Implementation of Portable Antenna Design based on Ublox M10Q-5883 for Unmanned Aerial Vehicle Movement Tracking

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Abstraks

Pelacak Antena adalah sistem yang secara otomatis mengarahkan antena ke sumber sinyal tertentu, seperti satelit atau objek bergerak, dan biasanya digunakan untuk komunikasi, pemantauan cuaca, atau pengendalian drone. Penelitian ini bertujuan untuk mengembangkan antena portabel berbasis modul GPS Ublox M10Q-5883 untuk meningkatkan akurasi dan kecepatan. Koordinat modul GPS digunakan untuk memastikan pelacakan yang tepat. Namun tantangan dalam pemrosesan data muncul ketika tidak dalam mode misi, seperti gangguan dari gedung bertingkat selama pengoperasian UAV manual. Modul GPS menunjukkan standar deviasi 1,47 untuk nilai jarak rata-rata. Dengan menggunakan metode GPS Positioning, antena pelacak dapat berputar secara akurat menggunakan nilai sinyal Pulse width Modulation (PWM) yang berkisar antara 1418 hingga 1624. Pan servo berputar 180 derajat, sedangkan tilt servo berputar 90 derajat.

Kata kunci: Antena portable, Pesawat Tanpa Awak, Ublox M10Q-5883

Abstract

An Antenna Tracker is a system that automatically directs an antenna toward a specific signal source, such as a satellite or a moving object, and is commonly used for communication, weather monitoring, or drone control. This study aims to develop a portable antenna based on the Ublox M10Q-5883 GPS module to enhance accuracy and speed. The GPS module coordinates are used to ensure precise tracking. However, challenges in data processing arise when not in mission mode, such as interference from high-rise buildings during manual UAV operation. The GPS module showed a standard deviation 1.47 for the average distance value. Using the GPS Positioning method, the antenna tracker can accurately rotate using Pulse Width Modulation (PWM) signal values ranging from 1418 to 1624. The pan servo rotates 180 degrees, while the tilt servo rotates 90 degrees.

Keywords: Portable Antenna, Unmanned Aerial Vehicle, Ublox M10Q-5883

1. Introduction

In modern times, network and communication technology are integral parts of human life, making our lives much easier [1]. Over the past 60 years, antenna technology has played a crucial role in the evolution of networks and communications [2]. For instance, the application of antenna tracker, which converts electromagnetic waves into a tool for providing information and communication in the field of unmanned aerial vehicle [3].

The antenna tracker is a system designed to detect moving signal sources [4]. It can move horizontally and vertically. The main components of the tracking antenna are a GPS module and a height sensor, which are used in the process of detecting unmanned aerial vehicles (UAVs) [5][6]. The movement system on the tracking antenna follows the coordinates produced by the Global Positioning System (GPS) to enable the antenna to communicate and receive real-time data from the Ground Control Station (GCS) [7]. This responsive movement ensures that the data obtained is accurate, as the antenna constantly follows the GPS coordinates [8].

The current antenna tracker operations still rely on a control system that uses a mini-USB cable directly connected to the antenna tracker [9]. Communication works well, but it has one drawback: the distance between the tracker antenna and the connected one is limited [10]. On the plus side, it reduces the delay in attitude value connected to the antenna tracker for the software used [11].

A telemetry system measures distances remotely and reports information to software. Telemetry refers to wireless communications, such as radio, ultrasonic, or infrared systems [12]. For example, telemetry can receive real-time data from the vehicle, such as height, speed, and horizontal and vertical angle data. This allows the antenna tracker to follow the vehicle's movement [13].

A crucial component in a data transmission system is the 433 MHz telemetry antenna. The antenna needs to be capable of detecting the direction of the UAV signal [14]. This allows the tracker antenna to track the UAV signal's direction and retrieve height and speed data from the UAV [15]. Various types of antennas are commonly utilized, including dipole antennas, skew-planar antennas, cloverleaf antennas, and patch antennas [15]. The choice of antenna type significantly impacts the construction of a communication system between the antenna tracker and the UAV [16].

This antenna tracker, constructed to replace the GCS, utilizes mission planner software. The software displays data including speed, telemetry signals, and horizontal and vertical angular attitude responses to track the UAV [17].

2. Research Method

2.1. Design of Antenna Tracker

Several steps are involved in designing the antenna tracker. The first step consists in printing an acrylic sheet cut to the required size. The acrylic sheet size is adjusted to fit the inner and outer circumference according to the bearing size. The next step is to install a spacer to create distance between the bearing's top mount and bottom mount. This same process is repeated

for the servo mounting holder and antenna pole. This design allows the servo to move freely and maximises the resulting data values. Figure 1 shows the design of the tracking antenna.

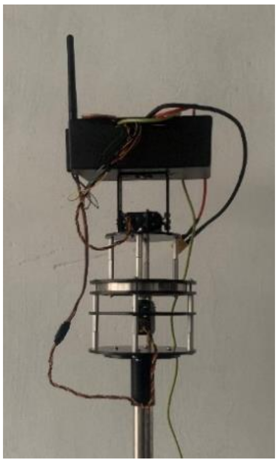

Figure 1. Antenna Tracker Prototype.

This design process has two different parts, namely the top and bottom. The upper part functions as a servo tilt driver and places electronic components. Meanwhile, the lower part functions as a servo pan driver, equipped with a bearing. The servo pan drive aims to reduce weight and make it easier for the servo pan to move horizontally.

At the top, precision is required in designing to assemble the components easily. The tilt servo used is the Hitec HS-645MG, which has dimensions of 40.6mm long, 19.8mm wide and 37.8mm high—then equipped with a servo bracket with dimensions of 21mm length, 56mm width and 52mm height. The servo horn is made of aluminium gear with a diameter of 23mm and a thickness of 6mm. The servo bracket is connected to a black plastic box which contains electronic components. The purpose of this upper part is so that the servo can move up and down properly.

2.2. Wiring Diagram

After designing the antenna tracker, the next step is to carry out the wiring design for the tracking antenna system. This wiring includes several components: a flight controller, GPS module, telemetry radio, power supply, pan and tilt servo. The flight controller used is the Mateksys F765-WING, which has a particular port for connecting a GPS module, enabling features such as Return-to-Home and automatic navigation [18]. The GPS module used is the Ublox M10Q-5883, and it plays a crucial role in the data collection process by allowing researchers to read the coordinate points between the tracking antenna and the UAV. Additionally, the 433MHz 100mW radio telemetry module, with its output power of 100mW and a frequency of 433MHz, supports various communication protocols for airplanes, drones, remote control cars, and tracking antennas. During the wiring process, it's essential to refer to the instructions for use and specifications of each component to ensure proper integration [19]. Figure 2 shows wiring system.

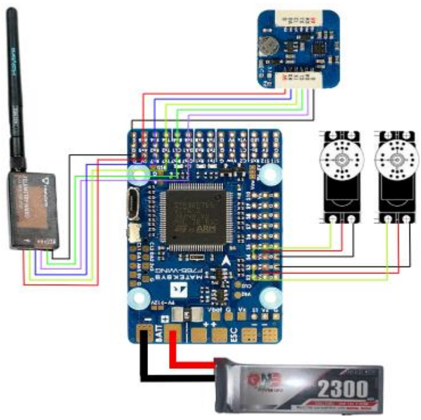

Figure 2. Wiring System.

Table 1 show pin address of each component

Table 1. Pin address of each component

No	Component	Pin Address
1	Pan Servo	Channel 3
2	Tilt Servo	Channel 4
3	LiPo Battery	Power
4	GPS	Ground, DA, CL, Rx, Tx, VCC
5	Telemetry Radio	Ground, RTS, CTS, Rx, Tx, VCC

2.3. Flight Control System

The Mission Planner Software is used for the GPS Module reading [20]. The first step in this system is to set the mission mode on the tracking antenna. By changing to "STOP" mode first, the tracking antenna will automatically change to "disarmed" mode. Then, change to “set waypoint” mode, directing the tracking antenna to the home point. The second step is to calibrate the accelerometer first, so that the tracking antenna can track the signal source in the direction determined by the UAV. Then, return to mission mode, select "AUTO" mode, and the tracking antenna will automatically track the UAV coordinates. Figure 3 shows the mission planner software setup.

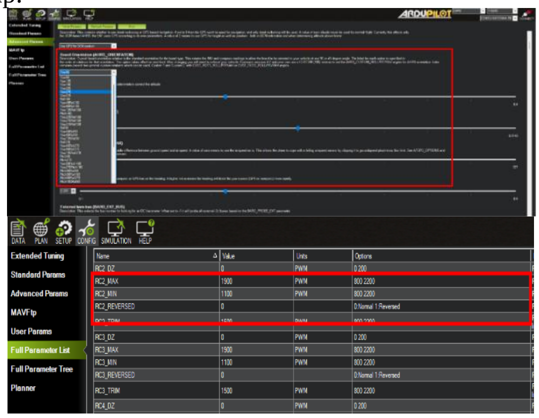

Figure 3. Setup mode visualization

2.4. Tracker System Design

The design of this system requires the creation of a system block diagram to provide an overview of how the antenna tracker works. It is expected that the device can function properly [21][22]. They allow us to analyze how a circuit works and to design general hardware. Figure 4 illustrates the block system design.

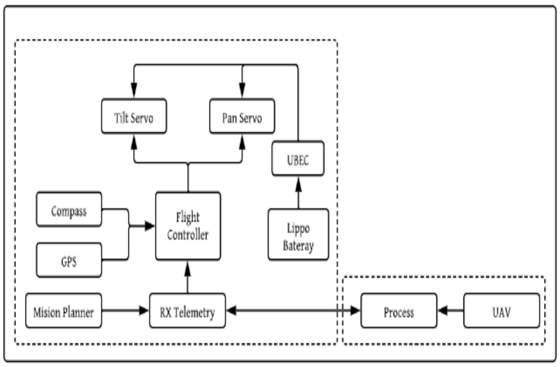

Figure 4. Block System Design

The program is designed to track and adjust the position of the UAV automatically based on coordinate information from the GPS system on the antenna tracker [23]. In this process, the flight controller receives information from various components, which is then converted into the output values for the two servos [24]. The software utilized in this study is Mission Planner, an open-source program employed for mission planning and control on UAVs or drones. Figure 5 is a flowchart of the antenna tracker software system.

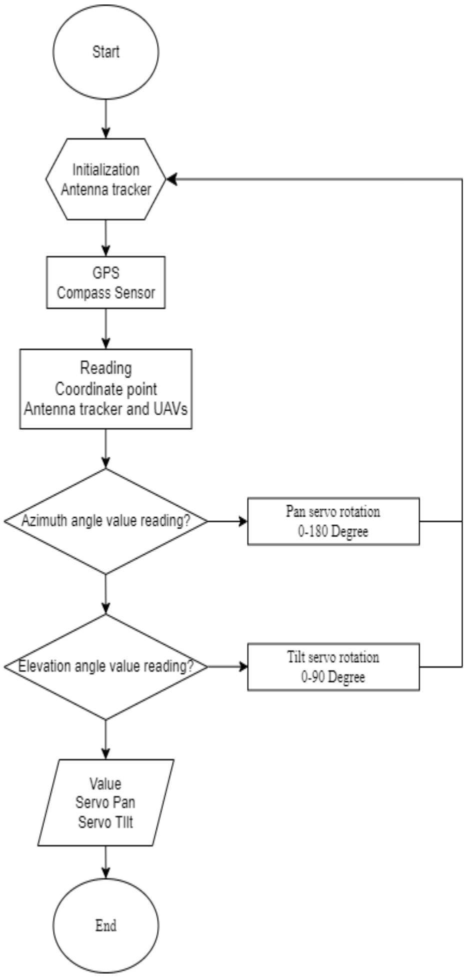

Figure 5. Tracker System Processing

A mission planner is used to design and organize UAV flight missions. It has an easy-to-understand user interface and supports applications such as aerial surveying, mapping, and environmental monitoring. [25].

2.5. Coordinate-based Measurement

Coordinate points between the tracking antenna and the UAV in the form of latitude and longitude. Latitude and longitude data require processing or breaking down large amounts of data provided by GPS sensors. Equation 1

describes distance between two latitude and longitude coordinate points.
ΔLat is the difference in the horizontal line between two points. ΔLon is a deviation in a vertical line between two points. LatAT is the horizontal line on the Tracking Antenna, and LatUAV is the horizontal line on the UAV. d is the distance between two points. R is the radius of the Earth (is a constant value: 6,371 km). C It is the Calculation value in the haversine formula.

$$\Delta Lat = LatUAV - LatAT \quad (1)$$

$$\Delta Lon = LonUAV - LonAT \quad (2)$$

$$\alpha = sin^2\left(\frac{\Delta Lat}{2}\right) + \cos(LatAT) \times \cos(LatUAV) \times sin^2\left(\frac{\Delta Lon}{2}\right) \quad (3)$$

$$C = 2 \times arctan^2(\sqrt{\alpha}, \sqrt{1-\alpha}) \quad (4)$$

$$d = R \times C \quad (5)$$

3. Results and Discussion

3.1. GPS System Module

The GPS module based on the Ublox M10Q-5883 has been tested with distance performance parameters. The GPS test aims to determine the distance, longitude, and latitude between an antenna tracker and a UAV coordinate point. The test assessed the GPS module's capability to read coordinates and distances periodically. The initial step of this test is to calibrate the compass between the tracking antenna and the UAV. After that, test the GPS module to confirm the longitude, latitude and altitude values. Testing will be conducted at 10 to 140 meters to obtain 14 coordinate points. So that the tracking antenna can detect the presence of the signal source sent by the UAV, this test is carried out by directing the UAV to a specific location during the test procedure. The software used in this test is Mission Planner. The test results are shown in Table 2:

Table 2. Distance Comparison testing of an antenna tracker

GPS Antenna Module		Flight GPS Module		Calculation Distance (m)	Module Distance (m)	Deviation Distance (m)
latitude	longitude	latitude	longitude			
-7.8345036	110.3832519	-7.8344221	110.3833132	11.3	10	1.3
-7.8345107	110.3832914	-7.8343584	110.3833955	20.4	20	0.4
-7.8344949	110.3832834	-7.8342848	110.3834576	30.2	30	0.2
-7.8344931	110.3832722	-7.8344221	110.3833132	40.6	40	0.6
-7.8344967	110.3832710	-7.8342090	110.3835038	49.6	50	-0.4
-7.8344900	110.3832680	-7.8341161	110.3835074	59.9	60	-0.1
-7.8344891	110.3832767	-7.8339571	110.3833476	70.5	70	0.5
-7.8344931	110.3832685	-7.8338625	110.3833757	79.2	80	-0.8
-7.8344943	110.3832643	-7.8337916	110.3833913	90	90	0
-7.8345026	110.383258	-7.8337365	110.3835535	104.8	100	4.8
-7.8344991	110.3832652	-7.8336236	110.3836129	110.6	110	0.6
-7.8344868	110.3832639	-7.8335979	110.3836990	120.3	120	0.3
-7.8344921	110.3832498	-7.8335517	110.3838139	131.3	131	0.3
-7.8344913	110.3832668	-7.8334821	110.3838751	137.6	140	-2.4

GPS module test results can be obtained from distance measurement calculations, which calculate an average standard deviation of 1.47 meters (m). Figure 6 shows a graph of manual distance calculations and the GPS distance module

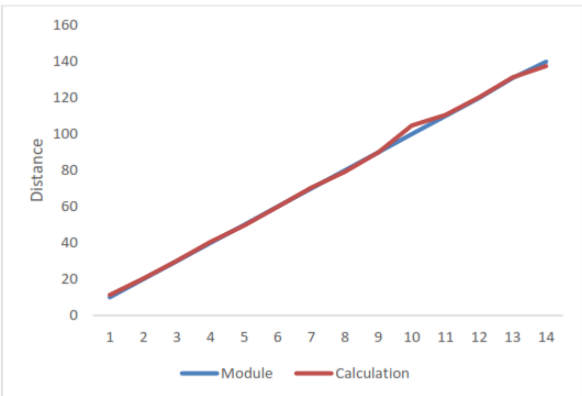

Figure 6. Distance comparison performance of GPS module

3.2. Azimuth and Elevation Performance

Calculating the azimuth and elevation is used for the distance, average, and standard deviation data. This study utilised the Omnicalculator application to streamline and standardise the data analysis.
The azimuth value involves several data processing steps, including calculating the altitude distance, computing the longitude distance, and deriving the two points.
The calculated azimuth and elevation degrees are detailed in Table 3.

Table 3. Azimuth and elevation degree values

Azimuth Degree (°)	Elevation Degree (°)
36.7	0.5
34.1	0.28
39.4	0.18
38.9	0.14
31.6	0.23
8.4	0.38
8.8	0.40
9.8	0.43
20.7	0.38
21.8	0.43
25.5	0.41
30.2	0.38
31.5	0.48
33.71	0.37

The azimuth angle calculation test results yielded a range of 8.4 to 39.4 degrees, while the elevation angle ranged from 0.18 to 0.5 degrees. The graph depicting the azimuth and elevation angle testing is displayed in Figure 7.

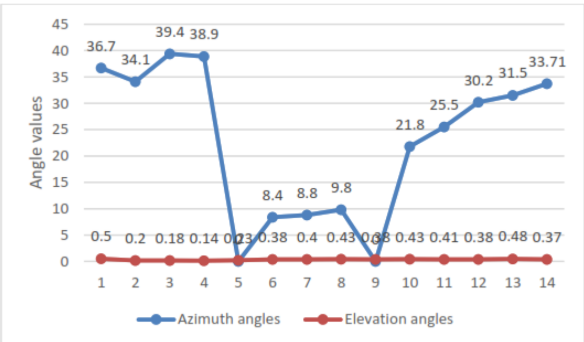

Figure 7. Azimuth and elevation degree comparison graph

3.3. Pan and Tilt Servo Rotary Motion

The test involves a pan servo that moves 180 degrees and a tilt servo that moves 90 degrees. This pan and tilt servo system requires several tests to ensure that the tracking antenna functions appropriately and can accurately follow the signal source on the UAV.

The initial stage is to determine the servo motion configuration in the form of a PWM (Pulse Width Modulation) signal value. The pan servo has a PWM value of 800 to 2200. In contrast, the tilt servo has a PWM value of 1100 to 1900. Furthermore, simulations are performed to test conditions on the tracking antenna, such as performing servo motion orientation. So that researchers can overcome or give orders in these situations. This test is carried out at different coordinates to get accurate PWM values.
This process involves directing the UAV to a specific location so that the tracking antenna can accurately detect the UAV signal source. The data collection results of servo PWM and tilt values are presented in Table 4.

Table 4. Pan and tilt servo PWM value performances

Distance	Pan Servo (PWM)	Tilt Servo (PWM)
11.3	1445	1200
20.4	1460	1200
31	1542	1200
40.5	1514	1200
49.5	1504	1200
59.6	1424	1200
70.2	1431	1200
78.8	1562	1200
89.7	1453	1200
104.8	1399	1200
110.6	1418	1200
119.9	1549	1200
131.3	1624	1200
137.2	1513	1200

In this test, the rotating movement of the pan servo produces a Pulse Width Modulation (PWM) signal value of 1399 to 1624. However, the tilt servo cannot respond to the direction of rotation because the test is not in flight mode on the UAV. As a result, the servo tilts produce a Pulse Width Modulation (PWM) value of 1200. The graph of the rotating motion of the pan and tilt servo can be found in Figure 8.

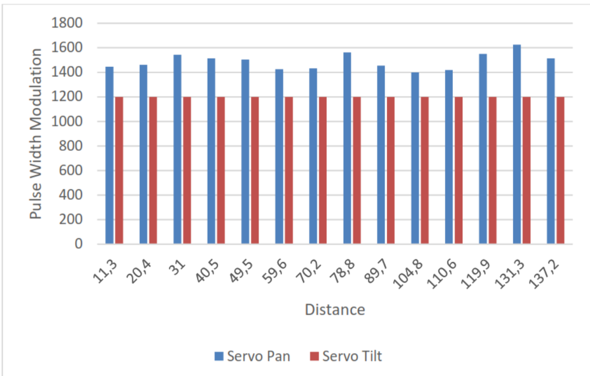

Figure 8. Comparison performance of pan and tilt servo

4. Conclusion

In testing the tracking antenna communication with the UAV, the GPS positioning method was used, which shows that the tracking antenna can follow the UAV well and accurately. The tracking antenna can track the UAV according to Mission Planner commands. It can display information between the tracking antenna and the UAV, such as data on coordinate point values, distance and servo rotational movements. The GPS Testing Module can produce accurate coordinate points and obtain measurements of distance differences with an average standard deviation value of 0.7. From the results of testing the rotational motion of the pan and tilt servo using the GPS positioning method, the tracking antenna could perform reasonably accurate tracking, with Pulse Width Modulation (PWM) signal values of 1418 to 1624.

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