Development of Elevation and Azimuth Rotator Antenna Telecontrolling System Design for Practicum at Malang State Polytechnic

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***Abstract*— Research presents the development of a telecontrolled antenna rotator system capable of controlling both azimuth and elevation angles through an Android-based application. The system was designed to enhance the effectiveness and efficiency of antenna practicum activities at the State Polytechnic of Malang. The research employed the Research and Development (R&D) methodology, involving several stages: literature study, system design, hardware and software implementation, and performance testing. The rotator mechanism was driven by a Nema 17 stepper motor and controlled by a Raspberry Pi 4 with a DRV8825 driver. The angular position was detected using an AS5600 magnetic sensor, while the Android application communicated with the controller via Firebase Realtime Database for real-time synchronization. Experimental results showed that the rotator achieved 360° rotation with an accuracy of 98.26% for the azimuth axis and 99.16% for the elevation axis. The system remained stable under loads of 500 g and 1 kg, with a maximum deviation of only 2°. These results indicate that the developed system is reliable and suitable for educational use, providing precise control, real-time monitoring, and improved practicality compared to conventional manual methods.**

***Keywords*— Android Application, Antenna Rotator, AS5600 Sensor, Raspberry Pi 4, Stepper Motor, Telecontrolling.**

I. INTRODUCTION

Automated antenna rotator system based on a microcontroller has been developed to support indoor measurement applications. The system enables full 360-degree rotation on both azimuth and elevation axes and provides three rotation modes to facilitate far-field antenna measurements. Experimental evaluation demonstrates that the rotator operates with high accuracy, producing more precise polarization and radiation pattern diagrams[1]. The mechanical structure is designed to accommodate microstrip antennas as well as small wire antennas, making the rotator versatile for various laboratory testing scenario[2].

Developed a microcontroller-based pointing controller for a Yagi antenna operating at radio frequencies. The system consisted of a pointing mechanism, a target-pointing module, installation configuration, and a graphical user interface. The hardware included an Arduino Uno as the main controller, an MG958 servo motor for pointing movement, an SX1278 LoRa module for wireless communication, a Yagi antenna for transmitting and receiving signals, and a BMP280 module as a sample transceiver sensor.[3] On the software side, the implementation utilized Arduino IDE, Google Earth, Visual Basic 6, and 4NEC2 for antenna simulation.[4] The evaluation process covered antenna measurements, controller motion testing, received signal strength assessment, GUI functionality testing, and transceiver validation. The results showed that the antenna achieved an SWR of 1.33, signal strength of approximately 12 dB, and a beamwidth of ±62°. The azimuth controller demonstrated a movement error of only 1°, while the best received signal level reached –88 dB at a spreading factor of 7 and a bandwidth of 500 kHz. Sensor testing using the BMP280 module produced a temperature measurement error of approximately ±2 °C.[5].

Arduino-controlled rotation system for TV antennas was engineered to facilitate wireless adjustment of antenna orientation. The design consists of both hardware and software components, integrating an Arduino Uno microcontroller as the primary controller, an HC-05 Bluetooth module for wireless communication, a DC motor and motor driver for mechanical rotation, and a 220V power supply. Functional testing was conducted directly on a television antenna to verify system reliability and responsiveness. [6]Through Bluetooth commands transmitted from an Android smartphone, the controller successfully regulated the DC motor movement, enabling smooth and precise antenna positioning. Evaluation results confirmed that all hardware modules—including the Arduino board, Bluetooth interface, motor driver, and DC motor—performed reliably, with the system consistently producing accurate rotational responses corresponding to user inputs[7].

Android-based antenna positioning system was developed to enhance wireless signal reception by enabling remote adjustment of antenna direction. The system was designed to overcome the limitations of manual antenna alignment, particularly in remote or hard-to-reach locations.[8] Utilizing a 28BYJ-48 stepper motor paired with a ULN2003 driver, the mechanism enables coordinated movement of the antenna in both azimuth and elevation axes.[9] Control is carried out through an Android application that communicates with a NodeMCU V3 microcontroller, allowing users to adjust antenna orientation seamlessly and more efficiently compared to manual methods[10].

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Prototype antenna tracker was developed using NEMA 23 stepper motors as dual-axis actuators for azimuth and elevation movement.[11] The system was designed to track signals transmitted from atmospheric balloon payloads, enabling accurate alignment of the receiving antenna with the signal source. This work aimed to create a precise and responsive drive mechanism capable of maintaining reliable tracking performance as the balloon shifts position during flight.[12]

Control strategy integrating Model Following Control (MFC) with a Proportional–Integral–Derivative (PID) controller was proposed for a DC servomotor–based antenna positioning system. The work aimed to improve system stability and reduce positioning errors commonly encountered in satellite communication antenna platforms.[13] The authors developed a dynamic model of the servomotor positioning system and designed an MFC scheme augmented with PID control to enhance transient response and overall robustness. MATLAB/SIMULINK was used for simulation, and the results demonstrated that the MFC–PID approach achieved a rise time of 1.4483 seconds, a settling time of 4.2470 seconds, and an overshoot of 5.5214%, outperforming conventional PID methods. These findings indicate that the integrated MFC–PID controller provides superior performance for precise antenna positioning in satellite communication applications[14].

Antenna azimuth position control system was developed using two control approaches, namely a PID controller and a state-feedback controller. The objective was to enhance positioning accuracy and improve system response during antenna movement. PID parameters were tuned using the Ziegler–Nichols method, while pole-placement techniques were applied in designing the state-feedback controller. System performance for both controllers was evaluated through simulations conducted in MATLAB/Simulink. The results indicated that the state-feedback controller outperformed the PID controller, achieving faster settling time, minimal overshoot, and zero steady-state error. This work emphasizes the importance of selecting appropriate control strategies for optimal antenna positioning and suggests the exploration of more advanced intelligent controllers to further improve system stability and dynamic performance[15].

II. METHOD

A. System Block Diagram

The block diagram of the dual-axis telecontrolled antenna rotator system. The system can be divided into two main sections: the input–output unit and the processing unit. The explanation of each part is described as follows:

Input and Output Unit

1. Serves as the user interface for controlling the antenna rotation. Through a wireless connection, the smartphone sends rotation commands and receives real-time angle data from the system.
2. Functions as the actuator that physically rotates the antenna in the required direction based on control signals received from the motor driver.

Wireless commands are transmitted through the WLAN and forwarded to the database before being processed by the Raspberry Pi 4 as the main controller. The Raspberry Pi manages motor control through the CNC V3 engraving board and communicates with the Arduino Uno when required. The AS5600 angle sensor provides real-time feedback to ensure accura terotation.Wireless connections link the smartphone, WLAN, and Raspberry Pi, while wired lines connect the Raspberry Pi, drivers, sensors, and motor to deliver precise and synchronized antenna movement.

B. Antenna Rotator Mechanical Design

The mechanical design of the antenna rotator system is presented in Fig. 1. The design emphasizes dual-axis rotation (azimuth and elevation) to achieve accurate and stable antenna positioning. A compact and integrated mechanical structure was implemented to simplify assembly and enhance system reliability.

The arrangement of key components, including the worm gear, small worm gear, and turntable, ensures smooth rotational motion and precise angle control. This design supports stable operation, ease of maintenance, and long-term suitability for antenna practicum applications.

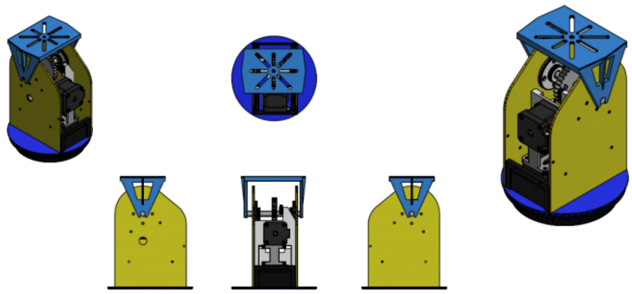

Figure 1 Antenna Rotator Mechanical Design

C. Box Panel Design

The mechanical design of the control panel box is illustrated in Fig. 2. The panel box functions as a housing for the antenna rotator control components and is designed with compact dimensions of 21 cm × 14 cm × 7 cm to accommodate all devices efficiently. The design emphasizes space efficiency, ease of installation, and adequate ventilation to prevent overheating during operation.

The panel box contains the Raspberry Pi 4 Model B as the main controller, a CNC V3 Engraving module as the interface between the controller and the stepper motors, and DRV8825 motor drivers for precise current and voltage regulation. All components are arranged on a ventilated base plate to ensure proper airflow. This organized layout facilitates assembly, maintenance, and troubleshooting.

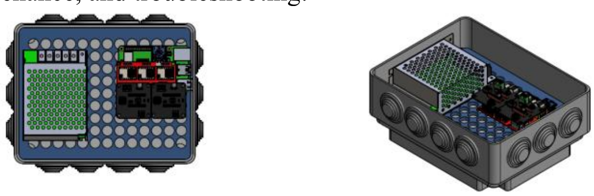

Figure 3. Panel Box Design

III. RESULTS AND DISCUSSION

The results of the research should be written clearly and concisely. Discussions consider outlines the importance of research, not repeat it. Avoid excessive uses quotations and discussions about literature published. This chapter will explain the implementation of mechanical project view and several parameter testing.

A. Implementation of Mechanical Design

Figure 4. Antenna Rotator Front View

Antenna Rotator Front View is shown in Fig 4.

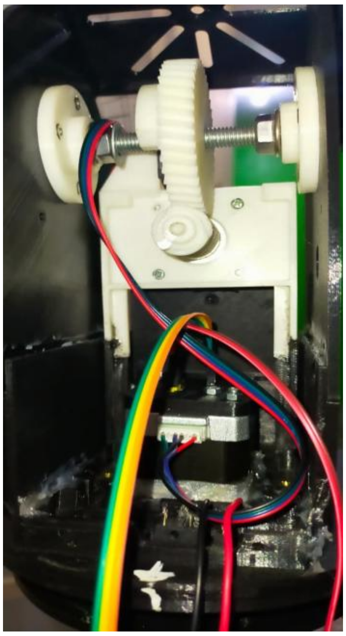

Figure 5 Antenna Rotator Inside View

Antenna Rotator Inside View is shown in Fig 5.

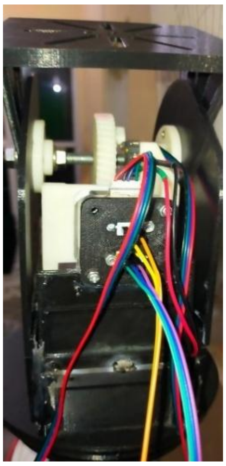

Figure 6. Antenna Rotator Backside View

Antenna Rotator Backside View is shown in Fig 6.

B. Implementation of Panel Box

Panel Box Front View is shown in Fig 7. Panel Box Right Side View is shown in Fig 8 and Panel Box Left Side View is shown in Fig 9.

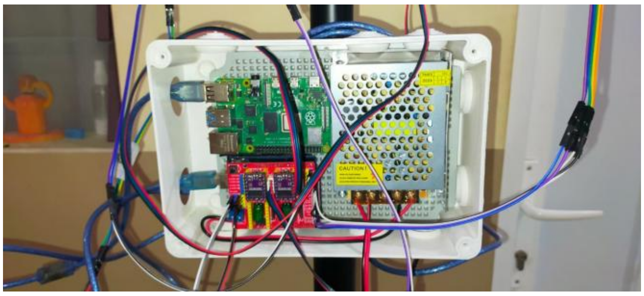

Figure 7. Panel Box Front View

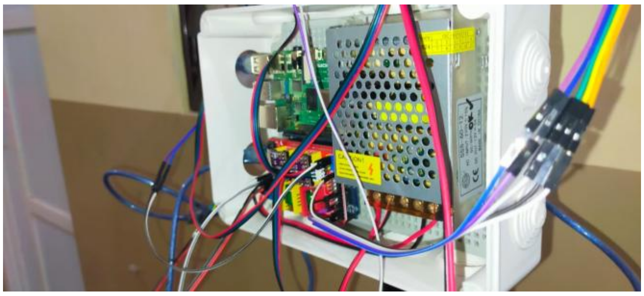

Figure 8. Panel Box Right Side View

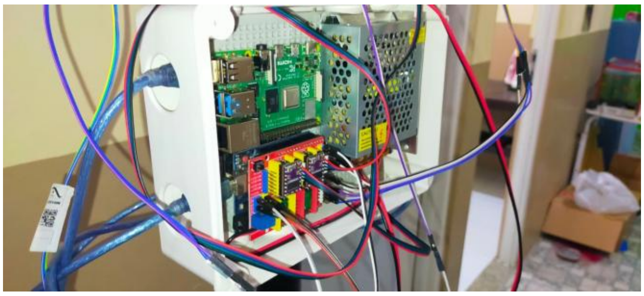

Figure 9. Panel Box Left Side View

C. Calibration Sensor AS5600

Table I and Table II present the calibration results of the angular sensor for the azimuth and elevation axes, respectively, which demonstrate the accuracy, consistency, and reliability of the measurement system in detecting angular positions during antenna rotation experiments.

TABLE I
CALIBRATION SENSOR AS5600 FOR AZIMUTH

Input angle(°)	Result Calibration		
	Measured angle(°)	**Sensor Angle Reading(°)**	**Error(%)**
10	10	10	0
20	20	20	0
30	30	30	0
40	40	40	0
50	50	50	0
60	60	60	0
70	70	70	0
80	80	80	0
90	90	90	0
100	100	100	0
110	110	110	0
120	120	120	0
130	130	130	0
140	140	140	0
150	150	150	0
160	160	160	0
170	170	170	0
180	180	180	0
190	190	190	0
200	200	200	0
210	210	210	0
220	220	220	0
230	230	230	0
240	240	240	0
250	250	250	0
260	260	260	0
270	270	270	0
280	280	280	0
290	290	290	0
300	300	300	0
310	310	310	0
320	320	320	0
330	330	330	0
340	340	340	0
350	350	350	0
360	360	360	0

TABLE II
CALIBRATION SENSOR AS5600 FOR ELEVATION

Input angle(°)	Result Calibration		
	Measured angle(°)	**Sensor Angle Reading(°)**	**Error(%)**
0	0	0	0
10	10	10	0
20	30	20	0
30	30	30	0

D. Sensor Accuracy Test Results

The AS5600 sensor accuracy test was conducted to evaluate the difference between the sensor's measured angle and the actual rotation angle. This comparison was used to determine sensor precision by calculating angular deviation and error values. The test was performed at 10° intervals, covering a rotation range of 0°–360° for azimuth and elevation angles of 0° and 30°, which correspond to antenna practicum requirements. Angular inputs were applied for both clockwise and counterclockwise rotations using a rotator angle gauge. The results are presented in Table III and Table IV.

To evaluate the accuracy performance of the AS5600 angle sensor, the measured angular values were compared with the predefined input angles. This analysis aims to quantify the deviation and error between the sensor readings and the actual rotation angles during the testing process. The accuracy assessment is mathematically expressed using Equations (1) and (2).

$$Average\ Angular\ Deviation = \left(\frac{\sum_{1}^{5} Result}{5}\right) - Angle\ Input$$

Equation (1) is used to calculate the average angular deviation, which is obtained by averaging the measured angle values from five experimental trials and subtracting the input angle.

$$error = \frac{Average\ Angular\ Deviation}{Angle\ Input} \times 100\%$$

Equation (2) defines the angular error, which is calculated by dividing the average angular deviation by the input angle and expressing the result as a percentage.

TABLE III
SENSOR ACCURACY RESULT AS5600 FOR AZIMUTH

Input angle(°)	Trial					Average Angular Deviation
	Trial 1(°)	**Trial 2(°)**	**Trial 3(°)**	**Trial 4(°)**	**Trial 5(°)**	
10	10°	11°	12°	10°	11°	0,7
20	20°	21°	22°	22°	22°	1,3
30	31°	33°	33°	32°	31°	1,9
40	41°	41°	42°	43°	42°	1,4
50	50°	51°	52°	51°	51°	1,0
60	63°	61°	62°	62°	61°	1,8
70	70°	71°	73°	72°	71°	1,5
80	80°	81°	83°	82°	82°	1,6
90	90°	90°	92°	94°	92°	1,6
100	100°	103°	101°	103°	102°	1,7
110	110°	114°	113°	112°	113°	2,7
120	120°	122°	122°	122°	123°	1,8
130	130°	133°	132°	132°	133°	2
140	140°	143°	143°	141°	143°	2
150	150°	153°	154°	152°	153°	2,4
160	160°	162°	163°	162°	163°	2
170	170°	173°	172°	173°	173°	2,2
180	180°	183°	182°	183°	182°	2
190	190°	192°	192°	192°	190°	1,2
200	200°	200°	201°	200°	200°	0,4
210	210°	211°	212°	210°	210°	0,7
220	220°	221°	222°	220°	220°	0,6
230	230°	231°	233°	230°	230°	0,8
240	240°	241°	243°	240°	240°	0,8
250	250°	250°	252°	250°	250°	0,4
260	259°	262°	261°	260°	260°	0,6
270	270°	269°	271°	270°	270°	0
280	280°	281°	283°	280°	280°	0,8
290	291°	292°	292°	290°	290°	1
300	300°	302°	302°	300°	300°	0,8
310	310°	312°	311°	310°	310°	0,6
320	320°	321°	322°	320°	320°	0,6
330	330°	341°	332°	330°	330°	2,6
340	339°	340°	341°	340°	340°	0
350	350°	351°	351°	350°	350°	0,4
360	360°	358°	359°	360°	360°	0,6
Average Total Angular Deviation						1,64°
Average Error						0.4556%

TABLE IV
SENSOR ACCURACY RESULT AS5600 FOR ELEVATION

Input angle(°)	Trial					Average Angular Deviation
	Trial 1(°)	Trial 2(°)	Trial 3(°)	Trial 4(°)	Trial 5(°)	
10	10°	11°	12°	10°	11°	0,7
20	20°	21°	22°	22°	22°	1,3
30	31°	33°	33°	32°	31°	1,9
Average Total Angular Deviation						0,84°
Average Error						0.028%

IV. CONCLUSION

Antenna Rotator successfully designed and implemented a dual-axis antenna rotator system with azimuth and elevation control. The mechanical and control designs provide stable and precise antenna positioning. Sensor accuracy testing using the AS5600 demonstrates low angular deviation and acceptable error values, confirming reliable angle measurement performance. The integration of the control system, feedback sensor, and mechanical structure supports accurate antenna rotation and meets laboratory antenna practicum requirements effectively.

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