Implementation Of Mobile Network-Based Unmanned Aerial Vehicle (UAV) Telemetry for Ground Control Station (GCS) Monitoring

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Abstract – This research focuses on cellular network-based Unmanned Aerial Vehicle (UAV) telemetry used to monitor the Ground Control Station (GCS) in the Long Endurance Low Altitude (LELA) division of the Indonesian Flying Robot Contest (KRTI). This research aims to implement a cellular network telemetry work system which then the value of the Received Strength Signal Indicator (RSSI) on the Unmanned Aerial Vehicle (UAV) is compared during aerial and land conditions, Pixhawk and RaspberryPi3 as a microcontroller of the Unmanned Aerial Vehicle (UAV). The Received Strength Signal Indicator (RSSI) test shows the signal strength received in an aerial state as far as 500 meters and an altitude of 100 meters from the surface is -61 dBm and the Unmanned Aerial Vehicle (UAV) in the land shows the Received Strength Signal Indicator (RSSI) results of -39 dBm. (RSSI) of -39 dBm. The Received Strength Signal Indicator (RSSI) value during aerial and land conditions shows that the signal is classified as very good for receiving and sending data. The conclusion of this research is that cellular network telemetry is effectively used in a long range and is expected to facilitate sending and receiving data for all types of Unmanned Aerial Vehicles (UAV).

Keywords: Unmanned Aerial Vehicle (UAV), Received Strength Signal Indicator (RSSI), Ground Control Station (GCS), Telemetry.

I. INTRODUCTION

In the last ten years, often known As Unmanned Aircraft Systems or (UAV), have been increasingly popular in the field of unmanned system research worldwide. The ministry of defense, the ministry of environment and forestry, and other research domains require Unmanned Aerial Vehicles (UAV). Detecting fires in Indonesian forest areas is one advantage of the ministry of environment and forestry's use of Unmanned Aerial Vehicles (UAV)[1].

Indonesia boasts a vast forest. The total area of Indonesia's forests is 125,795,306 hectares, and its boundaries span 373,828.44 km, of which 89,796.1 km are forest friend function limits and 284,032.3 km are outer boundaries. As previously said, due to Indonesia's vast forest area, forest fires frequently occur[2].

Since February 3 to March 15, 2024, there have been 17 fires on the Bunguran Besar island area, according to BPBD Natuna, Riau Islands Province. There are now 148 hectares of forest and land burned, which is more than the area destroyed in 2023[3].

Therefore, an Unmanned Aerial Vehicle (UAV) is required to cover Indonesia's vast woods and identify forest fires more easily in order to respond quickly to a fire.

The Long Endurance Low Altitude (LELA) category, with the theme "Utilization of Unmanned Aircraft for Hot Spot Validation Missions," is a new division competing in the 2024 Indonesian Flying Robot Contest (KRTI). With three hot spot locations which signify the presence of a fire the Long Endurance Low Altitute (LELA) division flew with a radius of roughly 23 kilometers and a total distance of roughly 60 kilometers[1].

The practice of measuring an object's characteristics and sending the information to a distant place via cable or wireless transmission is known as telemetry[4].

Due to Indonesia's extensive forests, radio telemetry cannot be used for communication between the aircraft and the Ground Control Station (GCS), which is necessary for unmanned aerial vehicle (UAV) operations. Cellular network telemetry can cover an infinite distance as long as there is a sufficient signal. This research attempts to establish a cellular network telemetry work system in which the value of the Received Strength Signal Indicator (RSSI) on the Unmanned Aerial Vehicle (UAV) is compared during aerial and land conditions, and then from both of these compared to the data taken.

II. LITERATURE

Ground Control Station (GCS)

The main interface between the pilot or operator and the UAV (Unmanned Aerial Vehicle) is a ground-based control system called the Ground Control Station (GCS). The Unmanned Aerial Vehicle (UAV) may be tracked, commands can be sent, and real-time data feedback can be obtained via the Ground Control Station (GCS). Additionally, the Ground Control Station (GCS) may be a tablet or small computer with certain software installed[5].

Waypoint

The flight controller at the Ground Control Station (GCS) uses waypoints as one of the navigational tools for unmanned aircraft[6]. This method uses the Global Positioning System (GPS) to control aircraft movement. In this study using waypoints with a distance of 500 meters horizontally and an altitude of 100 meters from the surface.

Figure 1. Waypoint

Received Signal Strenght Indicatore (RSSI)

The metric known as the Received Strength Signal Indicator (RSSI) shows the strength of the signal that a signal receiver is receiving at a specific moment[7]. The wireless signal strength is measured in dBm units, with a range of -10 dBm to roughly -100 dBm. The Received Strength Signal Indicator (RSSI) is used as an index that displays the signal intensity received by the receiver from the access point[8]. The following is the standardization according to Telecommunications and Internet Protocol Harmonization Over Network (TIPHON).

Table 1. Received Signal Strenght Indicatore (RSSI)
(Source: Tri and Indrastanti, 2018)

Standard Signal Strength TIPHON	
Category	**Signal Strength (dBm)**
Very good	> -70 dBm
Good	-70 dBm s/d -85 dBm
Medium	-86 dBm s/d -100 dBm
Very Poor	-100 dBm

Telemetry

Telemetry is the process of measuring an object's properties and transmitting the findings to a different location using a wireless or cable transmission method[9]. This research uses wireless telemetry, this telemetry is connected using a cellular network. As long as there is a signal that is reached, cellular network telemetry will function as it should.

Cellular Network

One form of mobile communication that can swiftly serve a large number of service consumers is cellular communications[10]. The service area's coverage area and the cellular system network's shape are connected[11]. In this research, cellular networks are used to connect wireless telemetry.

ZeroTier

ZeroTier Inc. is the company behind the open-source VPS and SD-WAN software ZeroTier. ZeroTier creates a network by joining endpoints via P2P technology. The proprietary protocol used by ZeroTier is comparable to IPsec and VXLAN. ZeroTier can be used as a VPN for private networks in addition to being a VPS[12].

Figure 2. ZeroTier Logo

III. METHODS

This research was conducted with the aim of implementing cellular network-based Unmanned Aerial Vehicle (UAV) telemetry for Ground Control Station (GCS) monitoring. The stages of this research are carried out in a structured manner to ensure the results are in accordance with the expected objectives.

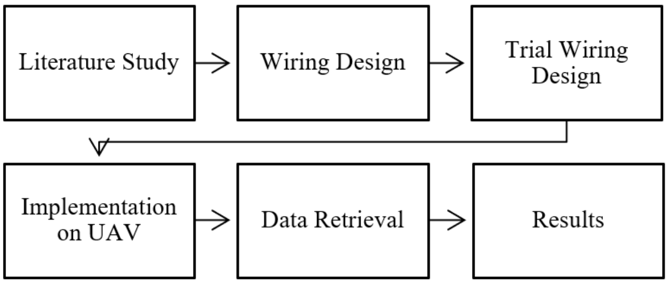


Figure 3. Stages of Research

The initial stage of this research is to analyze information from various sources related to cellular network telemetry. This analysis is supported by literature studies and observations of UAV (Unmanned Aerial Vehicle) communication over long distances. With the needs identified, the next step was to design a cellular network telemetry communication system using Raspberry Pi 3 and Pixhawk Cube Black microcontrollers. The design process involved planning and selection of appropriate hardware and structures. Testing and evaluation of the system was carried out to measure the work of the system, both in sending data and receiving data with a comparison of the UAV (Unmanned Aerial Vehicle) being flown and in a drive test. The test results are evaluated to ensure that the system operates according to the desired expectations.

A. Mechanical Design

The type of vehicle to be used is the talon type with styrofoam material coated with fiber and resin liquid that can be stable when flying and can accommodate several loads. Talon rides have wide and long wing shapes that make the rides able to fly long and stable. There is also a tail control in a V-shaped configuration (V-Tail) with an angle of 110 degrees so that the rides have better maneuverability and cceleration**.**

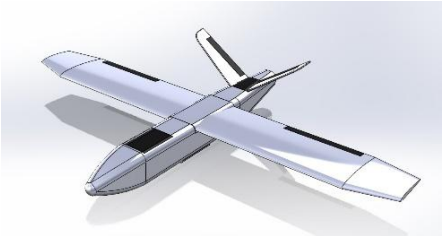


Figure 4. Mechanical Design

B. Hardware Design

The hardware planning of the overall cellular network telemetry system can be seen in Figure 5.

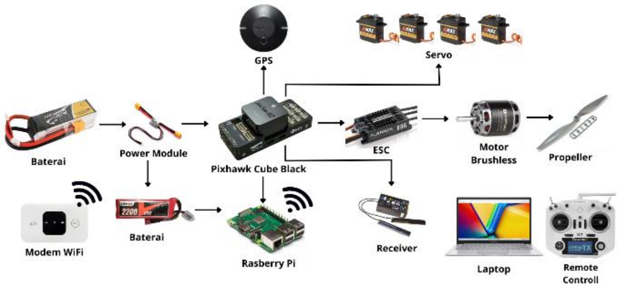


Figure 5. Hardware Design

Based on the hardware design planning in Figure 5, this research uses two microcontrollers that act as flight rate controls for Unmanned Aerial Vehicles (UAV). Pixhawk Cube Black plays an important role in the Unmanned Aerial Vehicle (UAV) flight process which is connected to Rasberry Pi 3 as a microcontroller where cellular network telemetry is carried out. The data processed by Rasberry Pi 3 is an output that will run cellular network telemetry and display Received Signal Strenght Indicatore (RSSI) value data on (Unmanned Aerial Vehicle, UAV) during aerial and land conditions.

C. Software Design

Unmanned Aerial Vehicles (UAV) fly by remotely measuring data and sending the information to another location for processing and analysis using telemetry.

In this research, the remote communication tool uses cellular network telemetry. The initial stage to connect cellular network telemetry is to connect RaspberryPi 3 to a cellular network using a WiFi modem and connect the device for ardupilot on a different network from the RaspberryPi 3 network. Then connect the IP address of the ardupilot device to ZeroTier, ZeroTier works by connecting devices in various locations via an encrypted private network, as if the devices were on the same local network. Figure 3.3 is a visual representation of the entire process of this research involving the cooperation between Raspberry Pi 3 and Pixhawk Cube Black.

The communication process between the Pixhawk Cube Black microcontroller and the Raspberry Pi 3 on the Unmanned Aerial Vehicle (UAV) is depicted systematically. Pixhawk Cube Black functions as the main microcontroller of the Unmanned Aerial Vehicle (UAV) flight which is connected to the Global Position System (GPS), Servo, Receiver, ESC (Electronic Speed Controller), Power and so on related to flight.

The Raspberry Pi 3 microcontroller is related to running the cellular network telemetry program and RSSI which will be studied in this study which later the value of RSSI will be compared when the UAV flies and drive tests. This comparison aims to find out whether the value when flying will be better with the drive test.

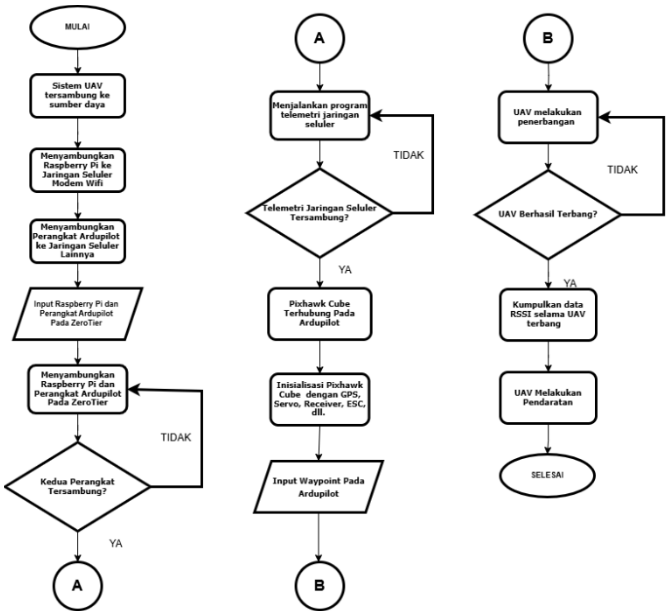


Figure 6. Software Design

IV. RESULT AND DISCUSSION

The research entitled "Implementation of Cellular Network-Based Unmanned Aerial Vehicle (UAV) Telemetry for Monitoring Ground Control Station (GCS)" has run as desired. Cellular network telemetry runs well, which can be connected to the Ground Control Station (GCS) device or Mission Planner application that will manage how the Unmanned Aerial Vehicle (UAV) flies. The following is an explanation of some of the tests carried out.

A. Cellular Network Telemetry Testing

In this test, the Unmanned Aerial Vehicle (UAV) uses cellular network telemetry as the main communication tool with the first step of connecting the Ground Control Station (GCS) device with the ZeroTier application. Before the Ground Control Station (GCS) device is connected to ZeroTier, a room on ZeroTier will be created first. The room is created with the name "LELA2024", where the room has a Network ID. Figure 7 is the room and Network ID that has been created.

Figure 7. Network ID

After the room is created, connect the RaspberryPi 3 and the Ground Control Station (GCS) device with Network ID: 48d6023c46e2caac. Figure 8 shows that the device is connected to the ZeroTier room.

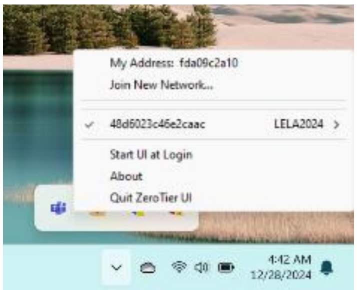


Figure 8. ZeroTier Connected Devices

If the RaaspberryPi 3 and the Ground Control Station (GCS) device are connected to the ZeroTier, the room on the ZeroTier will display the IP Address that has been connected. The IP address is used to connect from the RaspberryPi 3 terminal to the cellular network telemetry.

Address	Name/Desc	Managed IPs
00C188480E ae:ca:23:ce:74:0c	GCS LAPTOP RANI	192.168.191.88
E1BAA53DC5 ae:2b:58:e3:01:c7	RASPI LELA	192.168.191.57

Figure 9. IP Address

The last stage is testing of cellular network telemetry. The purpose of this cellular network telemetry test is to measure the parameters of the Unnamed Aerial Vehicle (UAV) object whose measurement results are sent to the Ground Control Station (GCS) device to measure how strong the signal is with a predetermined distance.

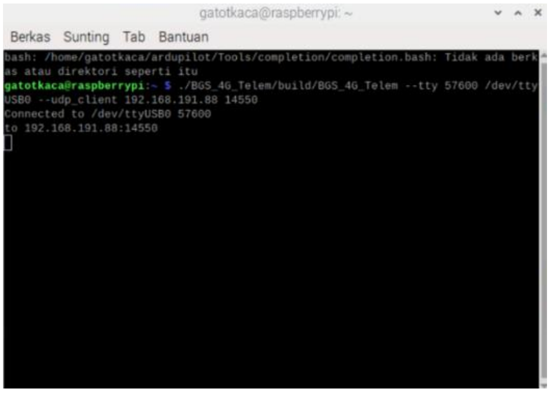


Figure 10. Mobile Network Telemetry Program Executed

The IP address of the Ground Control Station (GCS) device is input in the terminal. If successful, a “Connected” code is displayed on the terminal. If the cellular network telemetry runs as desired, the application to control the movement of the Unnamed Aerial Vehicle (UAV), namely Mission Planner, is automatically connected with the baudrate entered in the terminal. The display if successfully connected to the Ground Control Station (GCS) or Mission Planner application can be seen in Figure 11.

Figure 11. Ground Control Station (GCS) View

B. Received Signal Strenght Indicatore (RSSI) Testing While Aerial

In this test, the results of monitoring the Received Signal Strenght Indicatore (RSSI) value on the Unmanned Aerial Vehicle (UAV) are analyzed when flying at an altitude of 100 meters and a distance of 500 meters. The program display when run can be seen in Figure 12.

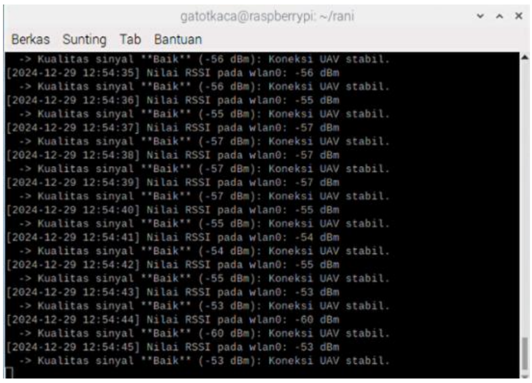


Figure 12. RSSI Aerial Program Run

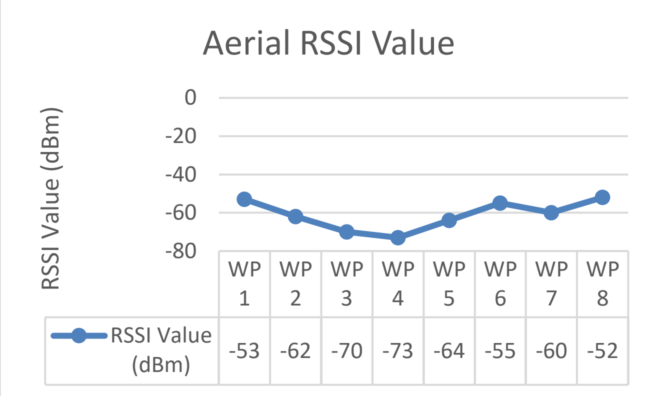
The results of the Received Signal Strenght Indicatore (RSSI) value when aerial at a height of 100 meters from the surface can be seen on the monitor described in Table 2.

Table 2. Aerial RSSI Value

Aerial RSSI Value		
Waypoint (WP)	**Signal Strengh (dBm)**	**Category**
1	-53	Very Good
2	-62	Very Good
3	-70	Very Good
4	-73	Good
5	-64	Very Good
6	-55	Very Good
7	-60	Very Good
8	-52	Very Good

The acquisition of Received Signal Strenght Indicatore (RSSI) data can be concluded that the Unmanned Aerial Vehicle (UAV) when flying at an altitude of 100 meters above the surface shows very good results or a stable Unmanned Aerial Vehicle (UAV) connection, but if you look at Table 1 at waypoint 4 shows good value results because interference is detected. The interference in question is the obstacle of trees that have a height of about 65 meters above the surface.

Received Signal Strenght Indicatore (RSSI) value data at each waypoint has a distance of 100 meters from each specified waypoint. A graphic image of the Received Signal Strenght Indicatore (RSSI) value while flying can be seen in Figure 13.



The acquisition of Received Signal Strenght Indicatore (RSSI) data can be concluded that the Unmanned Aerial Vehicle (UAV) on land shows very good results or the connection of the Unmanned Aerial Vehicle (UAV) to the Ground Control Station (GCS) is optimal, the value obtained shows stable data with an average of -39 dBm.

Table 3. Land RSSI Value
Figure 13. Aerial RSSI Value Graph

From the data results in Table 1 shows that the Received Signal Strenght Indicatore (RSSI) value when aerial is still relatively stable. So, Ground Control Station (GCS) monitoring can run smoothly, which can monitor how the Unmanned Aerial Vehicle (UAV) is flying at an altitude of 100 meters above the surface.

C. Received Signal Strenght Indicatore (RSSI) Testing on Land

In this test, an analysis of the results of monitoring the Received Signal Strenght Indicatore (RSSI) value on the Unmanned Aerial Vehicle (UAV) when landing with the same distance when flying, which is 500 meters. The program display when run can be seen in Figure 14.

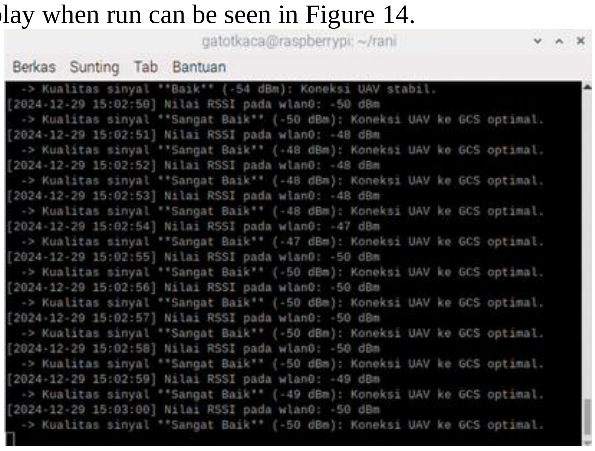


Figure 14. Running RSSI Land Program

The results of the Received Signal Strenght Indicatore (RSSI) land value with the same distance when the Unmanned Aerial Vehicle (UAV) flies can be seen on the monitor described in Table 3.

Table 4. Land RSSI Value

Waypoint (WP)	Land RSSI Value Signal Strengh (dBm)	Category
1	-39	Very Good
2	-38	Very Good
3	-39	Very Good
4	-41	Very Good
5	-40	Very Good
6	-40	Very Good
7	-39	Very Good
8	-40	Very Good

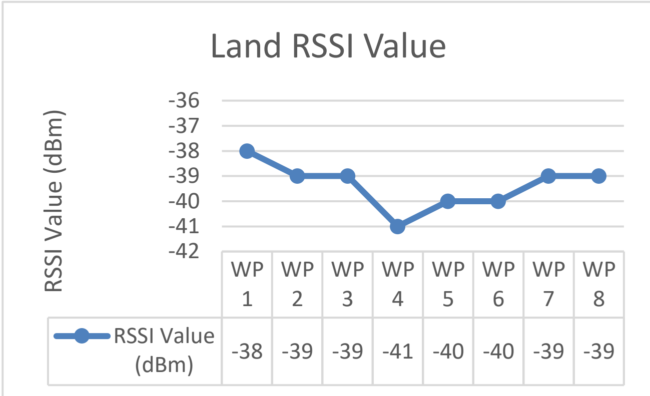


Figure 15. Land RSSI Value Graph

Received Signal Strenght Indicatore (RSSI) value data at each waypoint has a distance of 100 meters from each specified waypoint. A graphic image of the Received Signal Strenght Indicatore (RSSI) value while flying can be seen in Figure 15.

D. Comparison of Received Signal Strenght Indicatore (RSSI) when Aerial and Land

After testing the Received Signal Strenght Indicatore (RSSI) data when the Unmanned Aerial Vehicle (UAV) flies at an altitude of 100 meters above the surface and the Unmanned Aerial Vehicle (UAV) is tested on a plain with the same distance when flying, which is a distance of 500 meters from the launch point, Table 4 hows the data on the results of the Received Signal Strenght Indicatore (RSSI) comparison when in the air and plain.

Table 5. Comparison of Received Signal Strenght Indicatore (RSSI) when Aerial and Land

Waypoint (WP)	Received Signal Strenght Indicatore (RSSI) Value Aerial	Land
1	-53	-39
2	-62	-38
3	-70	-39
4	-73	-41
5	-64	-40
6	-55	-40
7	-60	-39
8	-52	-40

Comparison of Received Signal Strenght Indicatore (RSSI) readings when aerial and land is needed to test the quality and accuracy of parameters that display how strong the signal received by a signal receiver.

From the data in Table 4, it can be explained that the value of the Unmanned Aerial Vehicle (UAV) when the land accuracy level is lower than the Unmanned Aerial Vehicle (UAV) when aerial. The Received Signal Strenght Indicatore (RSSI) value when aerial has an average Received Signal Strenght Indicatore (RSSI) value of -61 dBm due to various obstacles or obstacles that occur in real time, for example flying above an altitude of 100 meters and obstacles in the form of rice fields and various trees that are about 65 meters above the surface. It is possible that the Received Signal Strenght Indicatore (RSSI) value when flying can still send and receive the necessary data from the Unmanned Aerial Vehicle (UAV).

The value of the Unmanned Aerial Vehicle (UAV) during land is lower in accuracy due to the lack of obstacles and other problems. Data received is faster than when aerial. This level of land signal strength can help when making Unmanned Aerial Vehicle (UAV) settings such as adding flight paths, adding parameters, and other settings. A comparison graph of Received Signal Strenght Indicatore (RSSI) values when doing aerial and land can be seen in Figure 16.

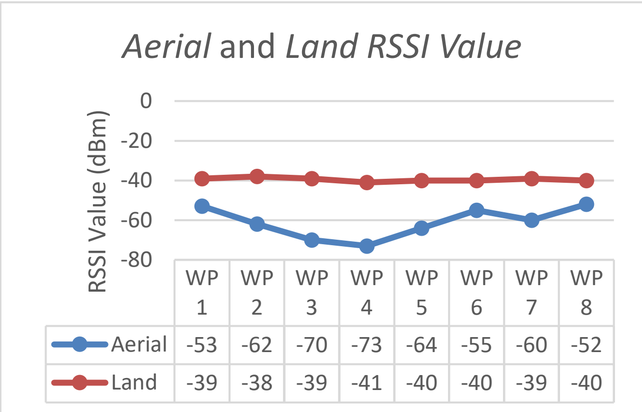


Figure 16. Aerial and Land RSSI Value

It can be seen from Figure 16, that the graph shows the average value of Received Signal Strenght Indicatore (RSSI) when aerial is higher interference than the value of Received Signal Strenght Indicatore (RSSI) when land. Aerial Received Signal Strenght Indicatore (RSSI) values have high interference values, but are still considered normal to be able to send and receive data parameters obtained from Unmanned Aerial Vehicles (UAV).

E. Implementation Ground Control Station (GCS)

The implementation of cellular network telemetry at the Ground Control Station (GCS) was successful as desired. Cellular network telemetry is successfully connected to the Ground Control Station (GCS) which functions to monitor how the Unmanned Aerial Vehicle (UAV) is traveling.

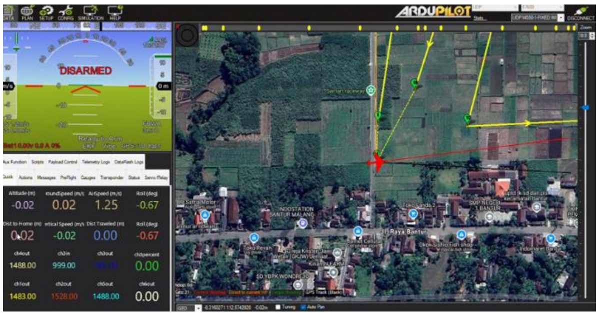


Figure 17. Ground Control Station (GCS) View

If the Ground Control Station (GCS) can already be used, the first step before flying is to set the servo position in the aileron and vtail section of the Unmanned Aerial Vehicle (UAV). The servo value can be set according to the needs of the Unmanned Aerial Vehicle (UAV). The servo setting display can be seen in Figure 18.

Figure 18. Servo Settings

After successfully setting the servo values, the next step is to set up the remote control for Unmanned Aerial Vehicle (UAV) flight. The remote controll settings have several channe, namely there is roll to regulate rotation around the front-to-back axis, pitch is rotation around the side-to-side axis, yaw is rotation around the vertical axis. Figure 19 is a view of the remote control settings.

Figure 19. Remote Control Settings

The next step is to add the parameters needed for the Unmanned Aerial Vehicle (UAV) flight, the display can be seen in Figure 20 and the last step is to add a path or waypoint for the Unmanned Aerial Vehicle (UAV) flight rate as shown in Figure 21.

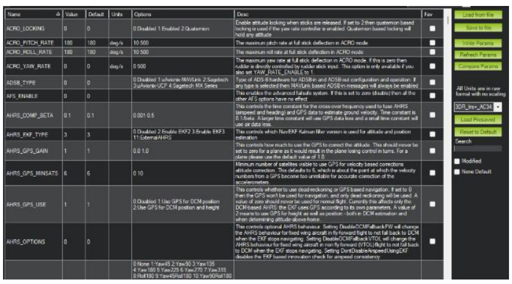


Figure 20. Parameters View

The Unmanned Aerial Vehicle (UAV) flight waypoint location for this trial was held in Bantur District, Malang. The Unmanned Aerial Vehicle (UAV) flew well and followed the desired waypoint with a distance of 500 meters and an altitude of 100 meters from the surface. The test was carried out only once with a short flight time.

Figure 21. Waypoints

V. CONCLUSION

The conclusion that can be drawn from the research results of the Implementation of Cellular Network-Based Unmanned Aerial Vehicle (UAV) Telemetry for Monitoring Ground Control Station (GCS) at the Indonesian Flying Robot Contest in the Long Endurance Low Altitute (LELA) Division is that the implementation of cellular network telemetry can be implemented as described by researchers by knowing the Received Signal Strenght Indicatore (RSSI) value when the Unmanned Aerial Vehicle (UAV) is aerial and Received Signal Strenght Indicatore (RSSI) when the Unmanned Aerial Vehicle (UAV) is land. The Received Signal Strenght Indicatore (RSSI) value of both data can be effectively used. The Received Signal Strenght Indicatore (RSSI) value when the Unmanned Aerial Vehicle (UAV) aerial state has an average value of -61 dBm and when the land state has an average value of -39 dBm, data from the TIPHON Signal Strength Standard shows that the Indicatore (RSSI) value when the Unmanned Aerial Vehicle (UAV) aerial and land conditions are classified as very good which means that the signal strength of the cellular network telemetry can send and receive data properly. 2. In addition to data results, Received Signal Strenght Indicatore (RSSI) can function properly for the Unmanned Aerial Vehicle (UAV) parameter measurement process whose measurement results are sent to the Ground Control Station (GCS) through the transmission process.

Suggestions that are expected in further research, are in Received Signal Strenght Indicatore (RSSI) testing, Unmanned Aerial Vehicle (UAV) needs to be tested again by flying over more obstacles to find out cellular network telemetry can still send and receive parameters or not, for example flying over a tree with a height of 100 meters. In addition to these suggestions, in testing cellular network telemetry, the Unmanned Aerial Vehicle (UAV) needs to replace the Wireless Fidelity (Wi-Fi) modem on the Unmanned Aerial Vehicle (UAV) so that the signal sent and received is better.

ACKNOWLEDGMENT

Thank you Dr. Muhamad Syariffuddien Zuhrie, S.Pd., M.T. as the final project supervisor who has guided and supported during the process of preparing this final project.

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