirasaba

in the 2nd circle with the closest distance of 100 km and the farthest distance in the 8th circle which is 400 km. This expanded detection range at YIA demonstrates the enhanced coverage capabilities of the ADS-B system when deployed in different environments, providing valuable insights into the system's performance across various operational contexts.

In Figure 10 above, the researcher took data from one of the aircraft, namely the Garuda Indonesia aircraft which is marked in yellow on the virtual radar. The aircraft was detected at YIA Airport at a distance of 400 km from the recipient. The plane was first tracked at 1 minute 45 seconds at a distance of 362.00 km from the receiver.

After tracking the initial detection of the aircraft, we

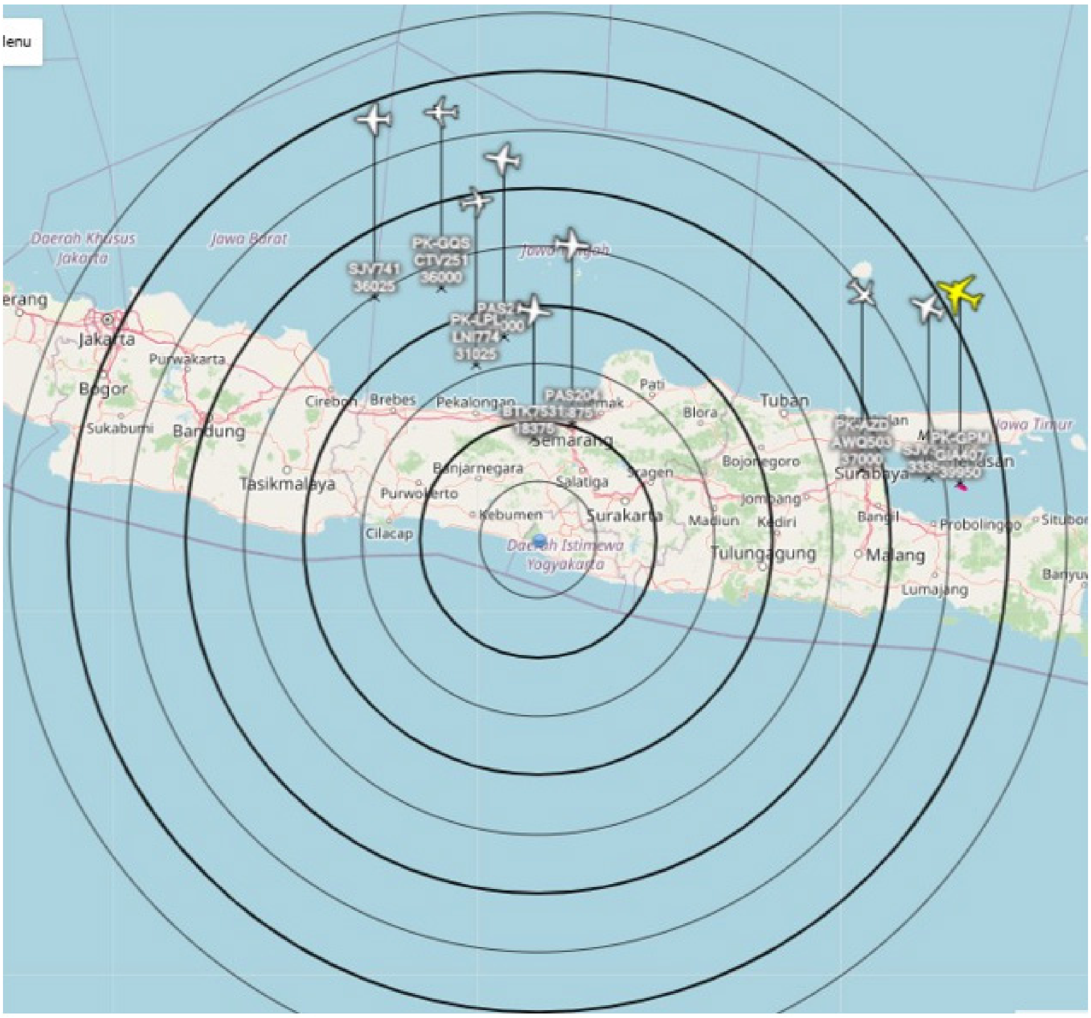

Figure 9. The beginning of aircraft detection at YIA

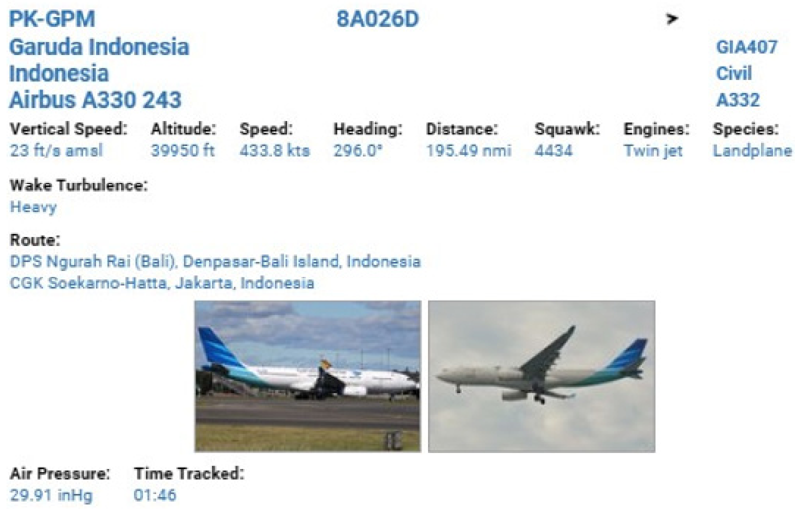

Figure 10. One of the initial aircraft information data detected at YIA

then monitored the aircraft before disappearing from radar. The goal was to find out how far the aircraft was before disappearing from radar at both airports, using the RTL-SDR device on the virtual radar app.

In Figure 11, we monitor the plane before it disappears from radar at Wirasaba Airport, with the Garuda Indonesia plane prominently marked in yellow and purple trails. The position of the plane before disappearing was within the 4th circle, indicating a distance of 176.88 km from the receiver at Wirasaba Airport. The detection of this aircraft highlights the effective range of the radar system in tracking aircraft even at significant distances. Furthermore, the

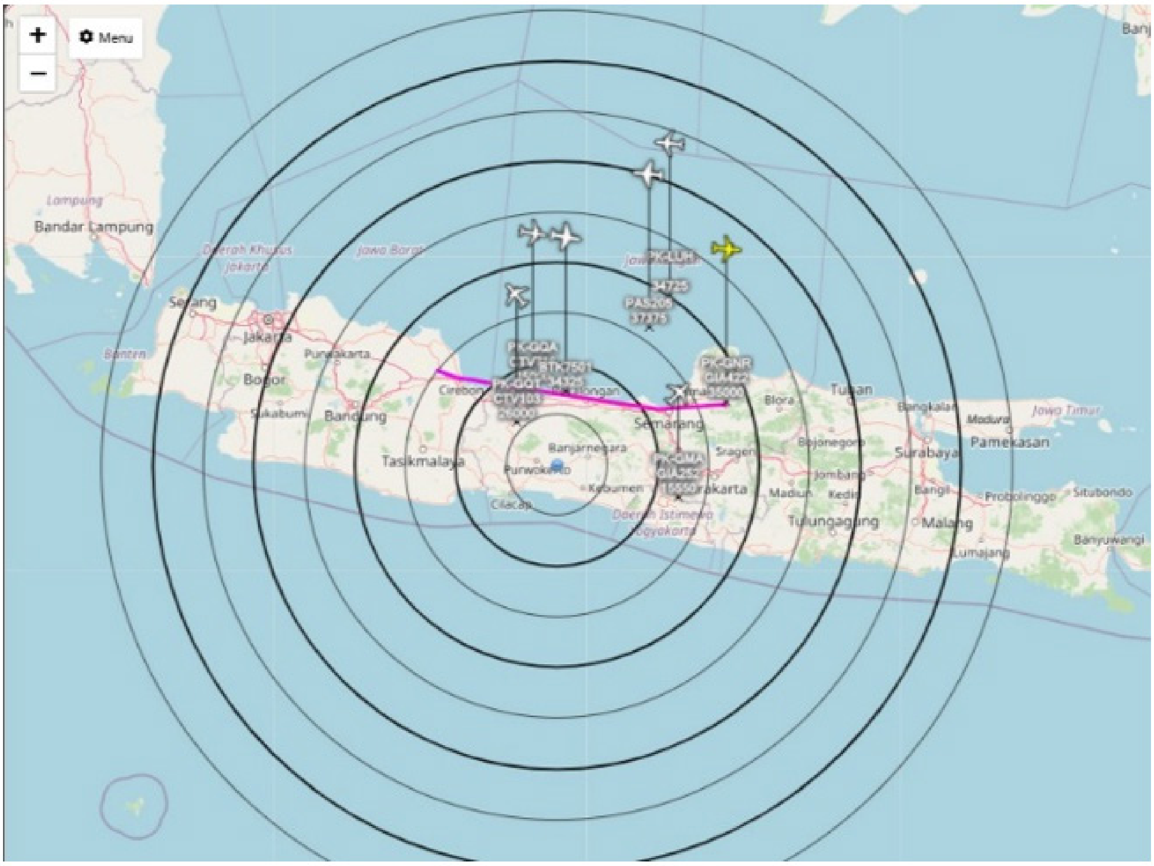

Figure 11. The position of the plane before it disappeared from radar in Wirasaba

number of detected aircraft increased from 4 to 7 as they either passed through or took off within the vicinity of the receiver at Wirasaba Airport, reflecting the system's robust capability in identifying and tracking multiple aircraft simultaneously. This increase in detected aircraft within the 4th circle demonstrates the system's enhanced sensitivity and responsiveness in capturing signals from various aircraft, providing comprehensive situational awareness and ensuring that no aircraft within the monitored area goes undetected.

In Figure 12, we monitor a Garuda Indonesia aircraft, marked with yellow and purple trails, before disappearing from radar at YIA Airport. The plane is in the 5th circle with a distance of 249.46 km from the recipient at YIA Airport. The number of tracked aircraft was reduced from 9 to 8 until the 5th circle. This reduction occurs because the aircraft passes or takes off in the vicinity of the recipient.

The final part of featuring software defined radio in airports for finding automatic descendants surveillance is when the aircraft disappears from radar. The aircraft disappears from radar due to the limited range of the antenna used or because the aircraft is too far away from the receiving area.

The Garuda Indonesia aircraft at Wirasaba Airport, which before disappearing in Figure 11, can be seen disappearing from radar in Figure 13. Previously, the plane was marked in yellow and had purple trails. This plane before disappearing from radar was in the 4th circle and disappeared in the 4th circle. Figure 14 shows the distance and information from the Garuda Indonesia aircraft at Wirasaba Airport that disappeared from radar.

In contrast to the initial information data of the detection of Garuda Indonesia aircraft at Wirasaba Airport, the data of the aircraft that disappeared from radar in Figure 14 shows changes in altitude, speed, heading, distance, and time tracked.

Similar to the situation at Wirasaba Airport, the Garuda Indonesia aircraft at YIA Airport also disappeared from radar coverage. In Figure 12, the aircraft is seen gradually disappearing from radar, a disappearance further illustrated in Figure 15. Initially marked with yellow and purple trails, the plane was being tracked within the 5th circle, where it remained until it disappeared within the same circle. This indicates that the aircraft was being closely monitored at a significant distance from the radar receiver before it vanished from the system's detection range. Figure 14 provides a detailed overview of the distance and other relevant information related to the Garuda Indonesia aircraft at YIA Airport. The data captured in these figures underscore the challenges in maintaining continuous radar contact with aircraft as they move towards the outer limits of the radar's effective range. The tracking and eventual disappearance of the aircraft highlight the limitations of the monitoring system at extended distances, emphasizing the need for potential enhancements in coverage or the integration of additional systems to ensure uninterrupted tracking of aircraft in these critical zones.

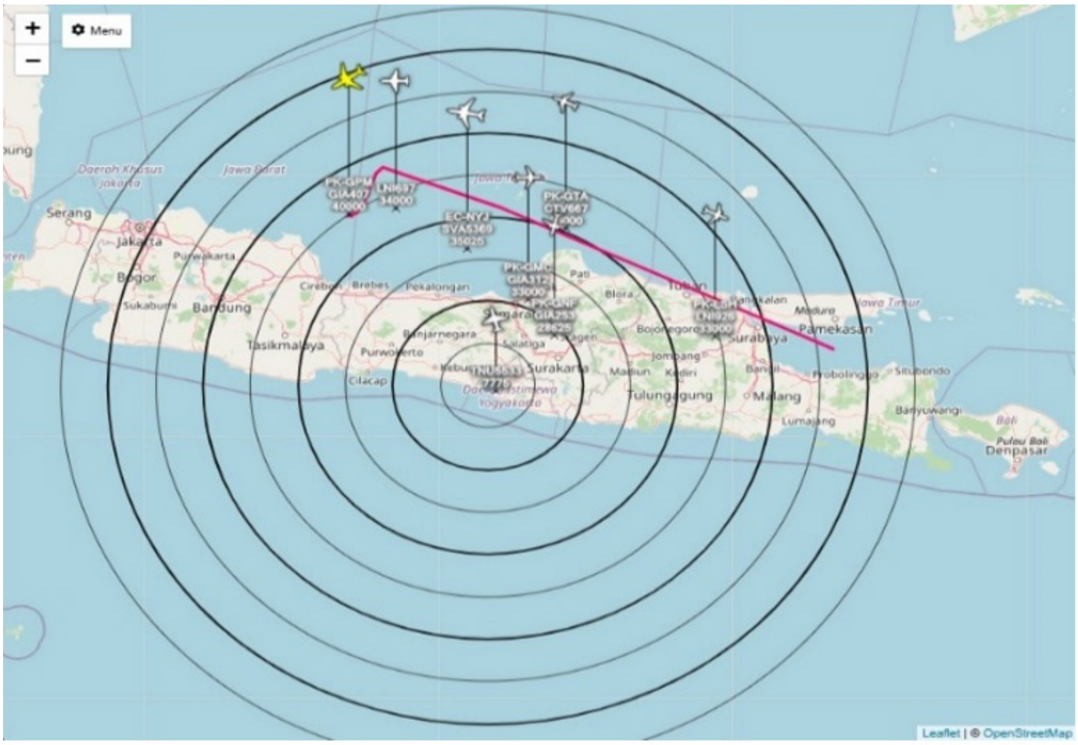

Figure 12. The position of the plane before it disappeared from radar at YIA Airport

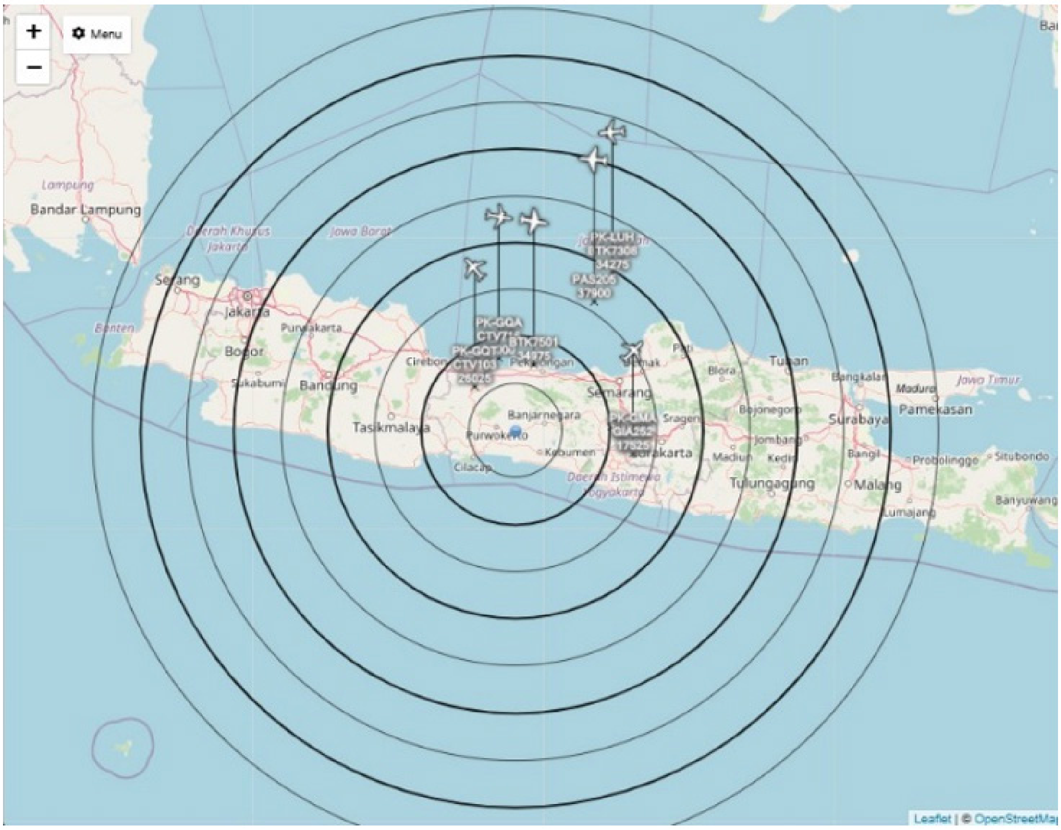

Figure 13. Plane missing from radar at Wirasaba Airport

IV. Conclusion

To detect ADS-B signals on aircraft, it is done by connecting the RTL-SDR to a laptop, using RTL1090 software and a Virtual Radar Server. In addition, a 1090 MHz PCB antenna is used to receive signals in the form of 24-bit binary data. This binary 24-bit data is a digital data format that contains aircraft position, altitude, and identity information, allowing RTL-SDR to capture those signals and convert them into aircraft position, altitude, and speed

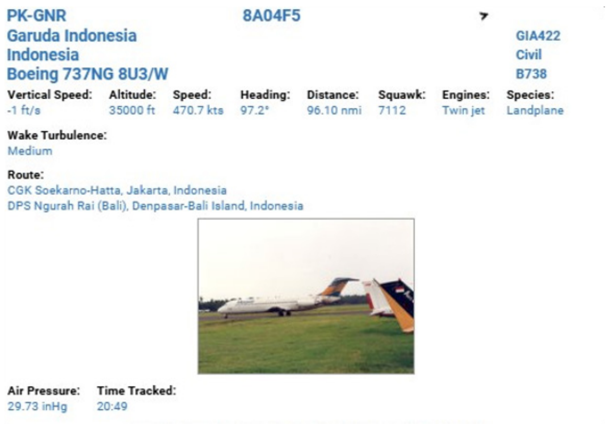

Figure 14. Aircraft information data disappears from radar in Wirasaba

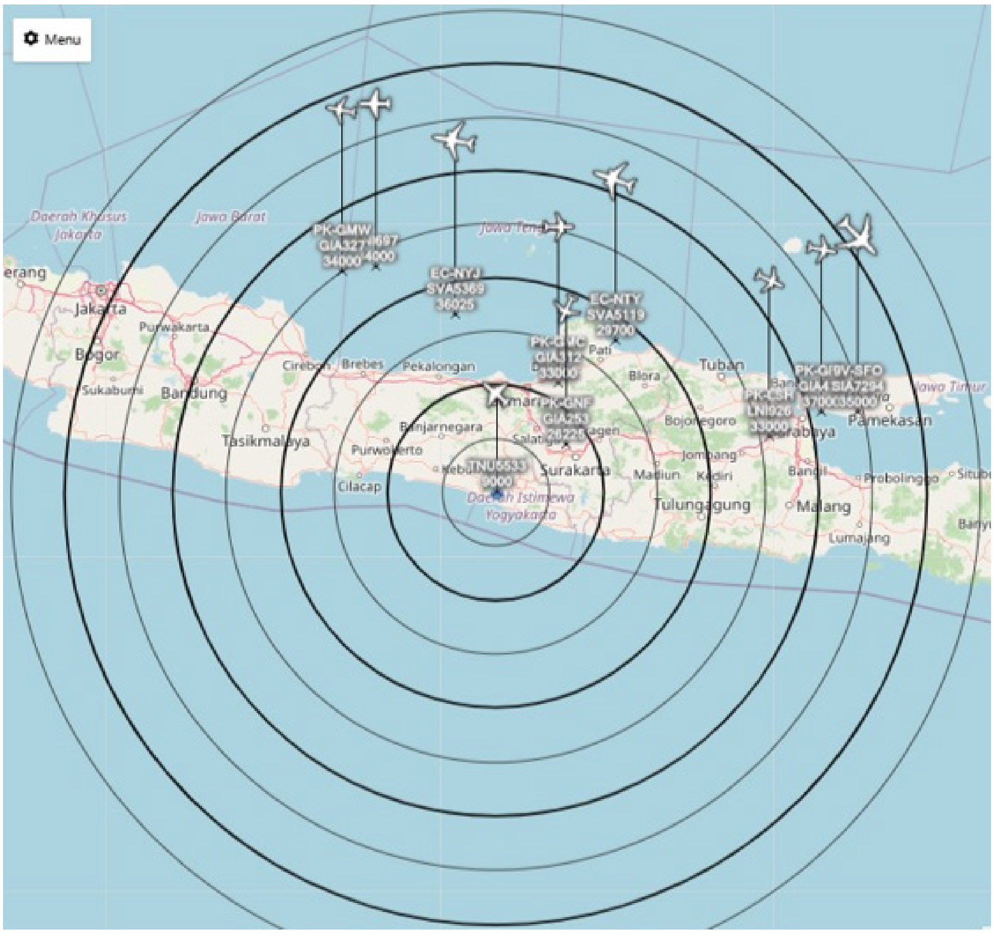

Figure 15. Plane missing from radar at YIA

information data. To obtain information on the position, altitude, and speed of the aircraft, RTL1090 software is used to capture raw data signals in the form of binary 24-bits. This data is then decoded/processed and visualized in the form of a real-time web map in virtual radar. This data displays complete information about the aircraft's position, altitude, and speed.

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