Analisis stabilitas antenna tracker otomatis dengan antena 21dBi terhadap kualitas sinyal

Tugas Akhir

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2026

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Batam, 15 Januari 2026

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Dengan judul:
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Stability Analysis Of Automatic Antenna Tracker With 21 dBi Antenna On Signal Quality

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Abstract – Communication on Unmanned Aerial Vehicles (UAVs) is very important because it affects data transmission to the base station. However, static antennas have limitations in maintaining signal stability over long distances, so an automatic tracking mechanism is needed. This study aims to analyze the stability of an automatic antenna tracker with a 21 dBi antenna on signal quality on UAVs. The main focus of the study is to test the extent to which the automatic tracking mechanism is able to maintain stability at a distance of 20 km. The test method is carried out in a single flight by measuring the values of Received Signal Strength Indicator (RSSI), Signal-to-Noise Ratio (SNR), and Signal Quality at distances of 5 km, 10 km, and 20 km. The results of the study show that the use of an automatic antenna tracker is able to maintain signal stability optimally. At the furthest distance of 20 km with a height of 150 m, the system successfully maintained RSSI values in the range of 104 dBm to 108 dBm with a Signal Quality of 49% and an SNR of -65 dB. The consistency of these values proves the effectiveness of the system in ensuring the reliability of UAV telemetry data transmission up to a distance of 20 km without experiencing a lost link.

Keywords: Automatic Antenna Tracker, 21 dBi Antenna, Signal Quality, RSSI, SNR, UAV.

1. Introduction

The development of wireless communication technology has had a significant impact in various fields, including control and monitoring systems for mobile devices such as Unmanned Aerial Vehicles (UAVs) [1]. Real-time data exchange between UAV and Ground Control Station (GCS) depends on the quality of a stable and reliable telemetry communication link [2]. However, when UAVs operate at long distances, signal quality often degrades due to distance attenuation, fading, and increased interference [3]. This condition can also result in a general decrease in signal quality due to distance attenuation and interference [4]. Other researchers added that path loss and the shadow effect of the UAV body worsen the performance of the telemetry link at long distances [5].

To overcome this obstacle, an automatic antenna tracker system is used as an effective solution. This system works by dynamically orienting the antenna at the ground station to follow the UAV's position, ensuring the communication line remains in line of sight [6]. Other studies have shown that the use of a two-axis antenna tracker significantly improves RSSI quality and telemetry communication reliability compared to systems without automatic tracking [7]. In another study, researchers developed a closed-loop control-based two-axis automatic antenna tracker system designed in-house for UAV applications, and test results showed that the system was able to operate well and follow the target direction according to the commands given during the laboratory testing stage [8]. Various other studies also show that two-axis antenna trackers produce better RSSI stability than systems without automatic tracking [9].

One of the antenna tracking systems that is the main focus of this research is the Auto Antenna Tracker, which functions to automatically control the direction of the antenna based on real-time UAV position data [10]. This technology has been proven to be able to maintain the quality of data transmission even though the UAV continues to move [3]. To support signal stability in long-distance scenarios, the system is equipped with a directional antenna with a 21 dB gain. This type of antenna has a directional pattern in the horizontal plane, thus supporting the free movement of the UAV without a fixed direction. With a gain as high as 21 dB, which is high for a directional antenna, the received signal can be significantly amplified, allowing stable telemetry communications even at distances exceeding 10 km [11]. In addition, other researchers developed a tracking system based on GPS and magnetometer sensors with high tracking accuracy and an automatic pan-tilt system [12].

Several previous studies have examined two-axis antenna tracking systems using directional antennas. The results showed improved RSSI stability compared to systems without tracking. However, these systems generally only cover distances under 10 km and still use low-power antennas [13]. [14] emphasizes the importance of line-of-sight and beamforming in long-range UAV communications, but does not present field test data at very long distances with high-gain directional antennas. To date, there is no comprehensive empirical data available on the stability of UAV telemetry communications at a distance of 20 km using a 21 dBi directional antenna combined with an automatic antenna tracking mechanism under realistic field conditions [15].

Table 1. Research comparison

Researcher (Year)	Tracking Method	Antenna Type	Test distance	Parameter are measured	Results	Limitations
Fahmi & Samad (2018) [9]	Closed-loop Control	Directional	Skala Lab	Azimuth and Tilt Precision	Motor is able to respond to target coordinates	Long-range data transmission testing has not been carried out.
Melvi (2020) [13]	Two-axis Tracking	Yagi	10 Km	RSSI (dBm)	Tracker improves RSSI stability compared to static antennas.	Limited range and antenna gain is not sufficient for extreme distances.
Akbar (2024) [12]	GPS dan Magneto meter	Portable patch	Visual Line Sight	Tracking accuracy	Tracker improves RSSI stability compared to static antennas.	Focus on sensor navigation, have not tested signal quality at distances >10 km.
This research 2026	AAT MFD Crossbow Mini	Directional Antenna	20 Km	RSSI, SNR, and Signal Quality	Stable connection at 20 km with Signal Quality 49% and SNR -65 dB.	Highly dependent on the update rate of GPS coordinates for tracking accuracy.

This research was conducted as an extension of previous studies as it focused on the stability analysis of an automatic tracking system using a 21 dBi high-gain antenna. As shown in table 1, While previous researchers (Melvi & Akbar) only tested below 10 km with a low-gain antenna, this study provides empirical evidence for long-range stability up to 20 km. Furthermore, this study addresses an important gap by providing an in-depth correlation between RSSI, SNR, and Signal Quality, which was not thoroughly analyzed in Fahmi's research which focused more on mechanics. This approach validates the reliability of high-gain directional antennas in maintaining telemetry links for long-range UAV operations.

Based on these problems, the formulation of the problem in this study is how the stability of the automatic antenna tracker performance based on AAT MyFlyDream Crossbow Mini during a single flight in a UAV flight scenario with a distance of 20 km, how are the characteristics of the RSSI, SNR, and Signal Quality parameters produced at a test distance of up to 20 km. Based on the formulation of the problem, the purpose of this study is to analyze the stability of the automatic antenna tracker with a 21 dBi antenna in maintaining the quality of the UAV signal at a distance of 20 km. The purpose is to measure the RSSI, SNR, and Signal Quality values at a distance of 5 km, 10 km, and 20 km, and evaluate the consistency of the automatic tracking mechanism in maintaining pointing accuracy.

2. Research Methods

2.1 Antenna

Figure 1. Antenna Tracker

MyFlyDream (MFD) Automatic Antenna Tracker (AAT) in figure 1 is an automatic antenna tracking device used by PT Bentera Tamba Tabang Nusantara to assist testing activities on UAVs when used for mapping and inspection. This antenna has a responsive mechanism, with a maximum Pan speed of up to 400 degrees / second and a Tilt speed of up to 120 degrees / second. It weighs 470 grams and a Tilt torque of up to 10 kgf cm. Through the support of the MFD VBI protocol and full compatibility with MAVLink V2.0. The use of the SIYI MK15 remote and telemetry is able to send and receive signals according to the specifications of the SIYI website. Which works at a frequency of 2.4 GHz, 25 dBm transmit power, -95 dBm receiver sensitivity, and optimal bandwidth for video and telemetry data. Telemetry data carries GPS coordinate information from the UAV so that the MFD AAT can track precisely. The use of a 6S 22.2V 16000mAh LiPo battery in the ground station tracker antenna ensures the system continues to work optimally when integrating data into the MFD Autopilot. The battery capacity is adjusted to the system voltage requirement of 12V-25V within 5 hours to ensure the system continues to work optimally when integrating data into the MFD Autopilot to maintain the stability of the signal quality status over long distances.

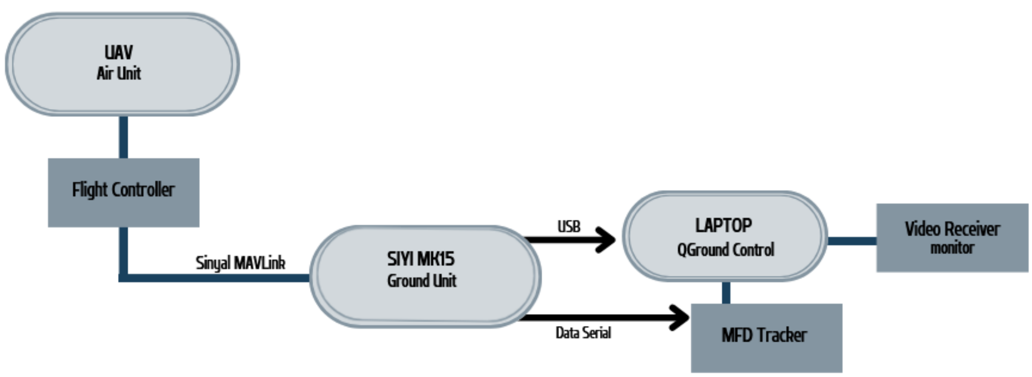


Figure 2. Communication Path

Navigation data and GPS coordinates are generated by the Flight Controller on the UAV, then transmitted using the MAVLink protocol to the SIYI MK15 Ground Unit. The SIYI MK15 acts as a data distribution center that forwards the information in parallel to two different paths. The first path uses a USB connection to a Laptop (QGroundControl) for mission monitoring needs on the map, while the second path uses a Serial Data connection that is connected directly to the MFD Tracker as shown in figure 2. The video signal from the UAV camera is received by the MFD Tracker antenna. The tracker unit uses MAVLink data received from the serial path to drive the Pan and Tilt Servo, ensuring the antenna is always pointed directly at the aircraft's position to maintain signal quality in Line of Sight (LOS) conditions. The video signal that has been captured by the antenna is then forwarded to the Video Receiver or display monitor for monitoring by the operator.

With this mechanism, the system is able to maintain stable and high-precision connectivity even though the aircraft is at a very long distance.

2.2 Unmanned Aerial Vehicle (UAV)

Figure 3. MFE FIGHTER VTOL UAV

The test used a UAV product from Make Fly Easy with a Quadplane configuration. This UAV has a wingspan of 2100 mm, a VTOL arm length of 744 mm, a fuselage height of 156 mm, a fuselage length of 1200 mm, and a wing area of 59 dm^2. This type of hybrid UAV combines the vertical takeoff and landing (VTOL) capabilities of a quadcopter with the horizontal flight efficiency of a fixed-wing aircraft. As seen in Figure 3

2.3 Testing Procedure

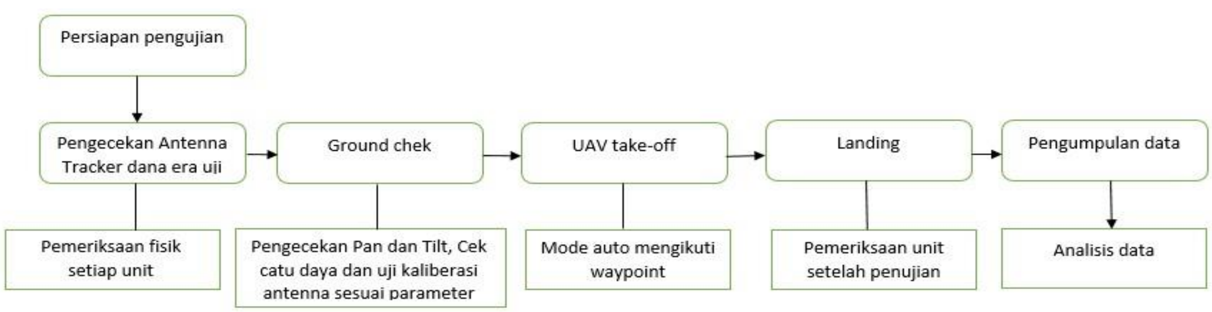


Figure 4. Testing procedure

The research procedure involved a structured flight test conducted on a UAV configured with an antenna. This research procedure was carried out regularly through the stages depicted in Figure 4. The initial step began with equipment preparation and a physical inspection of the antenna to ensure all connectors and servo drives were in optimal condition. Next, a ground check was performed, which included checking the power supply and important calibration procedures, namely the alignment of the north reference and calibration of the MyFlyDream ATT internal compass to ensure the precision of antenna tracking during operation. After the preparation phase was completed, the UAV took off and was directed to auto-following mode.

Figure 5. Waypoint

All data collection was conducted in a single flight at a constant altitude of 150 meters to maintain the consistency of environmental variables, as shown in Figure 5. The UAV flew a distance of 20 km. During the flight, the data collection process was carried out through real-time data logging to record RSSI, SNR, and Signal Quality parameters. The procedure concluded with the UAV landing and a final inspection of the unit before data was extracted for analysis.

2.4 Test Location

The test was conducted at Pamalayan Landing, Cikelet District, Garut Regency, West Java (-7.647484, 107.688132). The airfield is 20 km away. It is a coastal area with wind speeds ranging from 5–12 m/s. This geographical condition provides an ideal open field for antenna performance evaluation.

2.5 Data Collection Method

The data collection process in this test was carried out by recording the Ground Control Station interface display in real-time using a screen recorder device Figure 6. Signal parameter data including RSSI, SNR, and Signal Quality were recorded with a sampling rate of 10 Hz. The screen recording method was chosen to facilitate direct parameter visualization during the mission. However, the author acknowledges the limitations of this method in the form of potential frame drops or timing inaccuracy in the video recording. As a validation step to overcome these limitations, the recorded data was compared and synchronized with the MAVLink log file stored internally in the GCS. All data was then extracted using the UAV Log Viewer software Figure 7. This software works by parsing the log data generated by the Flight Controller and synchronizing it based on timestamps to produce precise parameter values. The UAV Log Viewer has a high level of accuracy because it reads data directly from the flight log, although it has limitations in the form of dependence on GPS signal stability for position data synchronization.

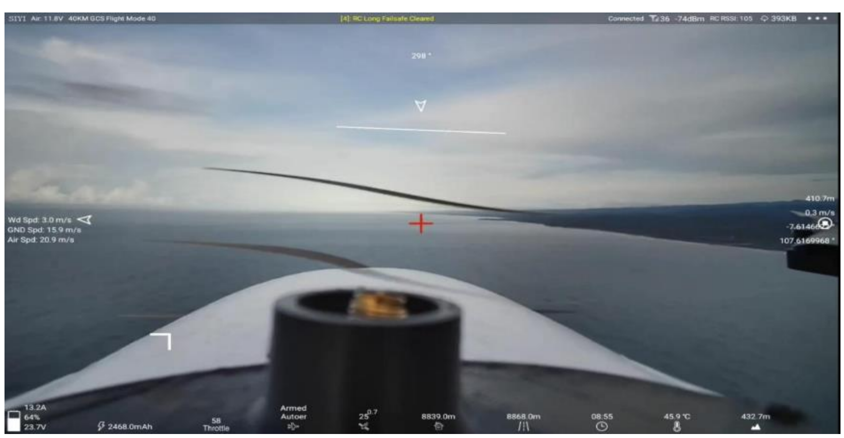


Figure 6. GCS screen recorder

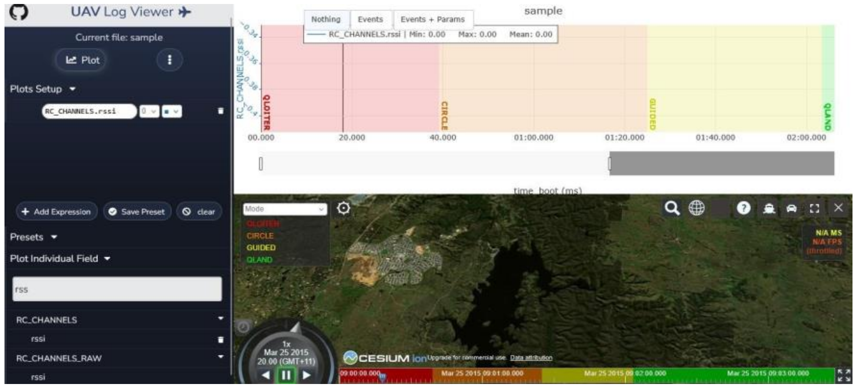


Figure 7. UAV Log Viewer view

This test was conducted in a single flight, maintaining a constant altitude of 150 meters to test the antenna's performance over distances of up to 20 km. The obtained signal data was then processed using Microsoft Excel for tabulation, graphical visualization, and comparative analysis between signal parameters at each UAV distance. A graphical analysis method was used to assess the stability of the tracking system and the effectiveness of the antenna amplifier in maintaining communication quality under Line of Sight conditions.

2.7 Orientation Analysis (RSSI, SNR, Signal Quality)

Communication performance analysis at a distance of 20 km was performed using three main parameters. Signal Quality converts RSSI values into relative percentages Equation 1 to provide a more intuitive interpretation of connection quality. To assess data clarity from ambient frequency interference, SNR is used in dB to measure the signal-to-noise ratio Equation 2. Meanwhile, RSSI is used to measure absolute signal strength in dBm Equation 3, which is a primary indicator of antenna range. By monitoring RSSI and SNR fluctuations simultaneously, the system can validate whether communication quality degradation is caused by distance or environmental interference. This analysis serves as the basis for ensuring that at an altitude of 150 meters, the system can maintain data integrity under Line of Sight conditions. The following formulas are used to process signal data obtained from the UAV Log Viewer:

$$Signal\ Quality(\%) = \left(\frac{RSSIcurrent - RSSImin}{RSSImax - RSSImin}\right) \times 100 \qquad (1)$$

The RSSImin=−110 dBm and RSSImax=−30 dBm marks are determined based on the receiver sensitivity specifications on the SIYI MK15 system. RSSImin is defined as the minimum signal threshold that can still be processed by the receiver before a lost link occurs, while RSSImax is the maximum signal strength recorded under ideal close-range Line of Sight conditions.

Next, to measure the level of signal cleanliness against frequency interference in the surrounding environment, Equation 2 is used regarding the Signal-to-Noise Ratio (SNR):

$$SNR(dB) = P_{Signal}\ (\text{dBm}) - P_{noise}\ (\text{dBm}) \qquad (2)$$

Signal power (PSignal) and noise power (PNoise) values are automatically obtained from the SIYI MK15 via the MAVLink telemetry stream. A positive SNR value indicates that the instruction signal is dominant over the noise floor, thus ensuring reliable data communication. Conversely, an SNR value close to zero or negative indicates a marginal signal and is susceptible to transmission failure.

The RSSI value calculated through Equation 3 serves as an indicator of the absolute signal power strength received by the system.

$$RSSI(dBm) = 10 \cdot Log_{10}\,(P_{received}) \qquad (3)$$

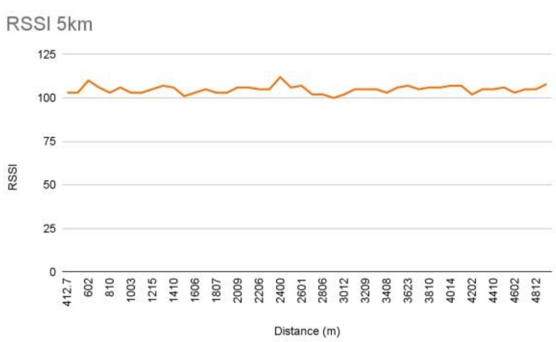
This parameter is a fundamental indicator to see the weakening of signal power as the UAV's distance increases during a single flight test at an altitude of 150 meters.

3. Results and Discussion

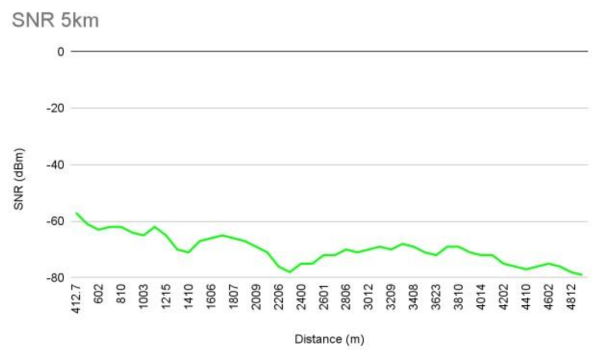
The focus of this test was to evaluate the extent to which the antenna's movement stability was able to maintain precision aiming at the UAV at a distance of 20 km and an altitude of 150 m. The signal quality parameters measured were Received Signal Strength Indicator, Signal to Noise Ratio, and Signal Quality as the main indicators of the tracking system's success.

3.1 5 km Distance Test Results

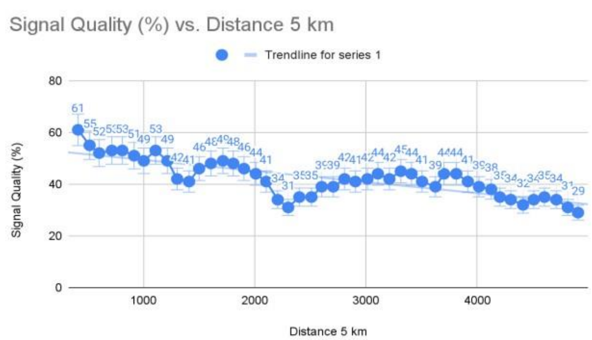
Based on testing at a distance of 5 km Figure 8, the system shows significant tracking stability as evidenced quantitatively by the RSSI Standard Deviation value of 1.12, which is below the industry threshold of <5 pointing.



(a) Received Signal Strength Indicator



(b) Signal-to-Noise Ratio



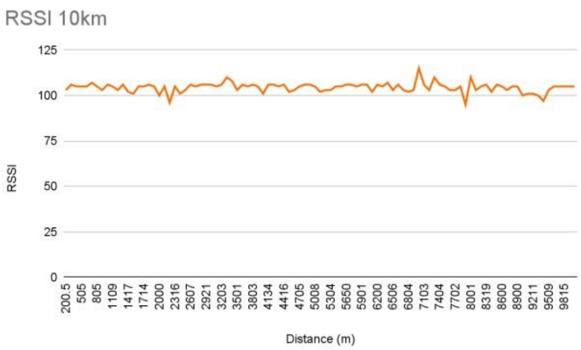
(c) Signal Quality

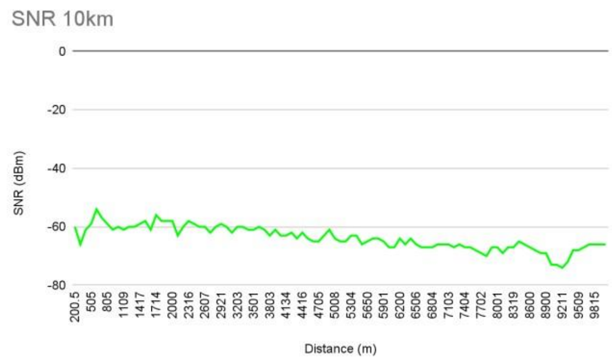
Figure 8. 5 km parameter graph
(a) Received Signal Strength Indicator, **(b)** Signal-to-Noise Ratio, **(c)** Signal Quality

A consistent RSSI value in the range of 100-103 indicates that the use of a 21 dBi High Gain Antenna on the automatic tracker is very effective in maintaining the radiation focus on the UAV. Although the Signal Quality was recorded at 42% and there was a noise floor reading of -70 dB, MAVLink telemetry communications continued to run smoothly without interruption because the system was able to maintain a stable link margin above the failsafe threshold.

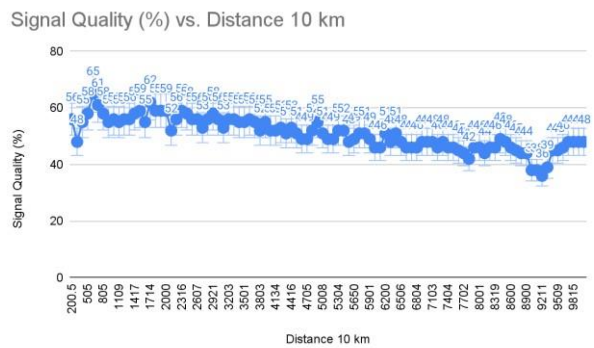
3.2 10 km Distance Test Results

At a distance of 10 km, the system achieved optimal performance with an RSSI of 105–110, an SNR of –63 dB, and a Signal Quality of 51%. In figure 9 this 51% Signal Quality achievement is due to a gentler elevation angle, resulting in the signal path being in optimal Line of Sig ht conditions, which minimizes surface reflection interference. This condition makes it easier for the Antenna Tracker to maintain target lock stability at a peak antenna gain of 21 dBi.





(a) Received Signal Strength Indicator **(b)** Signal-to-Noise Ratio



(c) Signal Quality

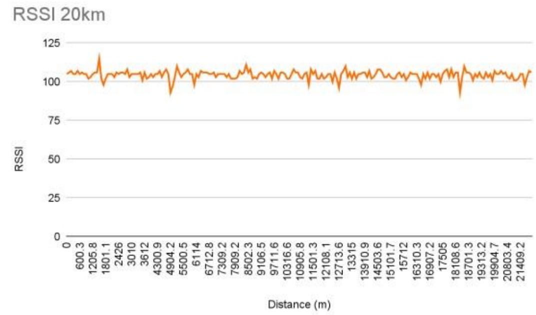
Figure 9. 10 km parameter graph

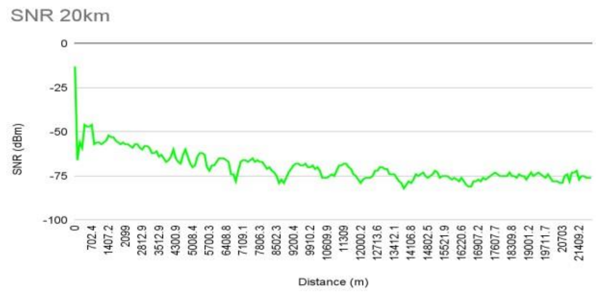
(a) Received Signal Strength Indicator, **(b)** Signal-to-Noise Ratio, **(c)** Signal Quality

Quantitative data stability through an RSSI SD value of 0.85, which meets the stability threshold of <5. Fresnel Zone Clearance at this distance effectively mitigates multipath fading, so that the telemetry connection remains reliable even when the spacecraft performs loitering maneuvers.

3.3 Testing at a distance of 20 km

At the 20 km range, the system stability level is quite good with an RSSI of 104–108, an SNR of –65 dB, and a Signal Quality of 49% figure 10. This stability is quantitatively proven by the RSSI SD value of 1.25, which meets the stability threshold standard of <5.





(a) Received Signal Strength Indicator **(b)** Signal-to-Noise Ratio

(c) Signal Quality

Figure 10. 20 km parameter graph

(a) Received Signal Strength Indicator, **(b)** Signal-to-Noise Ratio, **(c)** Signal Quality

Signal quality variability was analyzed as the impact of UAV attitude changes during loitering maneuvers, which triggered antenna polarization shifts relative to the GCS. However, the use of a 21 dBi antenna and automatic tracker successfully maintained sufficient link margin, preventing drastic signal drops that could trigger temporary link loss. This ensured the reliability of telemetry communications in real time.

Table 2. Signal quality measurement results

Distance (km)	**Signal Quality (%)**	**SNR (dBm)**	**RSSI**	**SD RSSI**
5 Km	42%	- 70 dB	100-103	1.12
10 Km	51%	- 63 dB	105-110	0.85
20 Km	49%	- 65 dB	104-108	1.25

Testing at an altitude of 150 meters showed a significant influence of elevation angle on transmission quality. At a distance of 5 km, recorded Signal Quality 42%, SNR –70 dB, and RSSI 100–103 with SD RSSI 1.12. Conditions as a result of a sharp elevation angle so that the vehicle is outside the main beamwidth of the GCS antenna. Performance increased to reach an optimal point at a distance of 10 km with Signal Quality 51%, SNR –63 dB, and RSSI 105–110. The 51% achievement indicates that the vehicle has entered the main lobe radiation. Validated by the highest level of stability SD RSSI 0.85.

Entering a distance of 20 km, the signal quality remains maintained at Signal Quality 49%, SNR –65 dB, and RSSI 104–108. Although there are fluctuations in UAV attitude changes with SD RSSI 1.25, it remains below the stability threshold <5 in table 2. The integration of high gain antennas and automatic tracking systems successfully maintains an adequate link margin to ensure the reliability of real-time telemetry communications.

4. Conclusion

Based on the results of field testing and analysis, it can be concluded that the stability of the automatic Antenna Tracker with a 21 dBi antenna has a significant influence on the quality of the telemetry signal up to a distance of 20 km with a height of 150 m. This is proven by the system's ability to maintain parameter values at all test points. Starting from a Signal Quality of 42% at a distance of 5 km, increasing optimally to 51% at a distance of 10 km, until it remains stable at the furthest distance of 20 km with an RSSI range of 104–108, Signal Quality 49%, and SNR -65 dB. The stability of these values indicates that the automatic tracking mechanism on MyFlyDream is able to maintain sufficient pointing accuracy to mitigate the impact of changes in elevation angle at an altitude of 150 meters. These results ensure that the telemetry connection between the UAV and GCS remains secure without experiencing lost links. As a suggestion for further research, it is necessary to collect specific angular error log data to analyze the correlation between pointing error and signal degradation in more depth.

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