STM JOURNALS

Journal of
Aerospace Engineering & Technology

https://journals.stmjournals.com/joaet

ISSN: 2231-038X (Online)
ISSN: 2348-7887 (Print)
Volume 14, Issue 1, 2024
January–April
DOI (Journal): 10.37591/JoAET

Research JoAET

# Antenna Positioning Unit for Defence Vehicles

Khadse Pavan Dilip[1,] *, Khalate Vinay Hanumant[2], Kasar Onkar Bhausaheb[3], G.N. Gaikwad[4], Ganesha Naik[5]

***Abstract***

*This paper introduces an advanced antenna positioning system specifically engineered for defense vehicle applications, featuring Azimuth angle rotation and Elevation angle rotation. The system, designed for precision and adaptability, achieves remarkable accuracy. Noteworthy is its immunity to magnetic field interference, ensuring unwavering reliability in electromagnetic-intensive defence environments. The system's substantial weight-bearing capacity, coupled with precise control, makes it an ideal solution for defense vehicles necessitating advanced communication and surveillance capabilities. Designed to precisely manage the alignment of antennas deployed on defence vehicles, the Antenna Positioning Unit is a multipurpose instrument. The APU maximizes signal reception for surveillance while facilitating smooth communication with satellites, ground stations, and other platforms by modifying the azimuth and elevation angles of the antennas. This skill is especially important in dynamic combat situations were staying connected and obtaining intelligence in real time is critical. Ensuring dependable communication between defense vehicles and command centers in all-weather situations is one of the main responsibilities of the Antenna Positioning Unit. The APU facilitates constant connectivity in a variety of environments, including dense forests, rough terrain, and metropolitan areas. It does this by automatically lining up the antennas to create and maintain satellite links or establish connections with ground-based stations. Coordinating troop movements, getting mission updates, and seeking assistance when needed all depend on this skill.*

**Keywords:** APU, Antenna, Stepper Motors, Azimuth angle, Elevation angle, Gyro-sensor, Defence Vehicles, ESP32 microcontroller.

## INTRODUCTION

In an era where communication is pivotal for the success of defence operations, the development of cutting-edge technologies becomes paramount. The "Antenna Positioning Unit for Defence Vehicle" project is conceived as a solution to enhance the communication capabilities of military vehicles, ensuring seamless connectivity in diverse operational environments. The primary objective of this project is to design and implement a sophisticated Antenna Positioning Unit (APU) that can dynamically adjust the orientation of communication antennas on defence vehicles.

This innovation aims to overcome the challenges posed by varying terrains and operational scenarios, providing a reliable and robust communication link between military units. The significance of a versatile APU lies in its ability to maintain optimal communication range and signal strength, even in challenging conditions such as rough terrains, urban

***Author for Correspondence**
Khadse Pavan Dilip
E-mail: pdk922@gmail.com

[1-3]Student, Department of Electronics and Telecommunication, Sinhgad College of Engineering, Savitribai Phule Pune University, Pune, Maharashtra, India
[4]Lecturer, Department of Electronics and Telecommunication, Sinhgad College of Engineering, Savitribai Phule Pune University, Pune, Maharashtra, India
[5]Researcher, Department of Research and Development, Horizon Electro Solutions Pvt. Limited, Engineering, Savitribai Phule Pune University, Pune, Maharashtra, India

Receiving Date: 21st May 2024
Accepted Date: 31st May 2024
Published Date: 24th June 2024

**Citation:** Khadse Pavan Dilip, Khalate Vinay Hanumant, Kasar Onkar Bhausaheb, G.N. Gaikwad, Ganesha Naik. Antenna Positioning Unit for Defence Vehicles. Journal of Aerospace Engineering & Technology. 2024; 14(1): 38–46p.

environments, and electronic warfare scenarios. By ensuring constant and reliable connectivity, the project directly contributes to the overall effectiveness and efficiency of defence operations.

This project represents a convergence of expertise from various domains, including electronics and software development. The Antenna positioning Unit for defence vehicle aspires to redefine the standards of communication security within defence vehicles, providing an intelligent solution that not only safeguards sensitive information but also ensures continuous, reliable connectivity during critical missions.

A standout feature of the Antenna Positioning Unit is its capability to operate seamlessly in any weather condition. Whether facing extreme temperatures, heavy rainfall, or challenging terrain, the APU is designed to maintain peak performance, ensuring uninterrupted communication vital for military strategies in diverse climates. In the landscape of defence technology, precision and reliability are paramount. The Antenna Positioning Unit, distinguished by its high accuracy, ensures pinpoint alignment for optimal communication range and effectiveness [1–2]. By significantly reducing noise in signal reception, the APU enhances the clarity and security of communication channels, contributing to mission success in dynamic operational environments.

## METHODOLOGY

The Antenna Positioning Unit (APU) for Defence Vehicles incorporates advanced technologies to achieve precise and reliable antenna positioning. Managed by an ESP32 microcontroller, the computing tasks are centralized, ensuring efficient control. A gyroscope sensor detects the vehicle's orientation and angles, providing real-time data to the APU for accurate positioning. Stepper motors, integrated with planetary gearboxes, allow for precise adjustments in both azimuth and elevation angles of the antenna. The choice of planetary gearboxes reduces rotation speed while increasing torque, ensuring smooth and accurate positioning. Additionally, a braking mechanism utilizing DC motor and L298N motor driver enhances stability during antenna rotation by providing controlled resistance. These DC motors act as brakes, generating opposing torque to prevent overshooting or unintended movement, thereby ensuring precise and stable antenna positioning. Together, these components form a comprehensive system designed to optimize communication capabilities in diverse operational environments encountered by Defence Vehicles.

## BLOCK DAIGRAM

1. *Sensor Module:* The sensor module consists of a Gyro-sensor which helps in finding the angle to which the antenna is to set. It communicates with ESP 32 using UART protocol.
2. *Microcontroller Module:* The microcontroller module consists of an ESP32 and a power supply. ESP32 helps in controlling the unit's movements by simple commands. We have code the ESP32 in python which helps in efficient and faster running of code [7–8]
3. *Stepper Motors:* We have used Planetary geared Stepper Motors to Rotate the antenna [3–4]. There is two Stepper Motors, one is used for rotating in Azimuth axis and other is used to rotate in Elevation axis.
4. *DC Motor:* We used DC motors to act as brakes, generating opposing torque to prevent overshooting or unintended movement, thereby ensuring precise and stable antenna positioning.
5. *Power Supply:* We have used a Stepdown Power supply to achieve the desired 48 Vdc Power, which powers the entire project. There are two different Stepdown circuits, one for the ESP32 which converts 48 Vdc to 5 Vdc; Other one is used for stepper motor driver as shown in Figure 1.

### Technical Details

#### *Angular Range*

- *Azimuth axis:* 0º to 360º.

- *Elevation Axis:* +/- 15º.

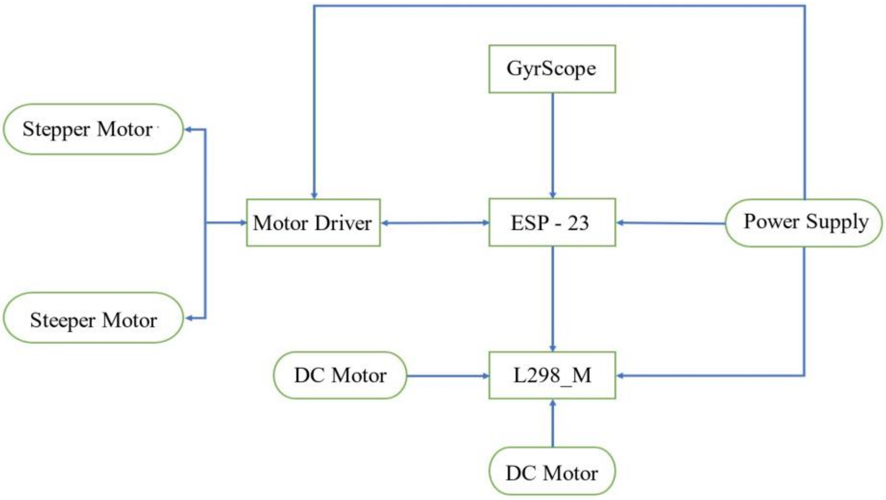



**Figure 1.** APU for Defence Vehicles.

***Accuracy***
- Sensor Accuracy 0.1°.

***Maximum Weight Capacity***
- 150 to 200 Kgs.

***Gear Rotation Ratio***
- 1:40 rotation.

***Motor Step Size***
- 1.8º

**Software Details**
- Mirco-Python
- Egale 9.6.2
- Thonny IDE

**Functional Capabilities:**
- *Shortest Path Detection:* The Antenna Positioning Unit (APU) is equipped with algorithms to detect the shortest path to the desired goal position. This capability ensures efficient and optimized movement of the antenna towards its target azimuth and elevation angles.
- *Speed Control:* Upon initiating movement towards the goal position, the APU gradually increases its speed to expedite the process. As the APU approaches the target azimuth and elevation angles, it automatically decelerates to ensure precise alignment with the goal.
- *Braking System:* To maintain stability and accuracy after reaching the goal position, the APU is equipped with a braking system. These brakes are engaged to securely hold the antenna in place, preventing any unintended movement or deviation from the desired azimuth and elevation angles.
- *Weight Handling:* The APU is designed to handle weights ranging from 50 to 70 kilograms. This robust construction ensures that the unit can effectively support and manoeuvre antennas of varying sizes and configurations, meeting the requirements of diverse defence applications**.**

## FLOWCHART

The provided flowchart in Figure 2 outlines the operational logic of a system designed for sensor data acquisition and user interaction [9–12], particularly aimed at controlling positions in azimuth and elevation directions. Here's a detailed theoretical explanation:

**Initialization**

At the initialization stage, the necessary modules are imported, and essential interfaces such as UART (Universal Asynchronous Receiver-Transmitter) and GPIO (General Purpose Input Output) pins are initialized. These interfaces are crucial for communication with external devices and controlling hardware components.

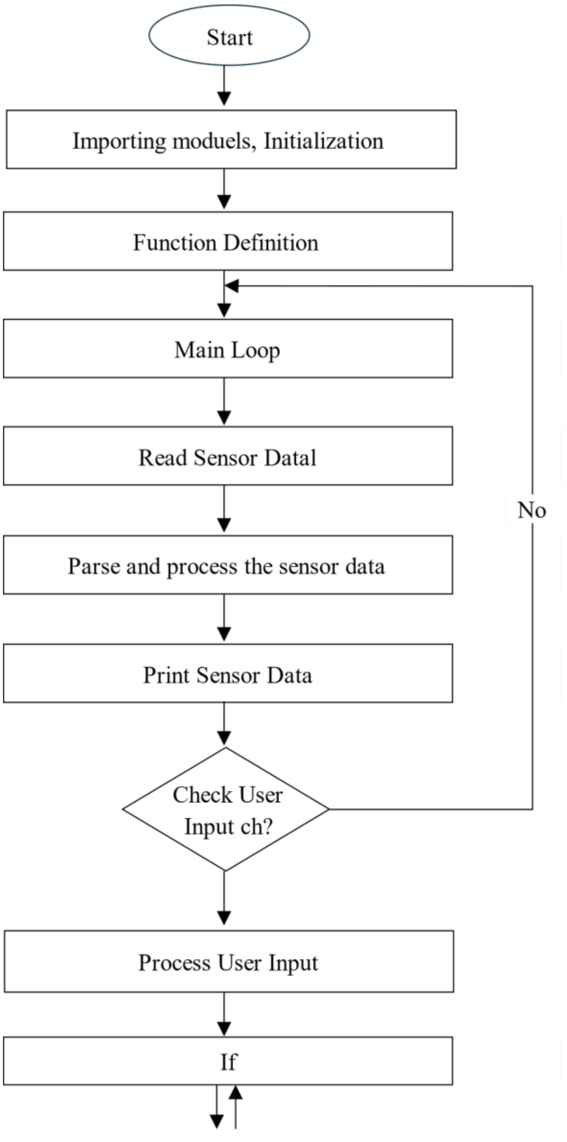
**Function Declaration**

This section involves declaring and defining functions essential for the system's operation. These functions likely include routines for reading sensor data and setting positions in both azimuth and elevation directions. By encapsulating these operations into functions, the code becomes modular and easier to maintain.

**Main Loop**

The main loop represents the core operational sequence of the system. It continuously reads input data from sensors, likely positioned to detect changes in orientation or position. Specifically, the loop reads Y and Z coordinates from the connected sensors, processes the acquired data, and then prints these coordinates for monitoring purposes. This loop ensures that the system is constantly aware of its spatial orientation.


Start
Importing moduels, Initialization
Function Definition
Main Loop
Read Sensor Datal
Parse and process the sensor data
Print Sensor Data
Check User Input ch?
No
Process User Input
If

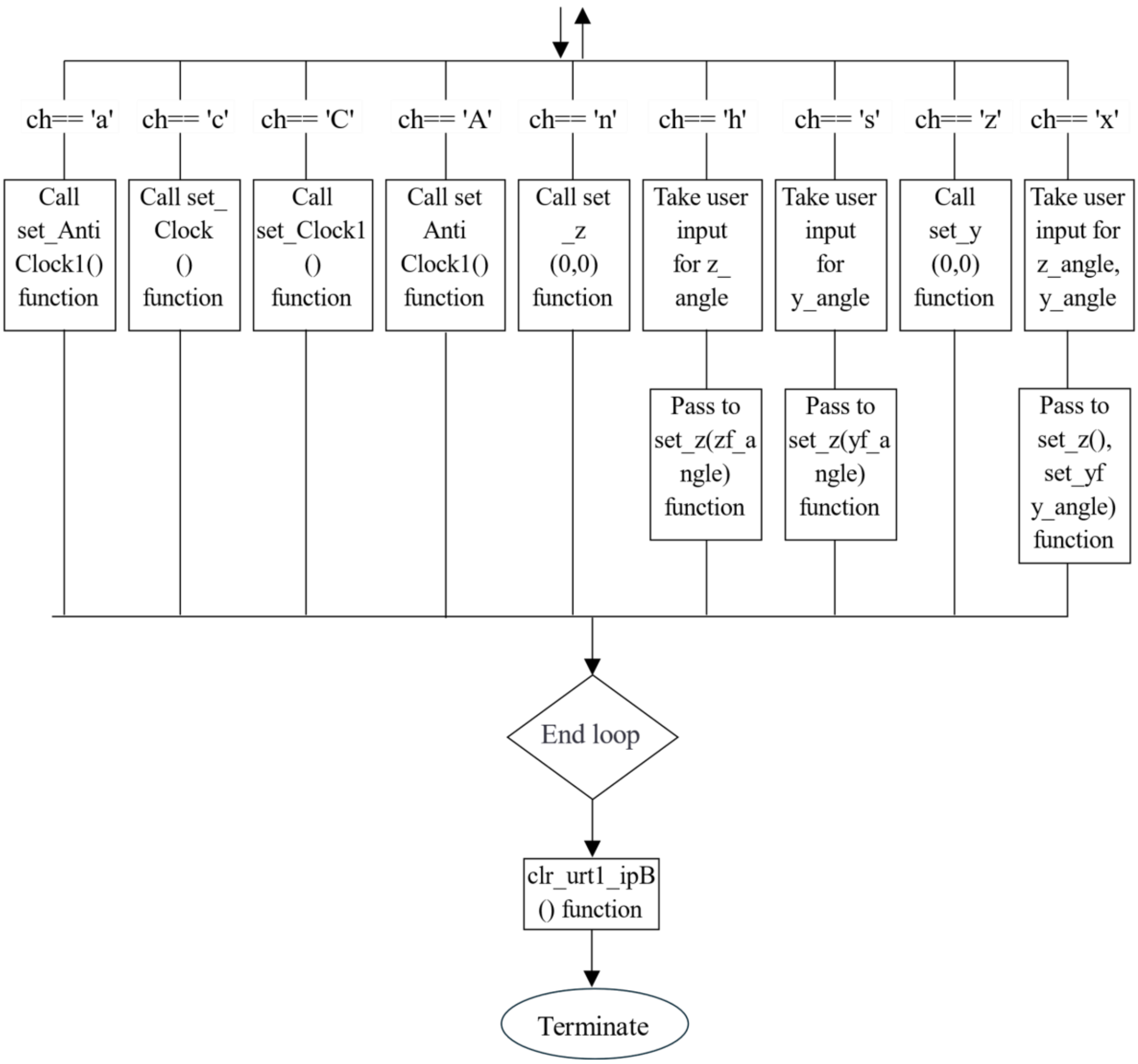



**Figure 2.** Flowchart for main.py.

**Second Loop (User Interaction)**

This nested loop is dedicated to handling user interaction. It first checks if there's any input available from the user. If input is detected, it processes the user's commands accordingly. The system responds to various commands initiated by the user, such as adjusting the position clockwise ('c') or counterclockwise ('a'), setting specific azimuth ('s') or elevation ('h') angles, or resetting the positions to neutral ('n' and 'z'). By catering to user commands, the system allows for dynamic control and customization.

**Wait**

After processing sensor data and user commands, the system briefly pauses execution using the utime.sleep(1) function. This delay ensures that the system doesn't overwhelm the sensors with continuous readings and allows users time to interact with the system comfortably. Additionally, the UART buffer is cleared to ensure that the latest sensor data is obtained during the next iteration of the main loop.

**End**

Finally, the program terminates when certain conditions are met, such as reaching the end of the code execution or upon user command. This ensures proper closure and cleanup of resources used by the program.

**Figure 3.** Antenna positioning unit prototype.

## RESULTS

The project's hardware comprises several essential components, each playing a vital role in achieving precise antenna positioning for defence vehicles as shown in Figure 3:

### Stepper Motors with Planetary Gearboxes

Stepper motors, renowned for their precision and control, serve as the primary movers for the antennas. Coupled with planetary gearboxes, these motors ensure smooth and accurate movement. The planetary gearboxes reduce motor speed while enhancing torque, facilitating precise antenna adjustments.

### Stepper Motor Drives

Stepper motor drives, also known as controllers, interface with the ESP32 microcontroller to execute commands. These drives generate electrical pulses to control the stepper motors' movement, ensuring they rotate in the desired direction and step count. This stepwise motion guarantees precise antenna positioning.

### ESP32 Microcontroller

Acting as the central control unit, the ESP32 microcontroller orchestrates the entire system's operation. It receives user inputs or commands from automated systems, specifying the desired antenna positions. Using this information, the microcontroller calculates the necessary steps and sequences for the stepper motors to achieve the target positions accurately.

### Gyroscope Sensor

Integrated into the system, the gyroscope sensor continuously monitors the defence vehicle's rate of rotation. This data is crucial for adjusting the antenna positions to compensate for vehicle movement [5–6], ensuring that the antennas remain accurately aimed even during dynamic operational scenarios.

### DC Motors and Drivers

Additionally, the system incorporates DC motors and their corresponding drivers to provide a braking mechanism. These DC motors engage when the antennas reach their desired positions, holding them securely in place. The driver’s interface with the ESP32 microcontroller to receive commands for activating the braking system, enhancing stability and accuracy post-positioning.

## WORKING

The flow of operation for the Antenna Positioning Unit (APU) utilizing MicroPython and Thonny IDE. The following steps outline the intricate operation of the APU:

### Initialization and Sensor Communication

At startup, the ESP32 microcontroller initializes communication with the gyroscope sensor, a crucial component for obtaining real-time orientation data. This initialization process establishes a reliable connection with the sensor, enabling continuous monitoring of the vehicle's orientation.

### Initial Motor Alignment

After initializing communication with the gyroscope sensor, the microcontroller checks the current position of the stepper motor. Utilizing the gyroscope data, the microcontroller aligns the motor towards the north direction, serving as the initial reference point for subsequent positioning adjustments. This alignment ensures an accurate starting position for the antenna.

### Command Monitoring

Throughout operation, the microcontroller continuously monitors for incoming commands from various sources, including user inputs or external control systems. These commands dictate specific actions for the APU, such as adjusting the antenna's azimuth and elevation angles to establish optimal communication links.

### Command Processing and Position Calculation

Upon receiving a command, the microcontroller processes the command parameters and calculates the desired position for the stepper motor. This calculation considers factors such as the target azimuth and elevation angles, as well as any environmental constraints or operational requirements.

### Stepper Motor Adjustment

With the desired position calculated, the microcontroller commands the stepper motor to adjust its position accordingly. Utilizing precise control algorithms, the microcontroller ensures smooth and accurate alignment of the antenna, effectively pointing it towards the specified azimuth and elevation angles.

### Real-Time Feedback and Communication

Throughout the operation, the microcontroller continuously updates and communicates the current position of the stepper motor in real-time. This feedback mechanism provides crucial information to the user or external systems, enabling them to monitor the APU's status and make informed decisions regarding communication setup and optimization.

## OBSERVATION

**Table 1:** Antenna Position Data for Azimuth axis

| Desired Position (in Degrees) | Obtained Position (in Degrees) |
|---|---|
| 0 | 0 |
| 10 | 10.05 |
| 20 | 20.06 |

| Desired Position (in Degrees) | Obtained Position (in Degrees) |
|---|---|
| 30 | 29.08 |
| 40 | 40.06 |
| 50 | 50.05 |
| 60 | 60 |
| 70 | 70.04 |
| 80 | 80.07 |
| 90 | 89.95 |
| 100 | 101.06 |
| 110 | 109.92 |
| 120 | 120.06 |
| 130 | 129.05 |
| 140 | 140.08 |
| 150 | 149.94 |
| 160 | 160.06 |
| 170 | 170.07 |
| 180 | 179.98 |

**Table 2.** Antenna Position Data for Elevation axis.

| Desired Position (in Degrees) | Obtained Position (in Degrees) |
|---|---|
| 3 | 3.05 |
| 7 | 7.04 |
| 9 | 8.95 |
| 13 | 13.03 |
| 15 | 14.96 |
| -1 | -1.04 |
| -4 | -4.05 |
| -7 | -7.04 |
| -10 | -10.01 |
| -12 | -11.98 |

## CONCLUSION

Following the successful completion of the “Antenna Positioning Unit for Defence Vehicles” project, significant advancements have been achieved in the realm of defence communication technology. The project has culminated in a fully integrated and thoroughly tested system, showcasing remarkable precision and functionality in antenna positioning.

The meticulously selected hardware components, including stepper motors, planetary gearboxes, stepper motor drives, an ESP32 microcontroller, and a gyroscope sensor, have seamlessly come together to form a robust and reliable system. Through extensive testing, the compatibility and effectiveness of these components have been validated, affirming their capability to deliver precise and dynamic antenna positioning.

Comprehensive testing conducted throughout the project's duration has revealed exceptional levels of precision and accuracy in antenna positioning. The system's ability to maintain strong and reliable communication links has been demonstrated conclusively, promising enhanced operational effectiveness in defence scenarios. Particularly noteworthy is the integration of the gyroscope sensor, which provides real-time compensation for vehicle movement, ensuring continuous and uninterrupted communication.

In conclusion, the successful completion of the "Antenna Positioning Unit for Defence Vehicles" project marks a significant milestone in defence communication technology. With its demonstrated ability to deliver accurate, dynamic, and robust antenna positioning, the project stands poised to revolutionize communication in defence operations. Moving forward, these achievements serve as a solid foundation for further advancements and innovations in the defence technology landscape.

**REFERENCES**

1. Zhou, X., Song, J., & Feng, Z. (2018). "Design and implementation of an antenna positioning system for vehicular communication." In Proceedings of the 2018 IEEE 8th Annual International Conference on CYBER Technology in Automation, Control, and Intelligent Systems (CYBER). DOI: 10.1109/CYBER.2018.8544036.
2. Kaur, G., & Kaur, A. (2019). "A review of antenna positioning systems for satellite communication." In Proceedings of the 2019 IEEE 9th International Advance Computing Conference (IACC). DOI: 10.1109/IACC.2019.8776470.
3. Singh, R., & Yadav, V. (2017). "Stepper motor control using microcontroller ATmega32." In Proceedings of the 2017 2nd International Conference for Convergence in Technology (I2CT). DOI: 10.1109/I2CT.2017.8226157.
4. Bartoli, A., & Stoyanov, D. (2018). "Optimizing stepper motor control." In Proceedings of the 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). DOI: 10.1109/IROS.2018.8593526.
5. Marinković, D., & Milanović, J. (2015). "Gyroscope sensor systems." In Proceedings of the 2015 IEEE 16th International Symposium on Computational Intelligence and Informatics (CINTI). DOI: 10.1109/CINTI.2015.7396343.
6. Hussain, F., Rashid, M. U., & Ikram, M. (2017). "A comprehensive review of MEMS gyroscopes technologies and commercial products." Sensors, 17(2), 497. DOI: 10.3390/s17020497.
7. Espressif Systems. (2021). "ESP32 Datasheet." ESP32 Datasheet (PDF).
8. González, D., & Jiménez, D. (2018). "Comparative analysis of Wi-Fi modules for the Internet of Things: ESP8266/ESP32 and CC3200." In Proceedings of the 2018 23rd IEEE International Conference on Emerging Technologies and Factory Automation (ETFA). DOI: 10.1109/ETFA.2018.8502603
9. Coyle A. Using directional antenna in UAVs to enhance tactical communications. In2018 Military Communications and Information Systems Conference (MilCIS) 2018 Nov 13 (pp. 1-6). IEEE.
10. Giray SM. Anatomy of unmanned aerial vehicle hijacking with signal spoofing. In2013 6th International Conference on Recent Advances in Space Technologies (RAST) 2013 Jun 12 (pp. 795-800). IEEE.
11. Rabinovich V, Alexandrov N. Antenna arrays and automotive applications. Springer Science & Business Media; 2012 Aug 9.
12. Ma'Sum MA, Arrofi MK, Jati G, Arifin F, Kurniawan MN, Mursanto P, Jatmiko W. Simulation of intelligent unmanned aerial vehicle (UAV) for military surveillance. In2013 international conference on advanced computer science and information systems (ICACSIS) 2013 Sep 28 (pp. 161-166). IEEE.