DESIGN OF TRACKING DIRECTIONAL ANTENNA

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بسم الله الرحمن الرحيم
والصلاة والسلام على خير الورى عدَّ
الحصى والرمل والثرى
وعلى آله وأصحابه ومن تبع هداهم
واهتدى
نحمد الله العلي القدير الذي قدَّرنا على
إنهاء هذا المشروع في الوقت المحدد

To our mothers and fathers who supported us through our lives, and to every Muslim in the world, we dedicate this work as a small expression of our gratitude. Without your love, guidance, and encouragement, we could not have achieved what we have today. Your unwavering support has been a constant source of inspiration, and we are forever grateful for all that you have done for us. May this work serve as a testament to the strong bonds of family and faith that have shaped our lives and guided us on our journey.

ABSTRACT

DESIGN OF TRACKING DIRECTIONAL ANTENNA

In this project, we designed a tracking directional antenna system to improve the quality, capacity, and distance of data transmission in communication between a ground station and a moving transmitter. To achieve this, we integrated a GPS antenna tracking system and beamforming system into the antenna system.

The tracking antenna system consists of two types of antennas: a Yagi antenna at the ground station and an Omnidirectional antenna on the transmitter side. These antennas facilitate the connection (receiving and transmitting) between the ground station and the transmitter, which is essential for maintaining reliable communication.

Our tracking antenna system was designed specifically for use in air-to-ground communication systems, such as FPV antenna systems. By using this system, we were able to significantly improve the range and reliability of data transmission in these applications.

One of the key challenges we faced in this project was developing a system that could accurately track and maintain communication with a moving transmitter, while also minimizing interference and signal loss. Through careful design and testing, we were able to overcome these challenges and achieve exceptional performance with our tracking antenna system.

The design and implementation of our tracking antenna system involved a combination of advanced technologies and techniques, including GPS tracking, beamforming, and antenna design. We believe that our innovative approach and technical expertise have resulted in a highly advanced and effective system that will be useful in a variety of applications.

In addition to its technical capabilities, our tracking antenna system also offers several practical benefits for users, including ease of installation, maintenance, and operation. These features make our system a highly attractive and cost-effective solution for a wide range of applications.

Index Terms *– e.g. Tracking antenna systems, Communication systems, Data transmission, GPS tracking, Beamforming, Antenna design, Air-to-ground communication, FPV antenna systems, Signal tracking, Interference reduction, Advanced technologies, Innovative design, Ease of use, Practical benefits*.

ACKNOWLEDGEMENT

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We are proud of what we have accomplished with the help of Dr. Muhammed Bilal and the CEIES team, and we look forward to continuing to work with them in the future.

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CHAPTER – 1 INTRODUCTION

1.1 ABOUT THE PROJECT

As the demand for precise long-range tracking and high data transmission rates grows in industries such as surveillance and delivery services, traditional tracking methods may not be able to meet these needs due to their limitations in cost, power consumption, and accuracy. To address these challenges, it is necessary to investigate and create innovative solutions.

This project aims to create a system that can accurately track a transmitter from a long distance, transmit high data rates such as video, and do so with low power consumption and cost. The transmitter, which can be installed on devices like quadrotors, drones, and robots, requires a clear line of sight and high accuracy for effective long-range tracking. To achieve this, the project will focus on evaluating and improving the cost, accuracy, power consumption, and efficiency of various tracking solutions. The ultimate goal is to design a system that meets the demanding requirements of long-range tracking while minimizing resources. This will involve analyzing the trade-offs between different design options and selecting the most appropriate solution based on project requirements and constraints.

1.2 BACKGROUND

In this section, we will provide background information on the physics and engineering principles involved in the project. We will also include relevant research and statistical data to better define the problem, generate solutions, and choose the best solution. The goal is to present this information clearly and consistently, citing various sources throughout the report.

To begin, we will define what a tracking antenna system is and its purpose. A tracking antenna is a system that tracks a transmitter from a long distance and receives data from that transmitter. The transmitter can be installed on devices such as quadcopters, robots, or other devices. The antenna of the station must be able to track the transmitter automatically and point to the object with high accuracy, so it can maintain the signal without losing it.

Next, we will discuss how the type of antenna used at the tracker station can impact power consumption and cost. There are two main types of antennas: directional and omnidirectional. A directional antenna has a limited angle of radiation according to its distribution pattern, which means it requires a mechanical system to change the direction of the antenna as the transmitter moves. In contrast, an omnidirectional antenna has a wider angle of radiation, but it consumes more power, particularly for long-distance transmission. As seen in Figure 3, the radiation pattern of a directional antenna is focused in one direction, while the radiation pattern of an omnidirectional antenna is distributed in a circular pattern (as shown in Figure 2). By using a directional antenna, it is possible to orient the strength of the signal towards the transmitter directly, which can save power."

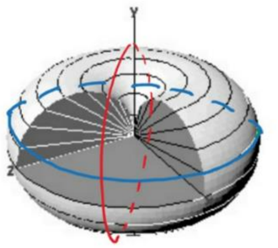


Figure 2: Radiation pattern of the omnidirectional antenna

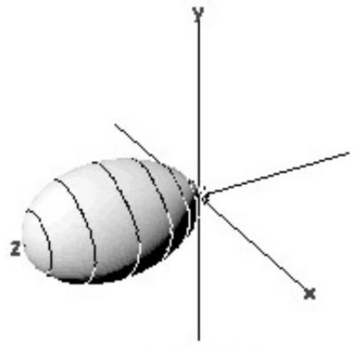


Figure 1: : Radiation pattern of the directional type

CHAPTER – 2 CONCEPTUAL DESIGN

2.1 SITUATION DESCRIPTION

This essay describes the current system for using smart devices that are controlled remotely, as well as wireless communication devices that send and receive data or information related to the application. It also mentions specific requirements for tracking low-speed objects and transmitting video between stations, as well as challenges posed by the need for high efficiency and long-term power, as well as climatic factors such as rain and snow. The essay also discusses the function of the antenna, including how it is used to transmit and receive signals, as well as constraints and limitations on its design. Overall, the essay provides a detailed description of the current system and its components, as well as the goals, inputs/outputs, variables, constants, and parameters of the system and the relevant environment in which it operates.

2.2 DEFINING THE PROBLEM

The main problem we are trying to solve is the ability to track a transmitter from a long distance. The transmitter can be installed on a robot, quadcopter, or any other device, but the main requirement is that there must be a line of sight between the transmitter and the antenna in the ground station. The antenna must be able to automatically track the transmitter and point to it directly with high accuracy and precise movement to maintain a strong signal and avoid losing track of the transmitter. This problem is important because it involves the use of smart devices and wireless communication devices to transmit data or information related to the application, and it requires a high level of efficiency and long-term power to function effectively in various environments, including those with adverse weather conditions.

2.3 PROJECT OBJECTIVES

Now that the main problem has been identified, it is time to gather customer requirements to discuss and define the project objectives and system requirements. The higher-level objectives of the project are to:

1. Increase the lifetime of the battery in the transmitter by improving power efficiency.
2. Establish long-range communication.
3. Allow small quadcopters to fly longer distances.

These higher-level objectives have been set to meet the customer's requirements and goals and address the main problem of power efficiency. In addition to these higher-level objectives, there are also lower-level objectives that need to be met, including:

1. The antenna in the station should be able to track a transmitter.
2. Achieve a range of line of sight for 2 km.
3. Achieve high bandwidth communication (e.g. video) using a low-power transmitter.
4. To assess the performance of the system, it may be helpful to use a present state/desired state analysis to develop specific, measurable objectives that are tailored to meet the customer's needs. This approach can be useful in identifying gaps between the current state of the system and the desired state, and in defining the steps needed to bridge those gaps.

2.4 PRODUCT DESIGN SPECIFICATIONS (PDS)

Our project is tracking antennae it works by tracking or determining the moving signal source in the drone. It's used radio wave signals between the sender and receiver. Also, it's helping to gather needed information faster over long distances.

Table 1: PRODUCT DESIGN SPECIFICATIONS

Musts
• At least a tracking range of 2 km. • Should be able to track the transmitter. • Receiving a video from the transmitter.
Wants
• Use two different antennas to track a different range of frequencies. • Extend the range of tracking to more than 2 km. • Ground station portable. • Using a battery to work a minimum of 2 hours. • Estimate the velocity of the moving mobile transmitter
Assumptions
• Should be able to track a transmitter in the 2.4 GHz or 5.4 GHz frequency range. • Sufficient area to test line-of-sight communication. • Network availability in the station.
Constraints
• The transmitter installed in the quadcopter must fly at or below 400 feet Above ground level (120 m). • The cost must not exceed 3000 SR. • The transmitter installed in the quadcopter must fly at or below 400 feet Above ground level (120 m). • Meeting(SASO IEC 62037-1-2012) Passive RF and microwave devices, intermodulation level measurement - Part 1: General requirements and measuring methods.

Table 2: Project Riks

Risks	Solutions	Probability (High, Mid, Low)	Impact (High, Mid, Low)
The Tracking station lost the signal from the transmitter	Make an algorithm to recapture the signal.	Mid	High
Electromagnetic Interference in the antenna cable	Use a thick coaxial cable for the antenna to reduce the Electromagnetic	Mid	High
Flying Drones could harm people	Avoid using the drone at low ground level	High	High

2.5 LITERATURE REVIEW

In this section, we will review current technologies and past designs related to our project idea, as well as relevant previously implemented work within the university and other institutions worldwide, and any previously used solutions to similar problems in the literature. This section will be heavily cited, mostly from conference papers, with a few references from books, journal papers, and university websites.

For each cited reference, we will include a summary of the relevant information, discuss the common theme or issue with our project topic, and construct theses based on logical inference from the presented summaries and discussions. These theses will provide the main points of what we need to know about relevant solutions to our project problem. It is important to note that we will mention the date of each publication and present the information in chronological order. By reviewing these technologies and past designs, we will gain a deeper understanding of our project and how previous researchers have tackled the problem of tracking antennas and transmitters. This will help us come up with alternative solutions to our problem.

2.5.1 GPS-based Automatic Antenna Management System and Satellite Tracking[3]

Tracking antenna systems have many projects and techniques that can be implemented and used. In this study, we will discuss one type of tracking antenna system: a low-cost antenna system used for satellite communication that is based on GPS and portable in the ground station. The people working on this project sought to find a low-cost and easy solution to the problem of the size and power consumption of tracking devices. They chose to use a small microcontroller, specifically a Raspberry Pi, as the mainboard because it is small and easy to implement with low power consumption, providing a significant advantage over other devices. They also used an Arduino board as a slave and a servo motor to control the movement of the rotator.

The figure below shows a block diagram of the GPS. It provides a brief overview of the project and makes it easy to understand and implement. As shown in the diagram, all the parts are connected to the Raspberry Pi, which solves the problem of size and power consumption by simplifying the design.

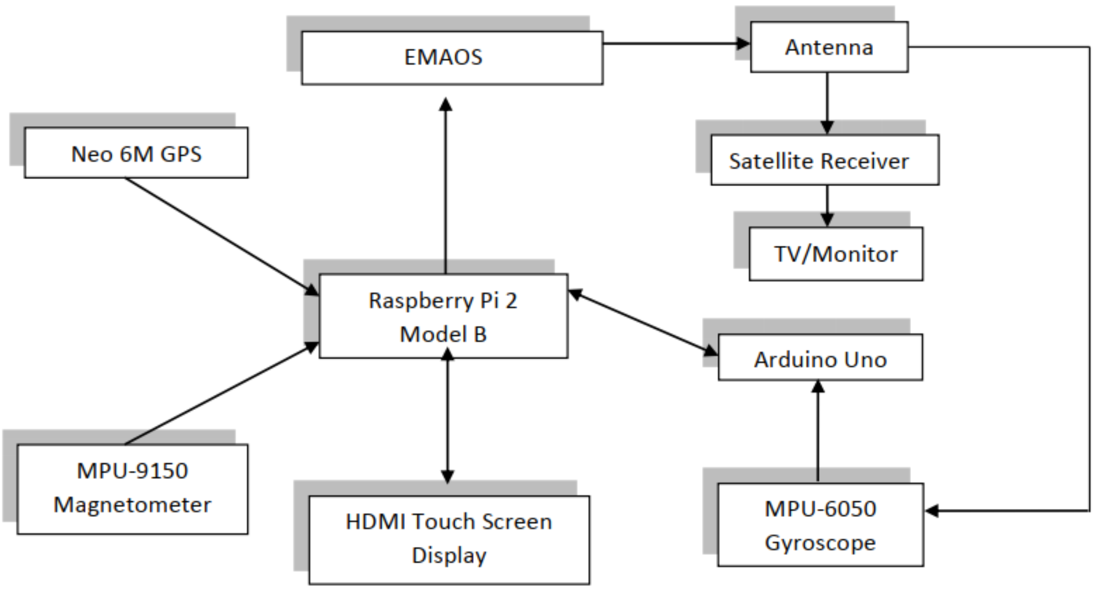


Figure 3: Block Diagram of the GPS System

For the antenna, it was necessary to use a high-range antenna with low power consumption. Therefore, they chose a parabolic antenna reflector, which has a high gain and transforms incoming plane waves in one axis into a focused wave. It is used in the system to receive and transmit the signal.

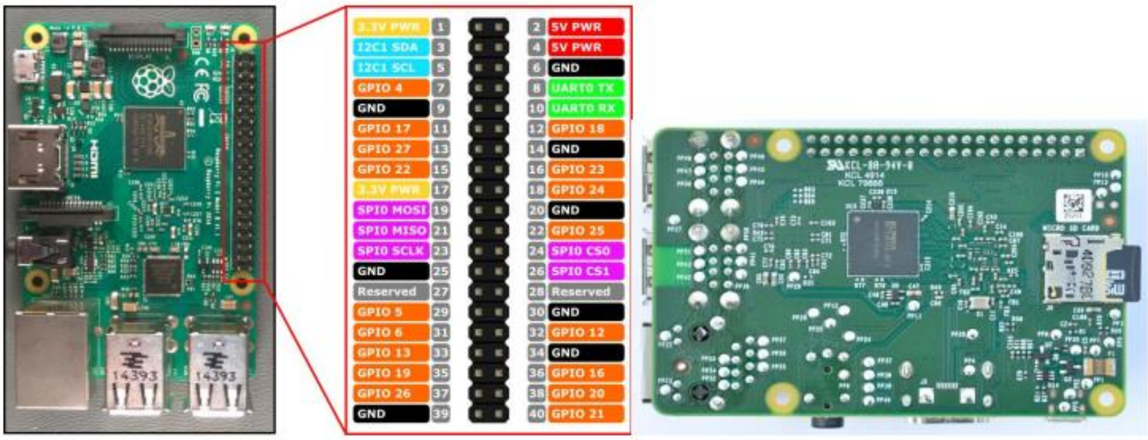


Figure 4: Raspberry Pi 2 Model B Front & Back Side

In summary, the low-cost antenna system described in this study is based on GPS and is portable in the ground station. It uses a small microcontroller and servo motor to control the movement of the rotator, and a parabolic antenna reflector to receive and transmit the signal. It was designed to be low-cost and easy to implement, with a small size and low power consumption."

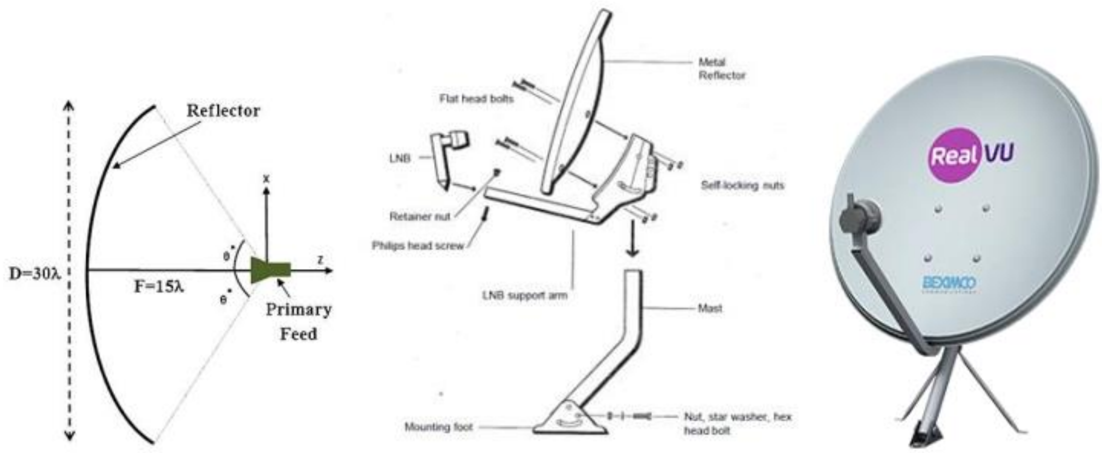


Figure 5: Parabolic Antenna Reflector

2.5.2 ESP32 WiFi Range Testing - 10km using Directional Antenna[4]

In this lecture review, we will see an implementation of long video transmission between transmitter and receiver for a far distance of 10 km, by using Wifi communication.

The parts of the project are an ESP32-S and a Camera module (OV2640) that are plugged into the daughterboard, the power supply of this transmitter is a power bank (5v) for starting a live video and a 2.4GHz parabolic antenna and USB Wifi adapter.

Figure 6: distance between the transmitter and directional antenna

From this process, we expected to establish a video transmitting between these points which is labeled by a blue mark in figure 6, which has a pure line of sight of free no surfaces that may cause interference.

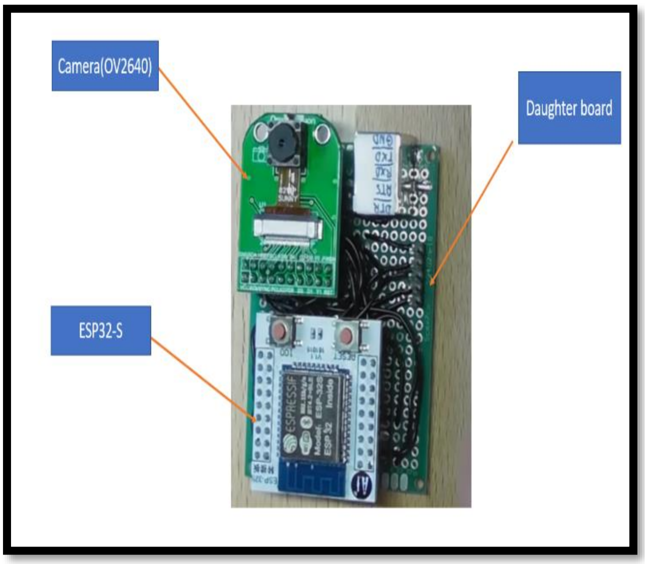


Figure 7: The parts of the transmitter

After uploading the code of WifiAP to work the ESP as an access point by Arduino IDE, and setting up the software of the receiver, the second phase defines the amount of the gain of the antenna and it was done by implying the Friss equation $(P_r=P_tG_tG_r(\frac{\lambda}{4*\pi*R})^2)$

Where Pr, Pt are signals power of the transmitter and receiver and Gt, Gr are respective gains of the antenna of the transmitter and receiver after making the calculations the gain of the antenna tracker is 24 dbi, after that connect the parabolic antenna to the Laptop through USB Wi-Fi adapter, then finally we see in figure 9 the screen of the laptop(receiver) successful transmitting video which the parabolic antenna was pointed directly to the transmitter.

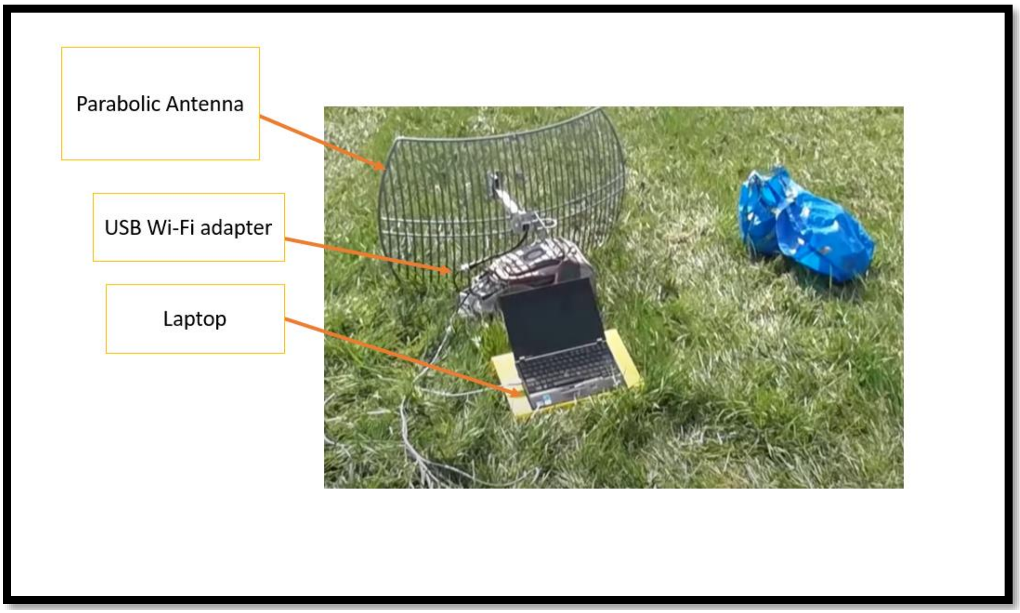


Figure 8: The station of the receiver

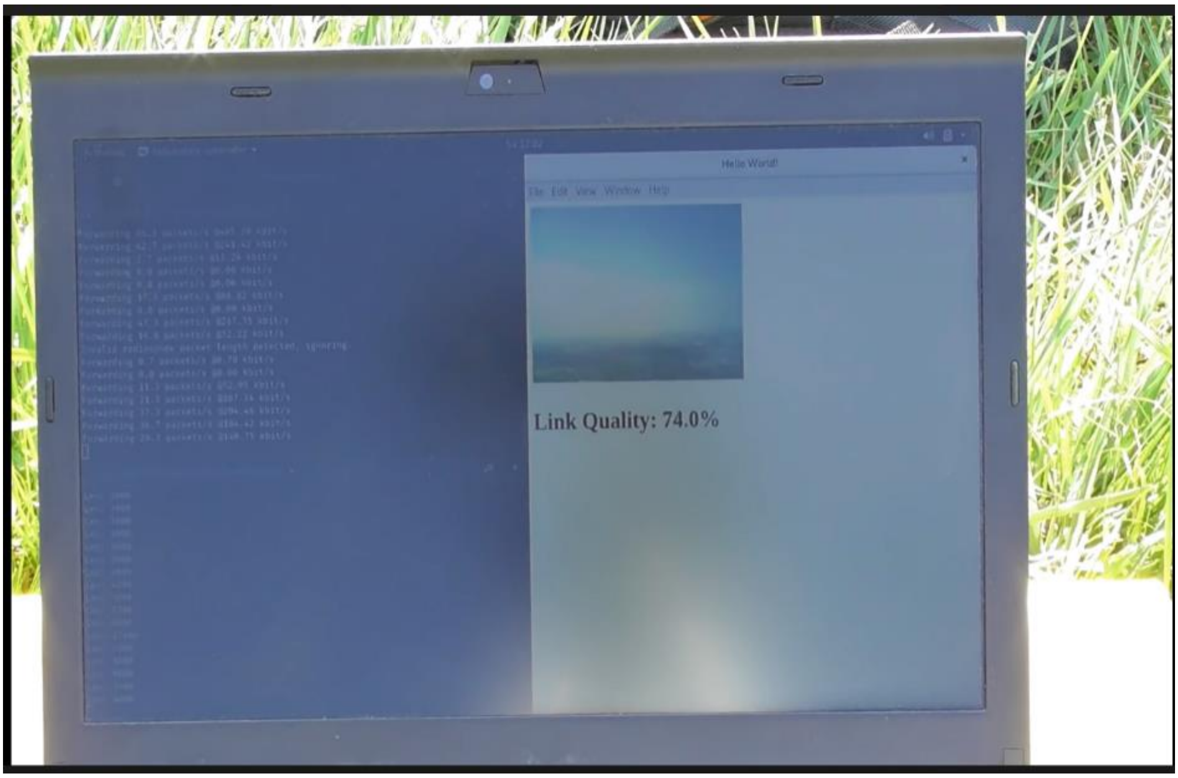


Figure 9: Successful video transmitting(screen of the user)

2.5.3 Arkbird AAT Auto[5]

It is one of the types of tracking antenna that is similar to our project which is designed to send and receive data at long distances. This antenna is important for FPV (Long Distance Video) operation by tracking the drone (transmitter) in all directions. A problem with our startup is that this antenna allows you to increase your range without having to point your antenna. This antenna works as an airborne tracker drone that embeds the GPS coordinate information into the transmitted FPV video signal and then the station receives and decodes it. The antenna uses an ATT system, which can be easily set up and requires a GPS. Before calibrating the tracking antenna, it must be pointed at your drone. This antenna is provided with integrated suction cups and then you can choose how and where to install the tracking antenna during use.

Figure 10: Arkbird AAT

1. **Universal way of connection: welding a parallel line from the GPS serial port:**

The GPS cable is connected to the GPS input to help determine refresh rates.

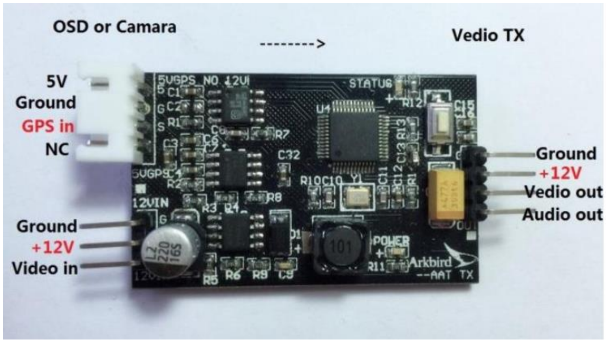


Figure 11: GPS serial port

2. **TX port wiring with Arkbird OSD:**

Connect the video to my Vout input, and another wire to the TX input which will help locate the signal.

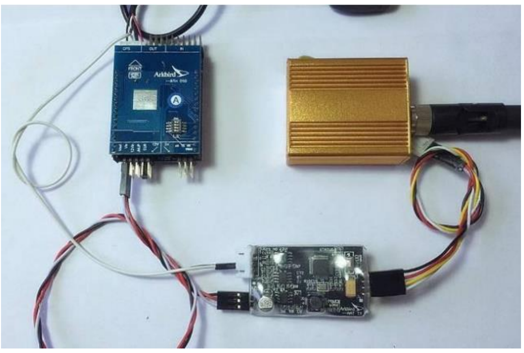


Figure 12: TX port

3. **Independent GPS module connection:**

Connecting the GND to the signal unit on the drone that contains a 5V power source for GPS.

4. **Power on after wiring check. Observe the STATUS LED in the upper right corner:**

Here the LED light must be on continuously. If the video signal is the only one specified; The LED flashes quickly (10 Hz) if the video signal and the GPS signal are correctly identified.

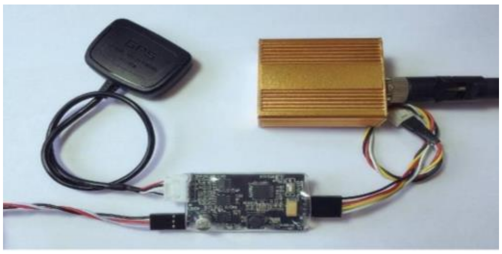


Figure 13: Wiring check

2.6 ANALYZING ALTERNATIVE SOLUTIONS

Now that we have identified our problem definition and higher and lower-level objectives, it is time to decide on a solution. To do this, we will generate at least three specific electrical engineering designs and evaluate them to choose our design baseline. We will use the Morphological Chart method to generate these alternative designs.

For each design, we will sketch and explain the general block diagram for the proposed system, including a description of the components needed and an overview of how the system would work. We will also explain how the system would satisfy the in-scope items specified in the project charter and whether it may or may not satisfy the out-of-scope items.

After describing each alternative design individually, we will create a table listing the pros and cons of each solution. We will then choose one of the designs and justify our decision based on the in-scope and out-of-scope specifications mentioned in the Product Definition Specification of section 2.4. By the end of this section, it should be clear which design we have decided to go with.

Table 3: Morphological Chart method of the project

Sub Function	Solutions		
Antenna	Directional Antenna		
Transmitter	Router	Raspberry Pi	ESP32
Signal Type	Wi-Fi		
Tracking Object	Robot	Quadcopter	
Communication protocol	UDP	TCP/IP	HTTP
Tracking Algorithm	GPS& RSSI	Step Algorithm	
Motor	Servo	Stepper	
Control-Unit	ESP32	Arduino	
Driver	L298N Dual H	L293D	

Now that we have identified the means functions of our project, it is time to generate the three alternative designs that meet the project specifications. The focus of these designs will be the communication protocol and type of antenna for the tracking antenna, followed by the type of motor used to direct and move the antenna to track the transmitter. The control unit and motor driver will also be considered in the design process. These components will be used to determine the three alternative designs.

2.6.1 Alternative #1

Table 4: Alternative #1

Sub Function	Solutions
Antenna	Directional Antenna
Transmitter	Raspberry Pi
Signal Type	Wi-Fi
Tracking Object	Quadqutor
Communication protocol	UDP
Tracking Algorithm	Step Algorithm
Motor	Stepper
Control-Unit	Arduino
Driver	L293D

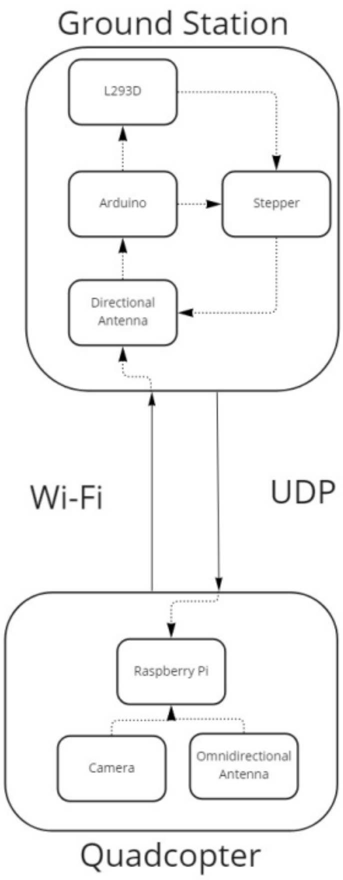


Figure 14: Alternative #1 Diagram

Alternative #1 Description

As shown in the Figure above, the system will receive the Wi-Fi signal using a directional antenna on the ground station. On the quadcopter, we will install a Raspberry Pi and connect an omnidirectional antenna to transmit the signal from the Raspberry Pi, as it does not have an internal antenna. We will also connect an external camera to capture video, which will be transmitted through a UDP protocol as it is fast for video transmission. When the directional antenna on the ground station receives the Wi-Fi signal, the mechanical part will start to react based on the signal strength using a step algorithm to track the transmitter.

2.6.2 Alternative #2

Table 5: Alternative #2

Sub Function	Solutions
Antenna	Directional Antenna
Transmitter	ESP32
Signal Type	Wi-Fi
Tracking Object	Quadrotor
Communication protocol	TCP/IP& HTTP
Tracking Algorithm	GPS& RSSI
Motor	Stepper
Control-Unit	Arduino
Driver	L298N Dual H

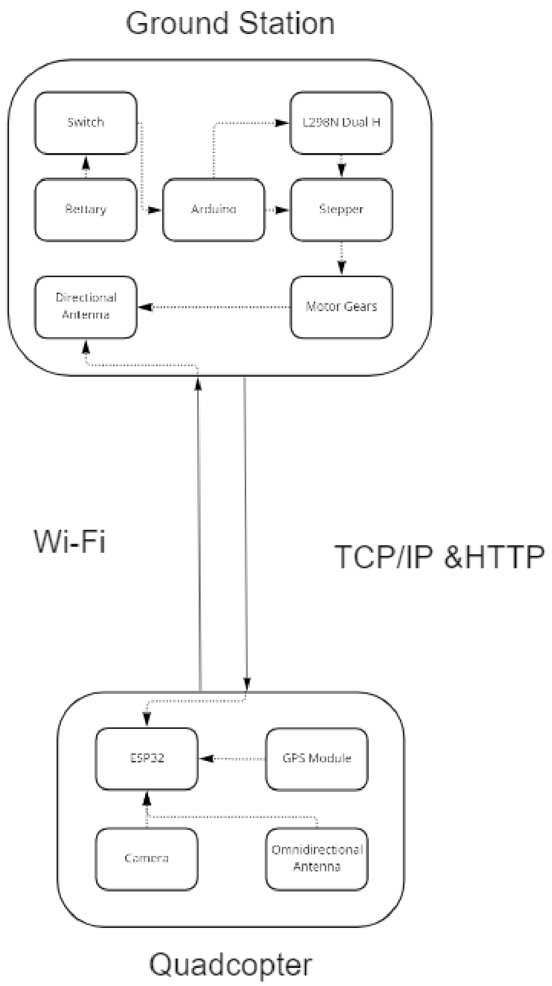


Figure 15: Alternative #2 Diagram

Alternative #2 Description:

Based on the block diagram in the figure 17, the system will use ESP32 microcontroller for the transmitting video by establishing a WIFI access point which using TCP/IP communication protocol, which is has many benefits for the security and more reliable for connection between source and destination node (client and webserver) ,and using HTTP for web page, the ESP32 will connected with omnidirectional antenna for extend the range of the transmitter ,the antenna of the tracker station will use an directional type, this type that has a very narrow beam of electromagnetic waves by it is possible to point in any direction, which is good for tracking the transmitter \with low power consumption , then the ground station will receive the data via the antenna then send it to the Arduino, the Arduino will setup the moving direction of the motors according to the GPS tracking algorithm by connect a NEO6M GPS module with ESP32 , If the signal of the ESP32 is available , if it not available will track according to the (RSSI) Received Signal Strength Indicator once detect the transmitter will it back again to then GPS algorithm , we will use two stepper motors one for by vertical direction, another one for horizontal, both motors will use L298N Dual H drivers which is cheap and powerful enough to drive motors.[12]

2.6.3 Alternative #3

Table 6: Alternative #3

Function	Means	
Antenna	Directional Antenna	
Transmitter	Router	
Signal Type	Wi-Fi	
Tracking Object	Robot	
Communication protocol	TCP/IP	HTTP
Tracking Algorithm	GPS& RSSI	
Motor	Servo	
Control-Unit	Arduino	
Driver	L298N Dual H	

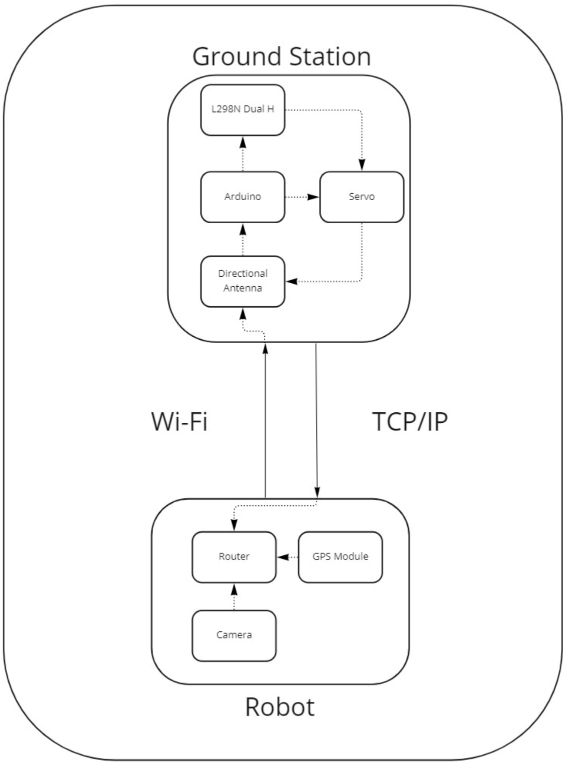


Figure 16: Alternative #3 Diagram

Alternative #3 Description:

As shown in the block diagram and based on it, it shows that we used this type of directional antenna to receive data. This directional antenna relies on the Wi-Fi wireless network protocols to receive mainly data. directional antenna depends on long-range distances, and it receives signals in one line direction where it reaches a radius of 45 to 90 degrees. With a long-range transmitter, Wi-Fi technology will provide wireless communication to transmit information from the robot to the antenna. On the other hand, when it comes to long-range tracking the power consumption is very high, but it will give accurate results for tracking the transmitter. A router can transmit a signal within a limited range, and this depends on the type of device used, and these routers can send your Wi-Fi signals to distant ranges of about 2500 feet. TCP/IP and HTTP are more secure and reliable, and they are the link between the transmitter and the receiver. Using RSSI helps bring the signal closer when losing connection or if it's in the opposite direction of a robot. GPS is used when finding the robot. For the Servo motor, it’s not the best choice but it’s very cheap and has very low power consumption with precise movement and rotation overall the design.

2.6.4 Alternatives Evaluation

After generating and discussing the three alternatives, it is time to evaluate and compare them. We will list the pros and cons of each design and give them a score out of 10. The design with the highest total score will be our baseline design. We will use this evaluation method to choose the best design for our tracking antenna system.

Table 7: Alternatives Evaluation

Alternative	Pros	Cons
1st Alternative	Supports all types of Codes	Overheating
	Faster Processor	Complex to deal with
	Fast video trasnmmting	unreliable connection protocol
		High cost
2nd Alternative	Low cost	Weak Security
	Reliable connection protocol	Complex Algorithm for Tracking
	Low power consumption	
	Team familiarity	
3rd Alternative	High-quality video transmitting	High power consumption
		Low accuracy
		heavyweight

Table 8: Alternatives Evaluation

Factors	1st Alternative	2nd Alternative	3rd Alternative
Cost	7	10	4
Accuracy	8	9	7
Flexibility	5	8	6
Safety	8	8	8
Easy to develop	4	7	5
Troubleshooting	6	8	5
Data rate	7	5	8
Portable	7	8	5
Power consumption	7	9	4
Tracking range	8	8	8
Total (out of 100)	67	80	60

2.6.5 Alternatives Evaluation Description

Before deciding on the best alternative, we will briefly explain how the two tables - one listing the pros and cons of each design and the other evaluating each design using a set of metrics - have influenced our selection. Based on Table 8, the pros of the first alternative include support for all types of codes and a faster processor (due to the use of the Raspberry Pi), and fast video transmission (due to the use of the UDP protocol). However, the cons include complexity, unreliable connections, and high cost. The second alternative is characterized by low cost, reliable connections (due to the use of the TCP/IP protocol), and low power consumption. However, the cons include a complex algorithm (due to the use of both RSSI and GPS) and weak security (due to the use of the HTTP protocol). The third alternative has the advantage of high-quality video transmission (due to the use of a router), but the cons include high power consumption (due to the use of a router and octocopter), low accuracy (due to the use of a servo motor), and heavyweight. The pros and cons table was based on estimates and information from the lecture review section and searches. The metric table scores each factor out of 10, with a total out of 100 (ten factors). These scores are based on the specifications of the project and other factors to help us evaluate the alternatives with the best accuracy.

2.6.6 Choosing Best Alternative

After considering the pros and cons and evaluating the factors of all the alternatives, we have decided to choose the second alternative for this project. This decision is based on the features and scores of the second alternative, which has the lowest cost (due to the use of the ESP32 cam), a reliable connection protocol, and lower power consumption compared to the other alternatives. Although it has a complex design and weak security (due to the use of the HTTP protocol), it still satisfies the musts and wants of the project. Specifically, it can track a range of 2 km, track and receive video from the drone, and has a portable design for the ground station.

2.7 MATURING BASELINE DESIGN

In developing our baseline design, we started by deciding on the specific components that we wanted to use in our system, including stepper motors, an Arduino UNO microcontroller, motor drivers, and programming languages such as C and C++. We also considered the interface between different blocks and the circuit design that would be required to connect these components. As we delved deeper into these details, we found that our initial design needed to be adjusted to meet our specifications and requirements.

To make our design more mature, we gathered and analyzed a variety of information, including the specifications of the components we were using, the details of the interface between different blocks, and the requirements of the circuit design. This process involved extensive research and testing to ensure that our design was effective and efficient.

Ultimately, our final design consists of a ground station with a directional antenna and stepper motors, as well as a transmitter with an omnidirectional antenna. The ground station uses an Arduino microcontroller and motor drivers to control the stepper motors, which rotate the directional antenna to track the transmitter. The transmitter, which is an ESP32 Cam, uses an omnidirectional antenna to transmit a 2.4 GHz WiFi signal in all directions. The ground station receives this signal with its directional antenna and converts it to an electrical signal, which is then processed by the microcontroller and used to control the stepper motors to track the transmitter. Overall, this system is designed to allow for accurate and efficient tracking of the transmitter from the ground station.

CHAPTER – 3 PRODUCT BASELINE DESIGN

3.1 BLOCK DIAGRAM

The Raspberry Pi 4 is a small, single-board computer that serves as the main server for the ground control station. It is connected to the Arduino Mega, which is a microcontroller that can be programmed to perform a variety of tasks. In this case, the Arduino Mega is connected to two stepper motors, which are used to adjust the vertical and horizontal angles of the tracking station. The stepper motors are driven by L298N dual H-bridge motor drivers, which allow for precise control of the motors and help to protect them from damage.

The Yagi antenna is a directional antenna that is used to receive signals from the transmitter. It is connected to the Raspberry Pi 4, which processes the signals and displays the relevant information on the LCD. The Raspberry Pi 4 is powered by a 12V battery, which is connected directly to the motor drivers using a DC-DC converter to drop the voltage to a level that is safe for the Raspberry Pi 4 to use.

On the transmitter side, the ESP8266 is a low-cost, low-power microcontroller that is connected to the ESP32 CAM via UDP. The ESP8266 is used to send altitude data from a BME280 sensor to the Raspberry Pi in the ground station. The BME280 sensor is a small, low-power device that measures temperature, humidity, and pressure, and can be used to calculate altitude. The mobile phone is used to send GPS data to the ground station, which allows the location of the transmitter to be tracked. The ESP8266 and mobile phone are powered by a 9V battery, which is dropped to a safe voltage level using a DC-DC converter.

Overall, this block diagram illustrates a system for tracking and communicating with a transmitter using a ground control station. The Raspberry Pi 4, Arduino Mega, Yagi antenna, and other components work together to receive and process signals from the transmitter, allowing the operator to track the location of the transmitter and adjust the tracking station as needed. The ESP8266, ESP32 CAM, BME280 sensor, and mobile phone on the transmitter side provide the necessary data for the ground station to function.

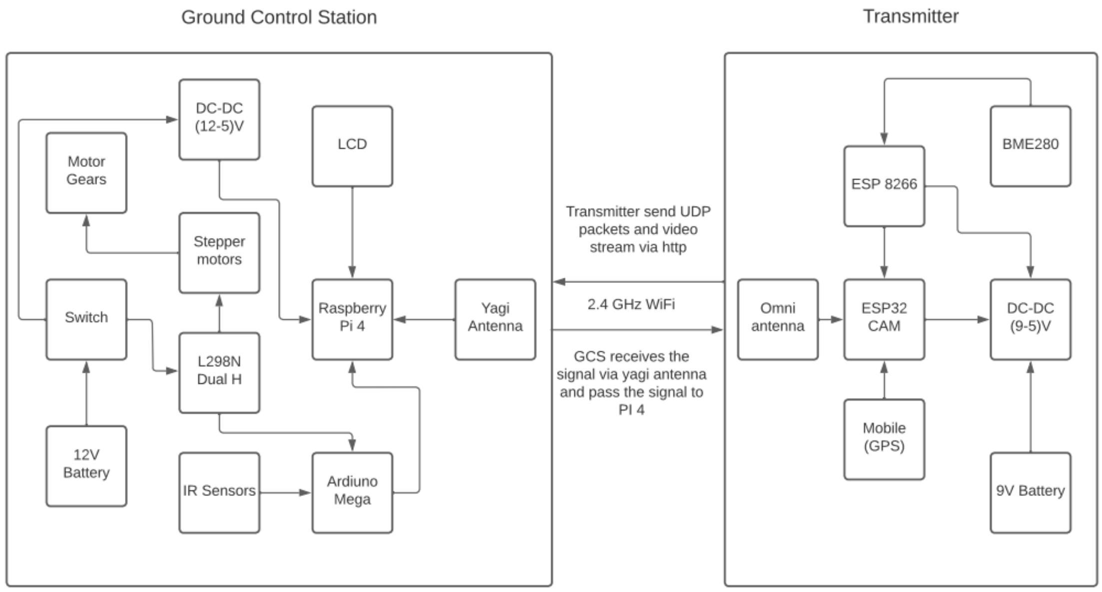


Figure 17: Block Diagram

3.2 SYSTEM DESCRIPTION

This section will provide a detailed explanation of the various components and processes involved in our project. We will start by discussing the circuit schematic diagram, which shows the connections and interactions between different electrical components. Next, we will delve into the specifications of each circuit component, including the transmitter, the receiving station with its antenna and receiver, and the mechanical system.

The receiving station uses an antenna to receive signals from the transmitter via WiFi communication. The Arduino then processes this information and directs the movement of the stepper motors accordingly. It is important to follow certain protocols and standards to ensure the smooth functioning of each part of the system.

In addition to the above, we will also cover the flow charts that outline the steps involved in various processes, as well as the mechanical specifications of the station. This will provide a comprehensive understanding of the project and its components.

3.2.1 Circuit schematics

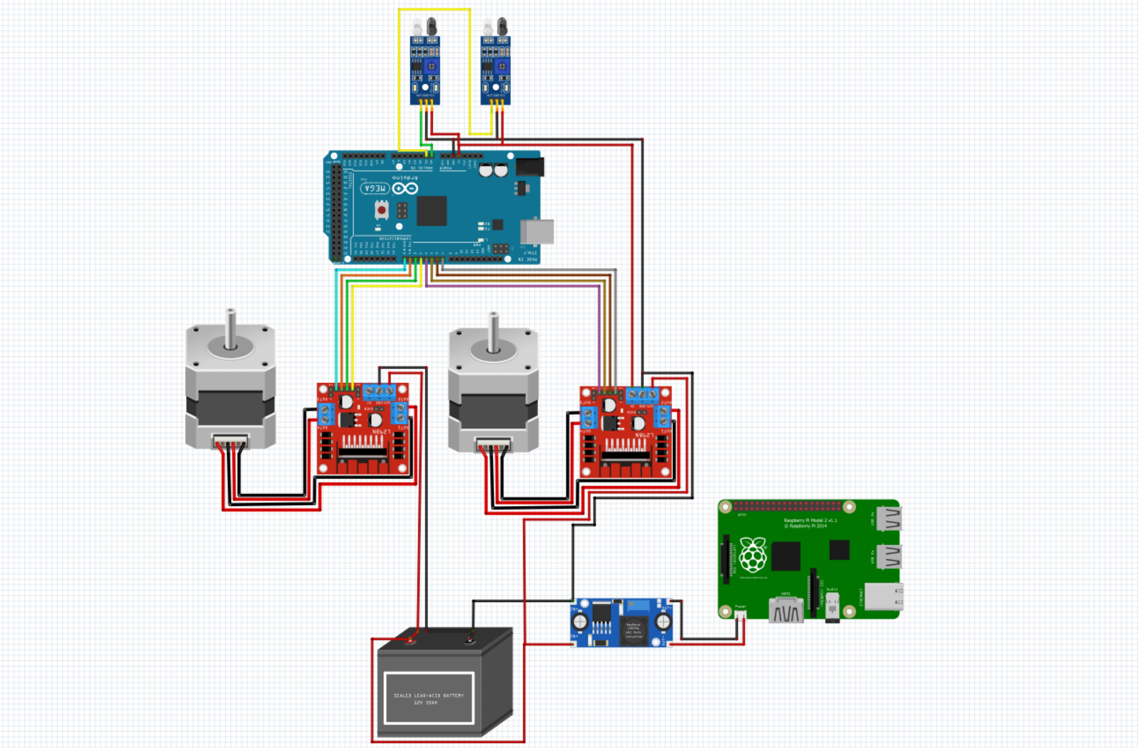


Figure 18: Circuit schematics of the Ground Control Station

The 12 V input from the battery is used to power the two motor drivers. One of the drivers converts the voltage to 5 V and passes it on to the Mega Arduino. The other driver is connected to a DC-DC converter, which converts the 12 V input from the battery to 5 V and passes it on to the Raspberry Pi. The Raspberry Pi and Arduino communicate with each other through a serial connection, allowing the Raspberry Pi to transmit values to the Arduino.

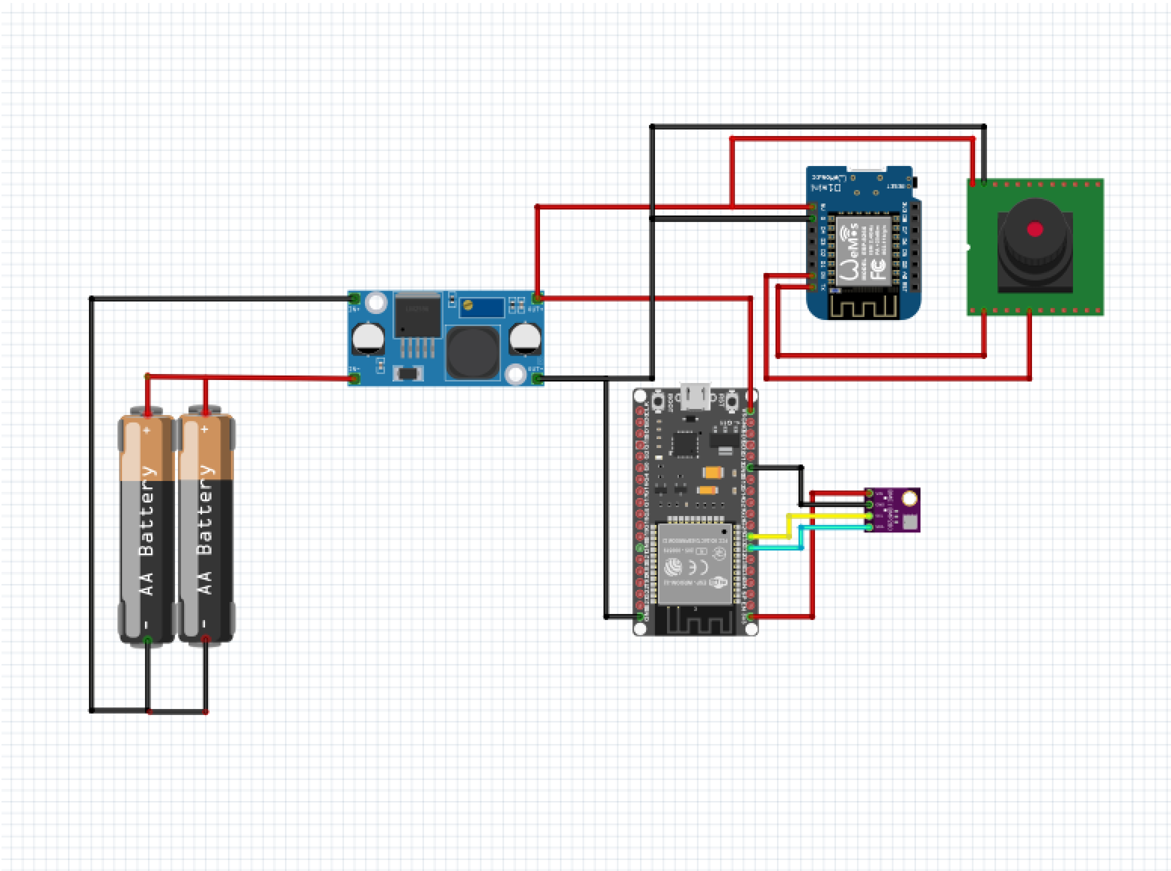


Figure 19: Transmitter circuit

This advanced circuit utilizes an ESP32-CAM and an ESP8266 microcontroller to transmit real-time video and sensor data to a ground station. The video is captured by the ESP32-CAM and processed by the ESP8266, which is responsible for establishing a wireless connection and transmitting the video to the ground station. The circuit also includes a BME280 sensor, which measures and records the altitude level in real-time. This information is critical for the ground station to track the position and movement of the circuit, especially in challenging environments such as high altitudes or remote locations. To power the circuit, a 9-volt battery is used and regulated down to a safe and stable 5 volts for the electronics using a DC-DC converter. Overall, this circuit is an essential tool for gathering and transmitting valuable data and video from remote locations to a central monitoring station.

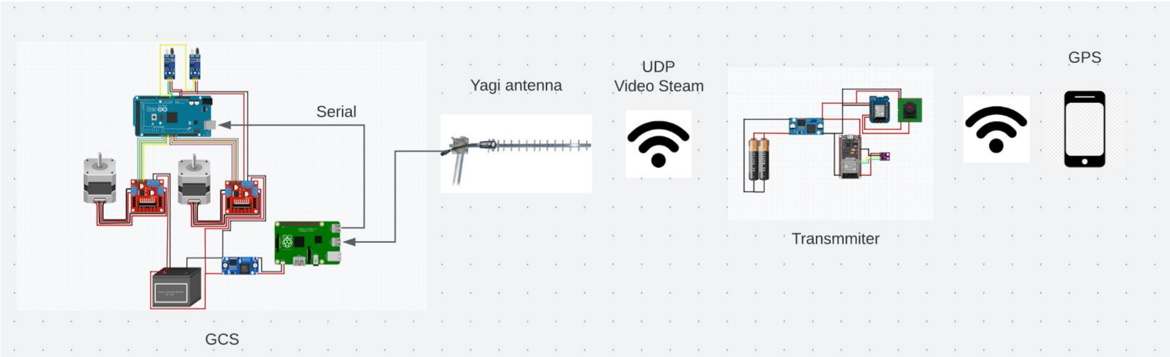


Figure 20: The circuit for the overall system

3.2.2 Circuit component specifications

1- ESP32-CAM

Figure 21: ESP32-CAM

Table 9: ESP32-CAM Specifications[

Module Model	ESP32-CAM
Size	27*40.5*4.5 mm
SPI Flash	Default 32Mbit
RAM	520KB SRAM +4M PURAM
Bluetooth	Bluetooth 4.2 BR/EDR and BLE standards
Wi-Fi	802.11 b/g/n/

Support interface	UART/SPI/I2C/PWM
Support TF card	Maximum support 4G
IO port	9
UART Baudrate	Default 115200 bps
Image Output Format	JPEG(OV2640 support only), BMP, GRAYSCALE
Spectrum Range	2412 ~2484MHz
Antenna	Onboard PCB antenna, gain 2dBi
Transmit Power	802.11b: 17±2 dBm (@11Mbps) 802.11g: 14±2 dBm (@54Mbps) 802.11n: 13±2 dBm (@MCS7)
Receiving Sensitivity	CCK, 1 Mbps: -90dBm CCK, 11 Mbps: -85dBm 6 Mbps (1/2 BPSK): -88dBm 54 Mbps (3/4 64-QAM): -70dBm MCS7 (65 Mbps, 72.2 Mbps): -67dBm
Power Dissipation	Deep-sleep: 6mA@5V Modern-sleep: 20mA@5V Light-sleep: 6.7mA@5V
Security	WPA/WPA2/WPA2-Enterprise/WPS
Power Supply Range	5V
Operating Temperature	-20 °C ~ 85 °C
Storage Environment	-40 °C ~ 90 °C, < 90%RH
Weight	10g
Cost (SR)	19

Pin layout for ESP32-CAM

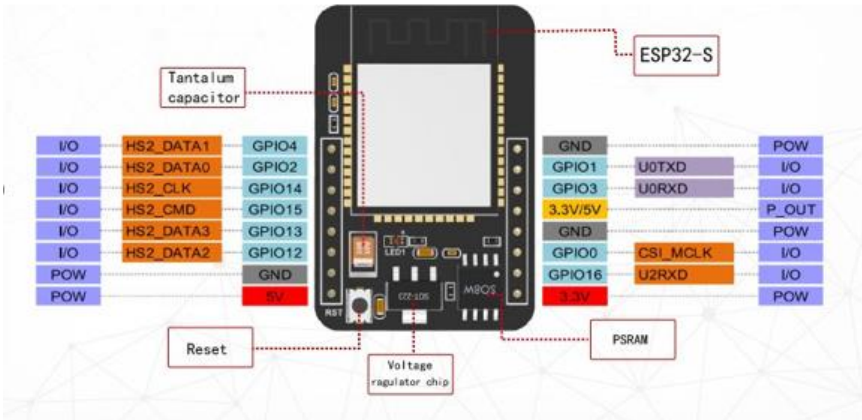


Figure 22: ESP32-CAM Pin Layout

2- L298N Motor Driver

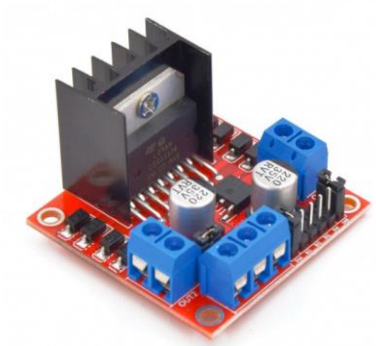


Figure 23: L298N Motor Driver

Table 10: L298N Features & Specifications[14]

Module Model	L298N 2A
Driver Chip	Double H Bridge L298N
Motor Supply Voltage	(Maximum): 46V
Motor Supply Current	(Maximum): 2A
Logic Voltage: 5V	5V
Driver Voltage	5-35V
Driver Current	2A
Logical Current	0-36mA
Maximum Power (W)	25W

Spectrum Range	2412 ~2484MHz
Cost	33 SR
Current Sense for each motor	
Heatsink for better performance	
Power-On LED indicator	

L298N Motor Driver in depth

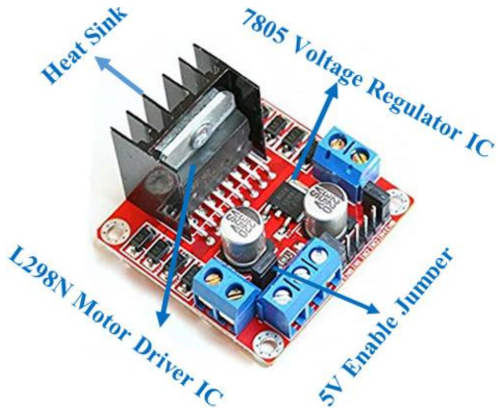


Figure 24: L298N Motor Driver Layout components

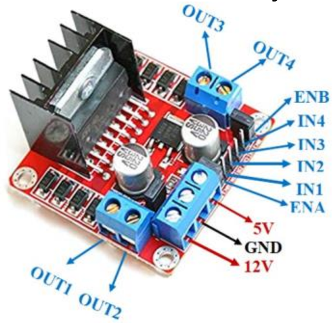


Figure 25: L298N Motor Driver Pins Layout

Table 11: L298N Pinout Functions[14]

Pin Name	Description
IN1 & IN2	Motor A input pins. Used to control the spinning direction of Motor A
IN3 & IN4	Motor B input pins. Used to control the spinning direction of Motor B
ENA	Enables PWM signal for Motor A
END	Enables PWM signal for Motor B
OUT1 & OUT2	Output pins of Motor A

OUT3 & OUT4	Output pins of Motor B
12V	12V input from a DC power source
5V	Supplies power for the switching logic circuitry inside L298N IC
GND	Ground pin

3- Nema-17 Stepper motor

Figure 26: Nema-17 Stepper motor

Table 12: Nema 17 Stepper motor Specifications[15]

Rated Voltage	**12V DC**
Current	1.2A at 4V
Step Angle	1.8 deg
No. of Phases	4
Motor Length	1.54 inches
Cost	50 SR
4-wire, 8-inch lead	
200 steps per revolution, 1.8 degrees	
Operating Temperature: -10 to 40 °C	
Unipolar Holding Torque: 22.2 oz-in	

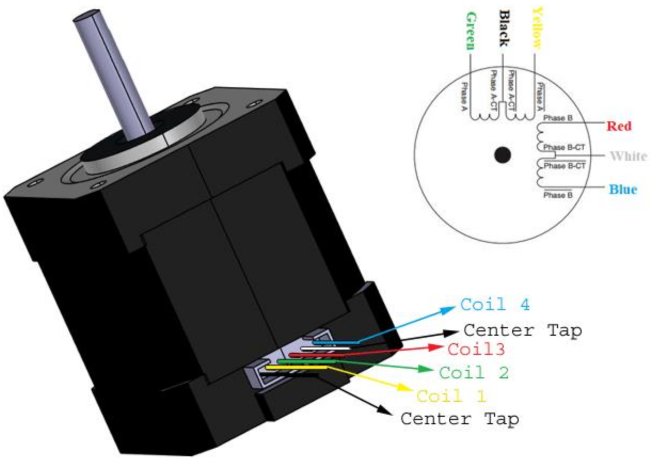


Figure 27: Nema-17 Stepper motor wires layout

4- Arduino Uno

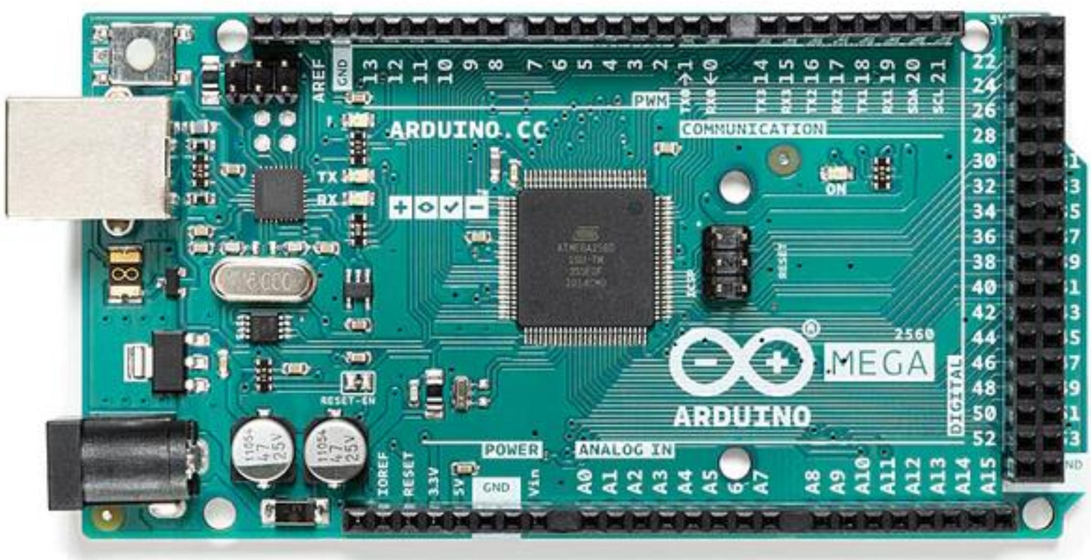


Figure 28: Arduino Mega

Table 13: Arduino Mega Specifications[16]

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM

	output)
PWM Digital I/O Pins	6
Analog Input Pins	6
Analog Input Pins	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P)
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	37 g
Cost	60 SR

5-Yagi Antenna

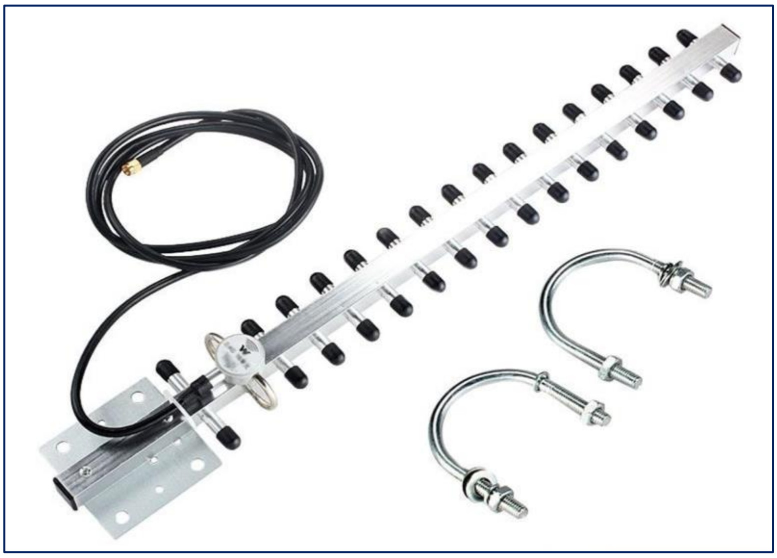


Figure 29: Yagi Antenna

2.4Ghz WiFi Antenna 25dBi RP SMA Outdoor Wireless Yagi Antenna Directional Booster Amplifier Modem Cable For Router	
Model	SKU715205
Material	Aluminium Alloy
Cable Length	150cm/59.06''(appr.)
Size	(L)X(W)X(H) 49.5X6.8X1.6cm/19.49''X2.68''X0.63''(appr.)
Frequency	2400 - 2500MHz
VSWR	1.8:1 max
Polarization Type	Linear Vertical
Voltage	5V
Maximum Power	50W
Input Impedance	50 Ohms
Bandwidth-MHz	100
Gain	25 dBi
Vertical lobe width	23°
Connector Type	RP-SMA
Attention	RP-SMA Male Connector (No pin inside). This item support 2.4 GHz frequency only (Wifi/WLAN/WiMax).
Cost(SR)	63

Table 14: Yagi Antenna[10]

6- Omnidirectional Antenna

Figure 30: Omnidirectional antenna

Table 15: Omnidirectional antenna Description[19]

2.4GHz 3dBi WiFi 2.4g Antenna Aerial RP-SMA Male wireless router+ 17cm PCI U.FL IPX to RP SMA Male Pigtail Cable ESP32	
Model	RP-SMA to Ufl./Ipx cable
Material	Aluminium Alloy
Length	11 cm

Cable Length	17cm
Frequency	2.4GHz
Voltage	5V
Gain	3 dBi
Attention	RP-SMA Male Connector (No pin inside). This item support 2.4 GHz frequency only (Wifi/WLAN/WiMax).

7- NodeMCU ESP8266

Figure 31: NodeMCU ESP8266

Table 16: NodeMCU Technical Specifications

Microcontroller	ESP-8266 32-bit
NodeMCU Model	Amica
NodeMCU Size	49mm x 26mm
Clock Speed	80 MHz
USB to Serial	CP2102
USB Connector	Micro USB
Operating Voltage	3.3V
Input Voltage	5V
Flash Memory/SRAM	4 MB / 64 KB
Digital I/O Pins	11
Analog In Pins	1
ADC Range	0-3.3V
UART/SPI/I2C	1 / 1 / 1
WiFi Built-In	802.11 b/g/n
Temperature Range	-40C - 125C
Cost(SR)	42

8- Raspberry Pi 4 Computer Model B

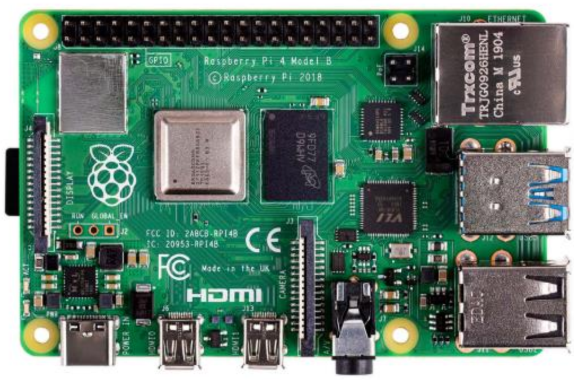


Figure 32: Raspberry Pi 4 Model B

Table 17: Raspberry Pi 4 Model Specifications

Processor	Broadcom BCM2711, quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
Memory	1GB, 2GB or 4GB LPDDR4 (depending on the model)
Connectivity	2.4 GHz and 5.0 GHz IEEE 802.11b/g/n/ac wireless LAN, Bluetooth 5.0, BLE Gigabit Ethernet 2 × USB 3.0 ports 2 × USB 2.0 ports.
GPIO	Standard 40-pin GPIO header (fully backward-compatible with previous boards)
Video & sound	2 × micro HDMI ports (up to 4Kp60 supported) 2-lane MIPI DSI display port 2-lane MIPI CSI camera port 4-pole stereo audio and composite video port
Multimedia	H.265 (4Kp60 decode); H.264 (1080p60 decode, 1080p30 encode); OpenGL ES, 3.0 graphics
SD card support	Micro SD card slot for loading the operating system and data storage
Input power	5V DC via USB-C connector (minimum 3A1) 5V DC via GPIO header (minimum 3A1) Power over Ethernet (PoE)–enabled (requires separate PoE HAT)
Cost(SR)	685

9- DC-DC buck converter step-down module LM2596

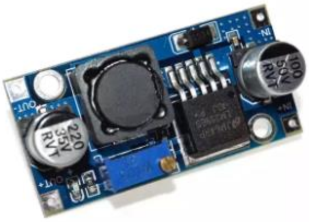


Figure 33: DC-DC buck converter

Table 18: DC-DC buck converter

Input Voltage	DC 3V to 40V
Output Voltage	1.25V to 35V
Output Current	3A
GPIO	Standard 40-pin GPIO header (fully backward-compatible with previous boards)
Material	PCB + electronic components
Weight	14 g
Color	Blue
Dimensions	45 (L) * 20 (W) * 14 (H) MM
Cost(SR)	19

10- BME280

Figure 34: BME280 Sensor

Table 19: BME280 Sensor Specifications

Operation range	Pressure: 300…1100 hPa Temperature: -40…85°C
Interface	I2C and SPI
Average current consumption	3A
Average current consumption in sleep mode	0.1 µA

Pressure sensor	RMS Noise: 0.2 Pa (Equiv. to 1.7 cm) Sensitivity Error: ± 0.25 % (Equiv. to 1 m at 400 m height change) Temperature coefficient offset: ±1.5 Pa/K (Equiv. to ±12.6 cm at 1°C temperature change)
Cost(SR)	27.5

11- WKA12-8F2 WERKER BATTERY

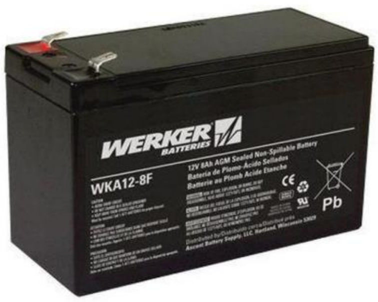


Figure 35: WKA12-8F2 WERKER BATTERY

Table 20 : WKA12-8F2 WERKER BATTERY Specifications

Nominal Voltage	12V
Rated Capacity - 20hr	8 Ah
Weight	2.54kgs
Cost(SR)	100

3.2.3 Flowcharts for software blocks

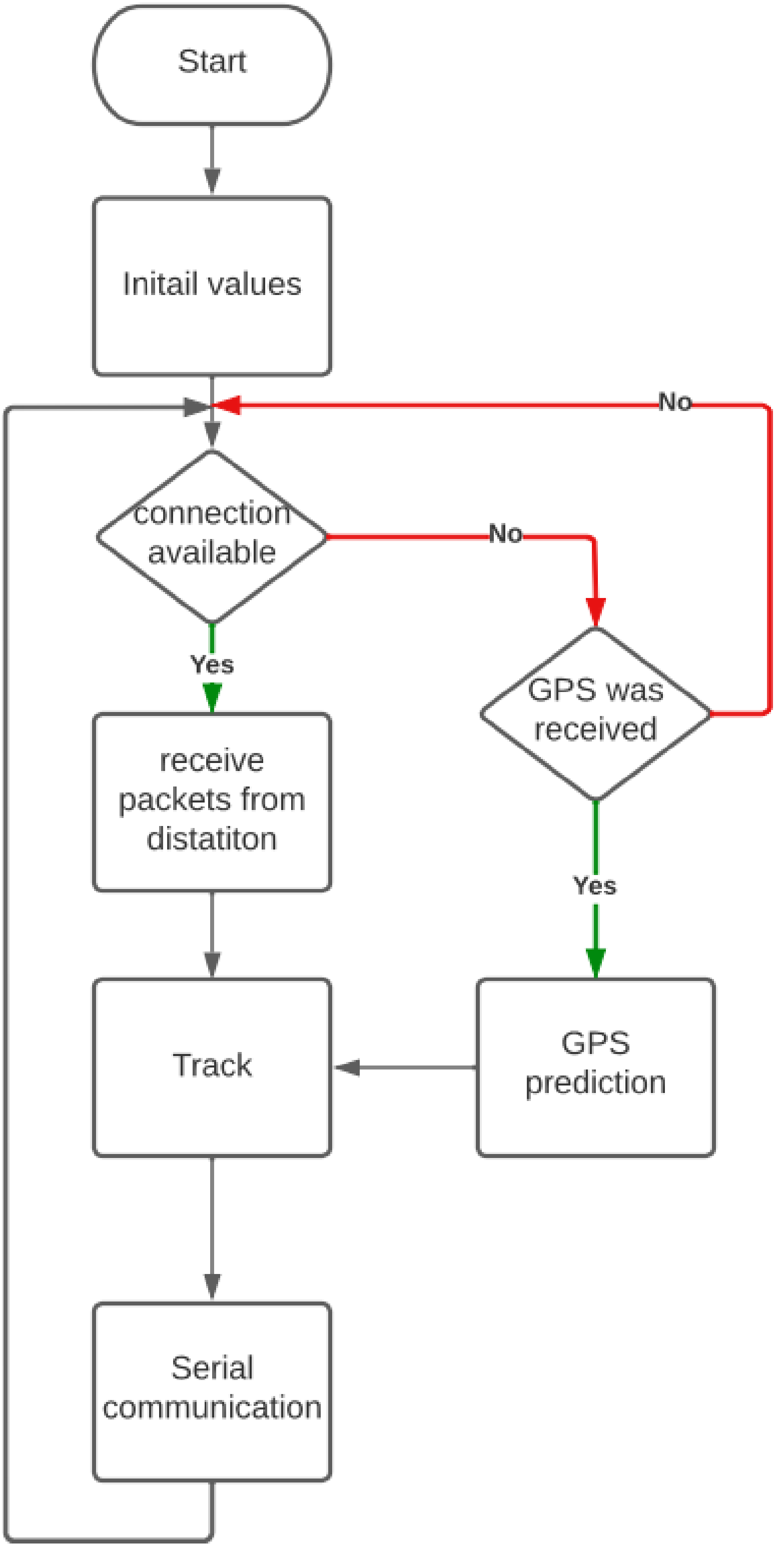


Figure 36: flowchart for ground control station

The code begins by initializing the GPS coordinates of the ground station. This information is used as a reference point for the tracking algorithm and helps to ensure that the antenna is pointed in the correct direction.

Next, the code checks for an internet connection. If an internet connection is available, the code begins to receive UDP packets from the destination device, which is an ESP32 camera streaming video. This video feed can be used to visually track the transmitter and adjust the antenna's direction as needed.

In addition to the video feed, the code also receives altitude data from an ESP8266 and GPS data from a mobile phone. These additional sources of information can be used to more accurately determine the location of the transmitter and fine-tune the tracking algorithm.

After processing this data and making the necessary calculations, the code determines the required number of steps for the stepper motor to move the antenna in the correct direction. This information is then sent to the Arduino via serial communication, allowing the antenna to be precisely pointed at the transmitter.

If an internet connection is not available, the code instead relies on GPS prediction to estimate the next location of the transmitter. This prediction is based on the previous GPS data received and takes into account the movements of the transmitter. The code then applies the tracking algorithm to determine the required number of steps for the stepper motor to move the antenna to the predicted location. This information is also sent to the Arduino via serial communication, allowing the antenna to track the transmitter even in the absence of an internet connection.

Overall, the code is designed to control a tracking antenna ground station by receiving and processing data from various sources and using this information to accurately point the antenna at the transmitter. Whether an internet connection is available or not, the code can use advanced algorithms and sensor data to ensure that the antenna is always pointing in the correct direction.

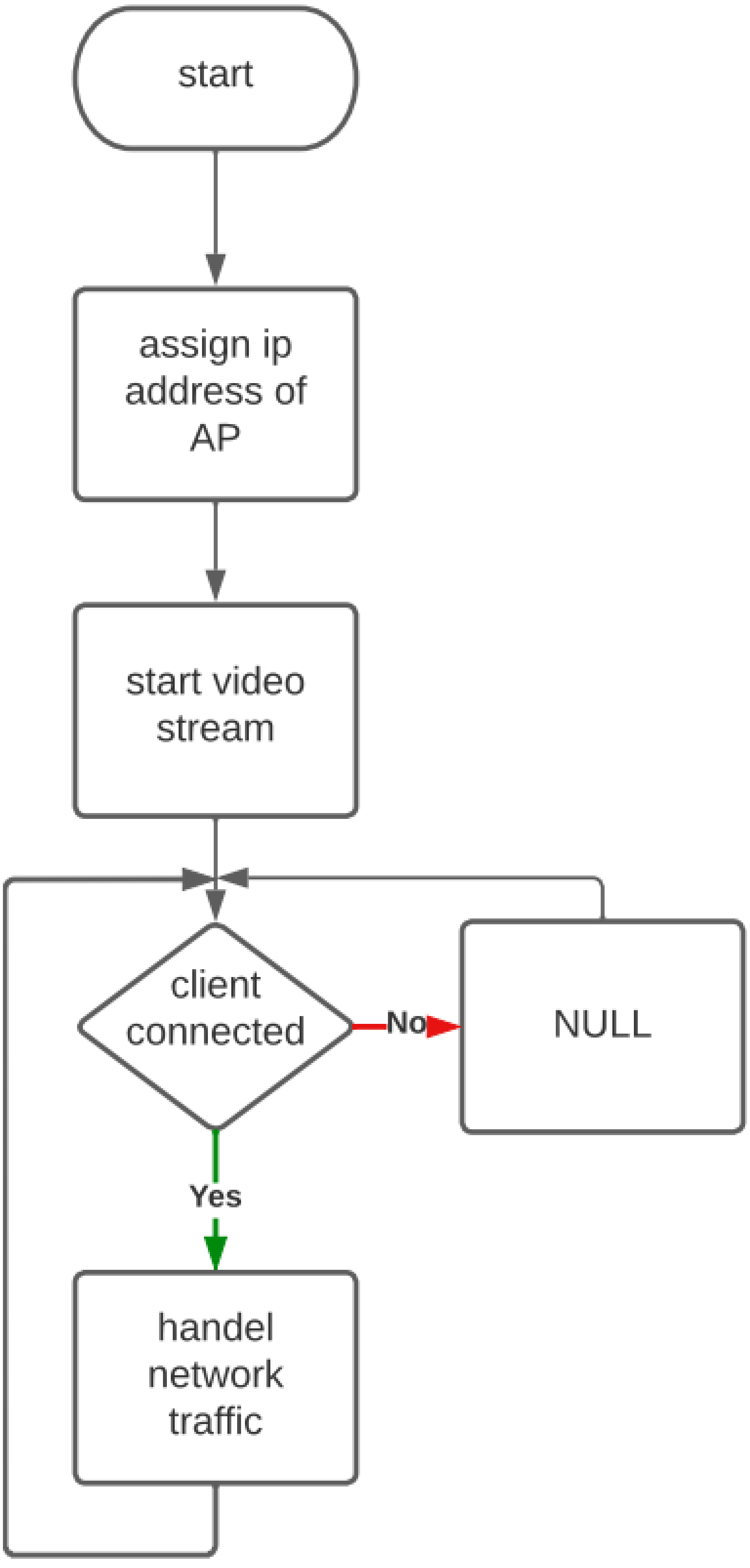


Figure 37: flowchart for ESP32-CAM

The ESP32-CAM is a device that is designed to stream video and act as a wireless access point. When it is powered on, the ESP32-CAM will first configure itself as an access point by assigning itself an IP address. This allows other devices to connect to the ESP32-CAM and access its capabilities.

Once the ESP32-CAM is configured as an access point, it will start streaming video via HTTP. This allows clients to view the video feed by connecting to the ESP32-CAM's IP address using a web browser or other video streaming software.

In addition to streaming video, the ESP32-CAM is also capable of forwarding data between different devices. If a client connects to the ESP32-CAM, the device will act as a bridge between the transmitter and the ground station, as well as between the mobile phone and the ground station. This allows these devices to communicate with each other, even if they are not directly connected.

Overall, the flowchart describes the steps that the ESP32-CAM will take to stream video and facilitate communication between different devices. This makes the ESP32-CAM a valuable tool for a wide range of applications, including video surveillance, remote communication, and more.

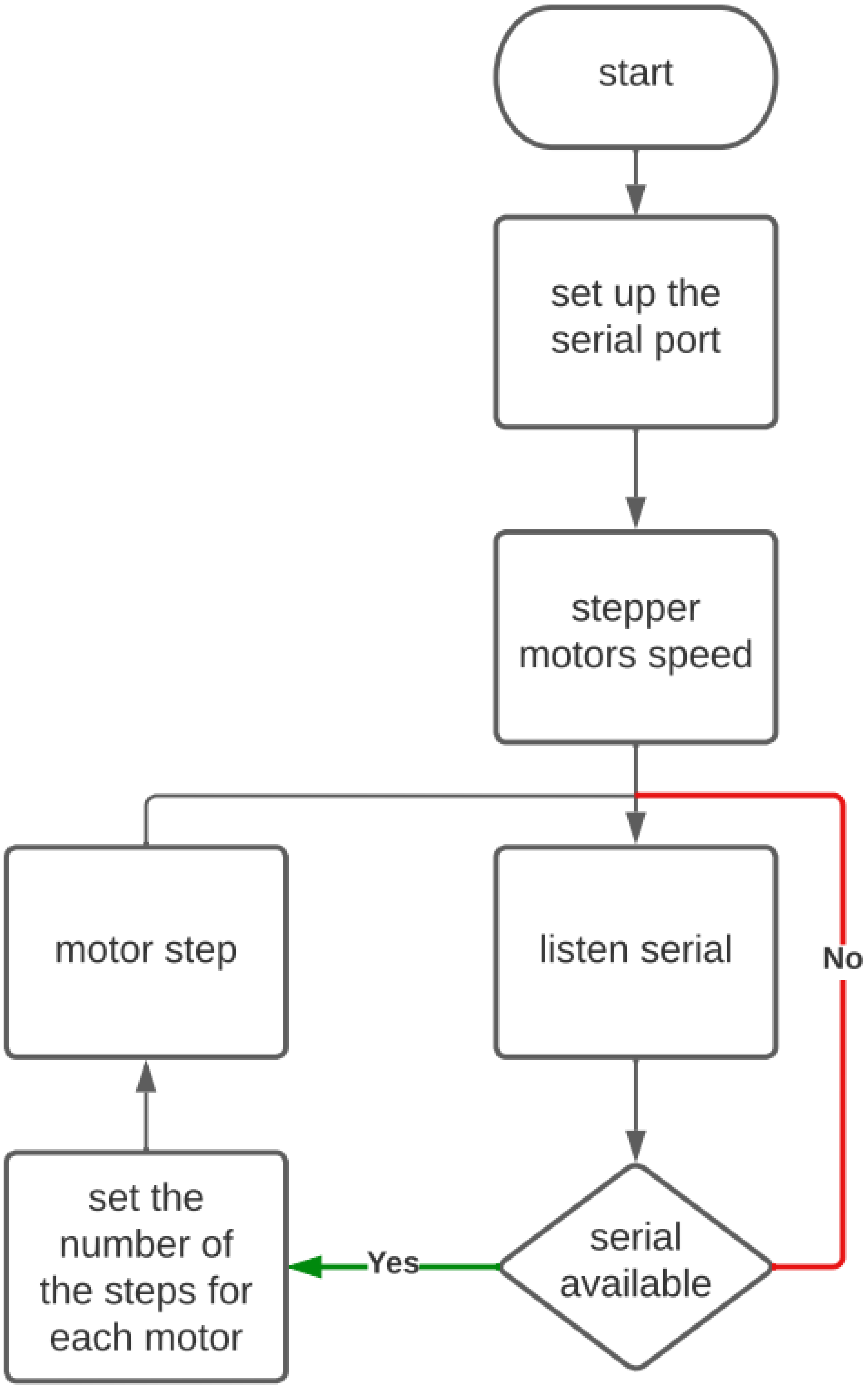


Figure 38: Arduino flowchart

The Arduino is a microcontroller that is designed to communicate with a ground control station via a serial port. When it is powered on, the Arduino will first set up the serial port and initialize the stepper motors. This ensures that the Arduino is prepared to receive and process data from the ground control station, and allows the stepper motors to be controlled in response to this data.

After the serial port and stepper motors are initialized, the Arduino will enter a loop where it continuously listens for incoming data on the serial port. Whenever data becomes available, the Arduino will process this data and use it to set the speed and direction of the stepper motors. This allows the ground control station to remotely control the movement of the stepper motors, enabling precise and efficient movement.

If no data is available on the serial port, the Arduino will continue listening until data becomes available. This ensures that the Arduino is always ready to receive and respond to instructions from the ground control station.

Overall, the flowchart describes the steps that the Arduino will take to establish serial communication with the ground control station and control the movement of the stepper motors.

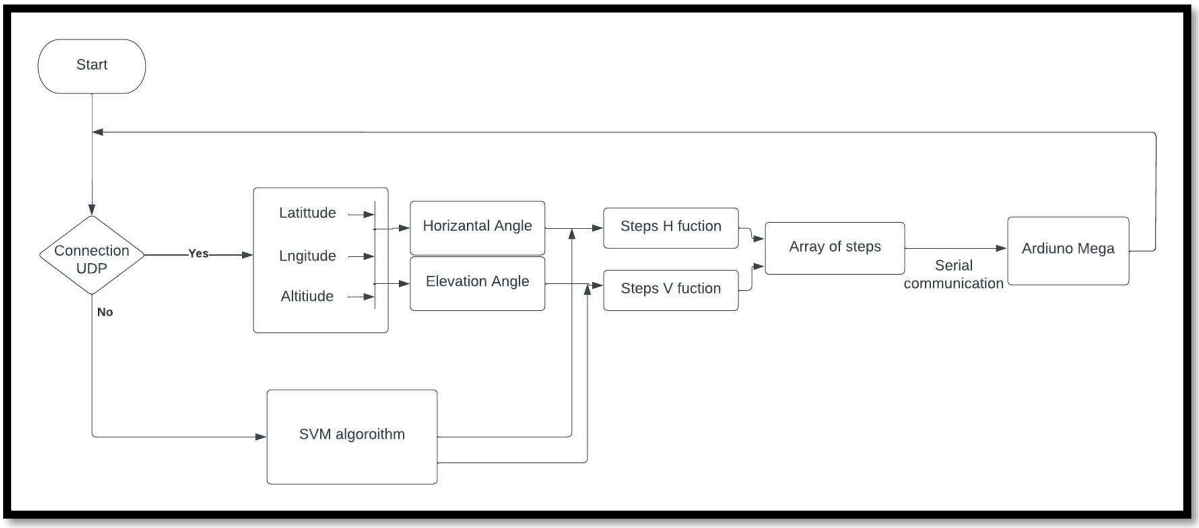


Figure 39: Flow chart of the tracking algorithm

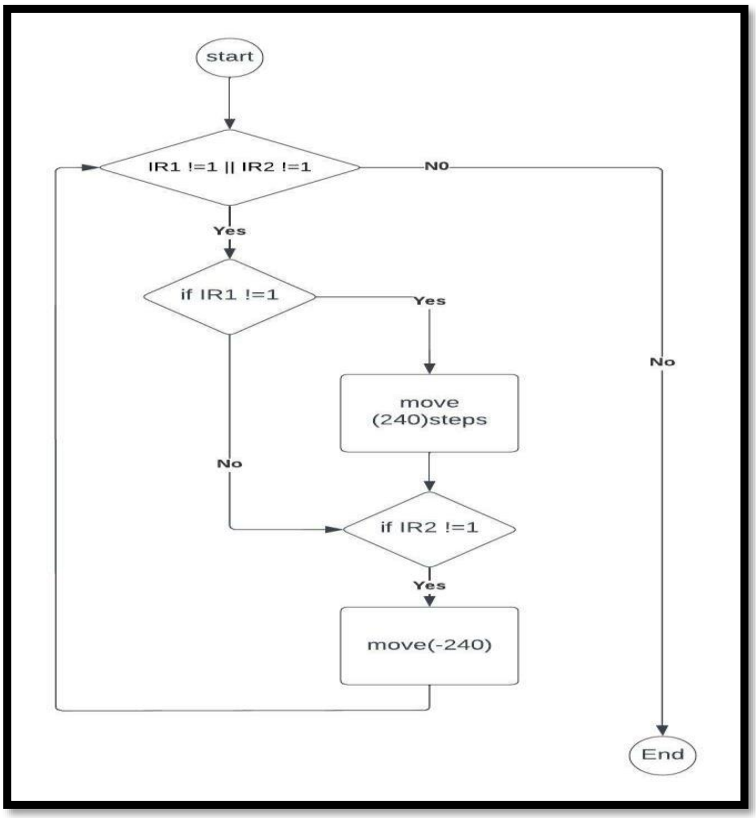
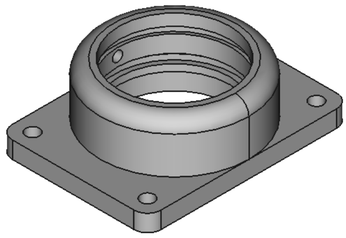
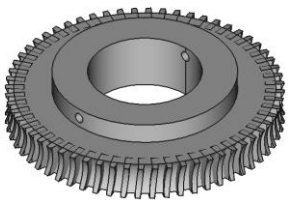
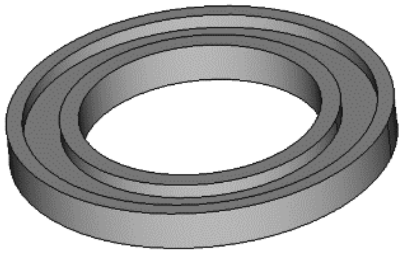


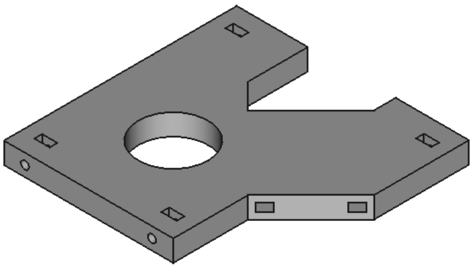
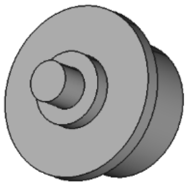
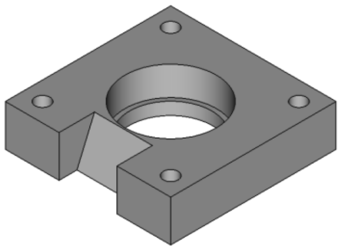
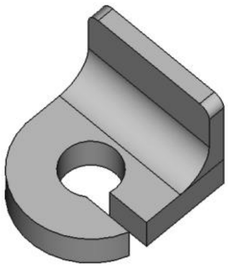
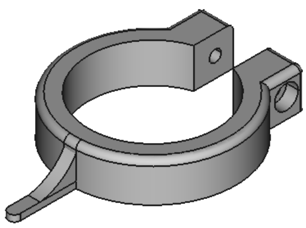
Figure 40: block diagram of IR calibration

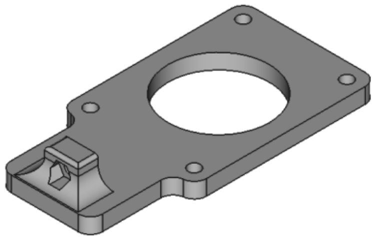
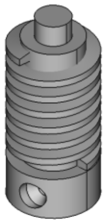
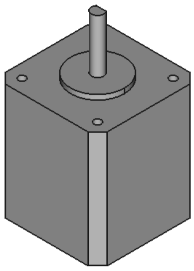
3.2.4 Mechanical specifications of the case

In this section, we will examine the mechanical components that will be utilized in the construction of our tracking antenna. These parts have been carefully designed using 3D software and will be printed, assembled, and ultimately mounted on a stand to complete the antenna. Let's take a closer look at each of these components and how they will fit together to create a functional and efficient tracking antenna.

Table 21: Mechanical Prats[18]

Name	Qty	Part
Axis Bushing	3	
Axis Gear	2	
Axis Gear Spacer	2	

Axis Side	4	
Azimuth Axis Pillar	1	
Ball Bearing Holder Cup	3	
Cable Hook	1	
Homing Ring	2	

Homing Sensor Holder	2	
Worm Gear	2	
Nema17 Stepper Motor	2	

Tracking Antenna Ground Station Mechanical Assembly

Step 1 – First of all, we need to have an enclosure box to put all the mechanical parts together.

Figure 41: Enclosure Box

Step 2 – Next we need to assemble the gear for both axes, we will use two stepper motors (NEMA 17) and equip the worm gear for each stepper motor then install the motor on the axis side.

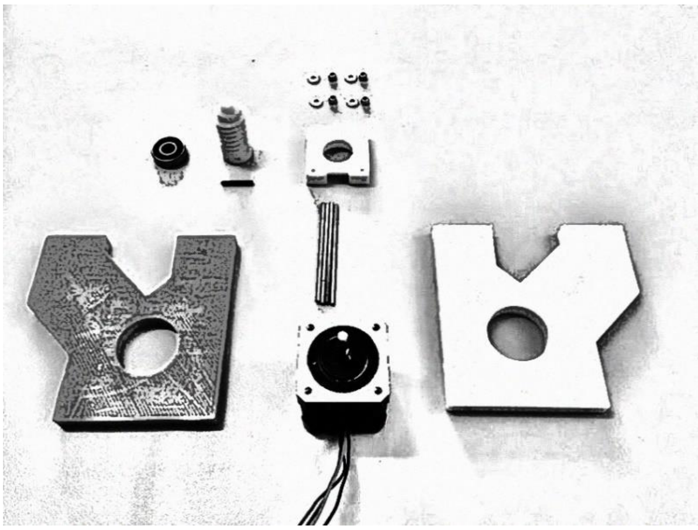


Figure 42: Mechanical Assembly -1

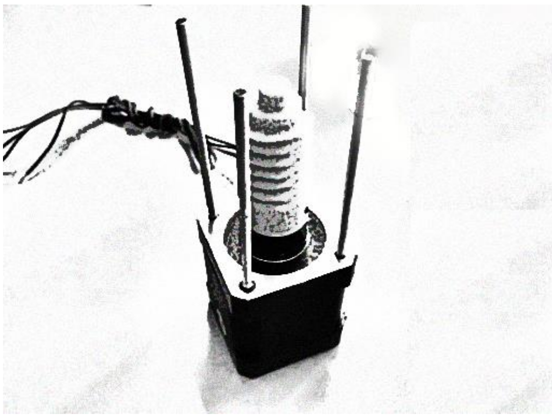


Figure 43: Mechanical Assembly -2

Step 3 – Next we need to install a ball bearing with a bearing holder cap, then place it on top of it.

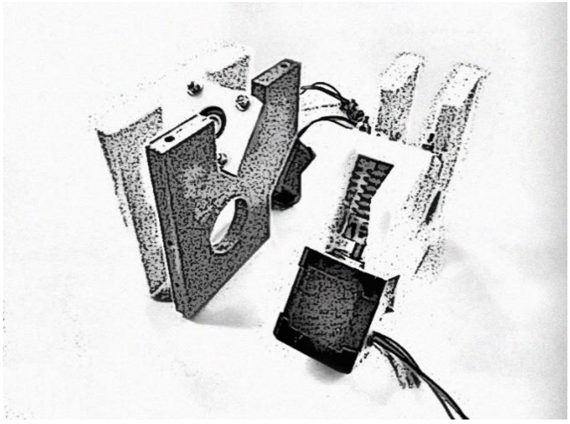


Figure 44: Mechanical Assembly -3

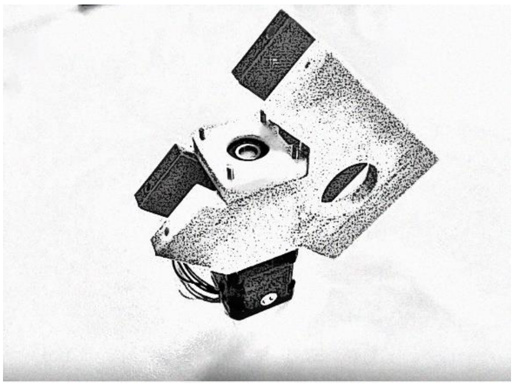


Figure 45: Mechanical Assembly -4

Step 4 – later we need to use washers and screws to make sure they are tight together.

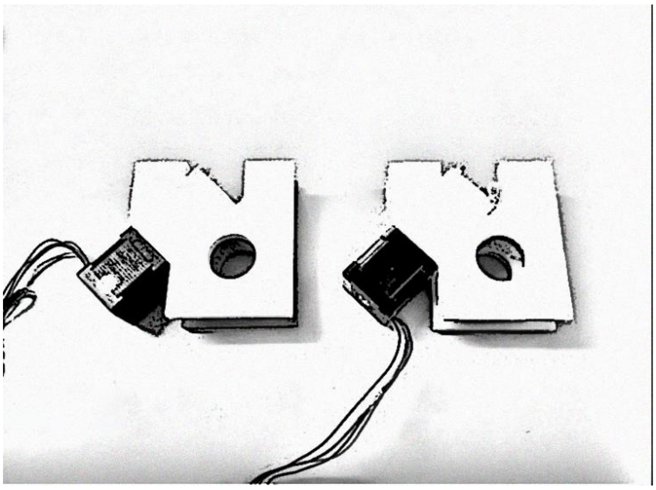


Figure 46: Mechanical Assembly -5

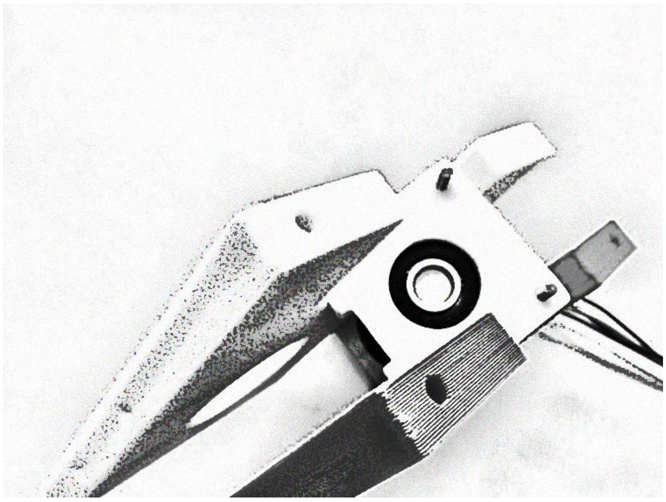


Figure 47: Mechanical Assembly - 6

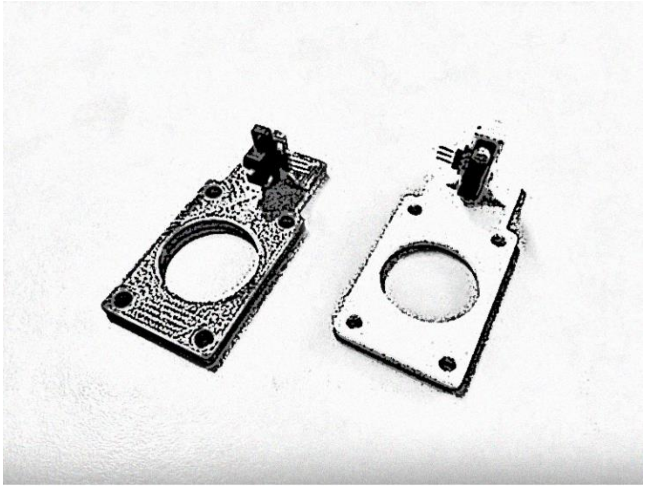


Figure 48: Mechanical Assembly -7

Step 5 – next step is to make the position of the holes inside the box as shown.

Figure 49: Mechanical Assembly -8

Step 6 – Use a drill to make 3 holes, two for the axis and one for Azimuth, now the box is ready to put all the parts all together.

Step 7 – put the gear and gear slider together inside the gear assembly, after making sure they fit together put the screws.

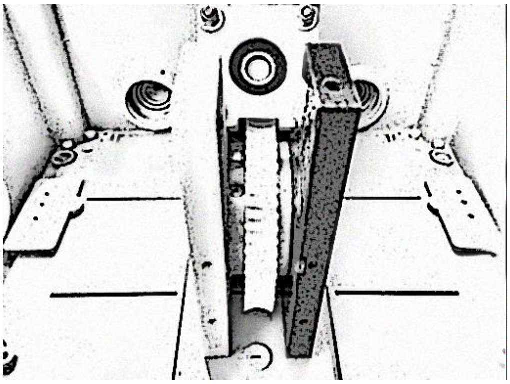


Figure 50: Mechanical Assembly -9

Step 8 – make sure to put the axis tube in the homing ring before it exits the box.

Step 9 – put the axis tube into the gear assembly then place the azimuth pillar on the top.

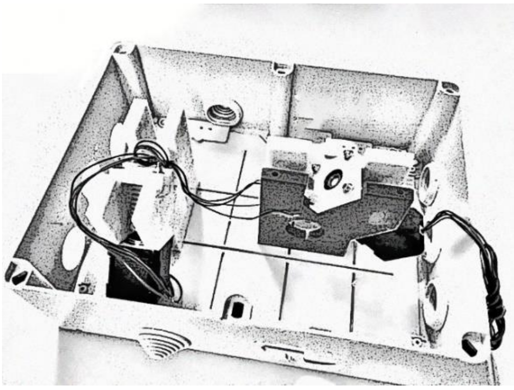


Figure 51: Mechanical Assembly -10

Step 10 – now the Azimuth axis is ready and the electronics parts are ready to install.

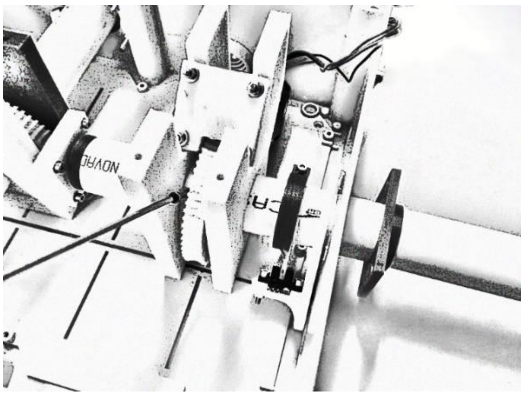


Figure 52: Mechanical Assembly -11

3.2.5 Possible aesthetics

To make our project more convenient and user-friendly, we will be upgrading the current camera with a higher-quality model to enhance the video stream. We will also be optimizing the step algorithm for recapturing the transmitter to ensure efficient and smooth tracking. To ensure the professional appearance and durability of our project, we will be using high-quality materials for the ground station's fundamental components to protect against various weather conditions. By making these improvements, we aim to provide a seamless and reliable experience for the user.

3.2.6 Input/output specifications

Table 22: Input/Output specifications of the tracker system

Device	Input	Output
ESP32 cam	5V	2.4GHZ Wi-Fi network
Yagi Antenna	5V	47 dbm
Stepper motors	4.1V	200 steps per revolution
L298N 2A	12V	5 V
Arduino Mega	7V	5V
NodeMCU ESP8266	5V	3.3V
Raspberry Pi 4	5V	3.3V
BME280	3.3V	3.3V
DC-DC Converter	12. V	5V
DC-DC Converter	8V	5V

3.2.7 Operating Instructions

Before you run the tracking antenna, follow these steps to ensure everything is working correctly:

1. Check the condition of the battery of the ground station. If the battery is not charged, charge it before proceeding.

2. Establish a connection to the Wi-Fi for the ESP32. If you are having trouble connecting, make sure that the Wi-Fi network you are attempting to connect to is working properly and that the ESP32 is within range.

3. Test the camera on the ESP32 to ensure it is working properly. To test the camera, follow these steps:
    a. Turn on the ESP32 and wait for it to boot up.
    b. Navigate to the camera settings on the ESP32.
    c. Take a test photo or video to verify that the camera is functioning correctly.
    d. If the camera is not working as expected, try troubleshooting common issues such as checking that the camera is properly connected and that no obstructions are blocking the camera's view.

4. Make sure there is a clear line of sight for the tracker. The tracker will need an unobstructed view of the sky to function properly.

5. Run the main program for the ground station. Follow the prompts on the ground station to start the tracker.

6. For safety, make sure to stay a safe distance away from the tracker while it is running. A minimum distance of 50 cm is recommended.

3.3 PRIMARY IMPLEMENTATION

Figure 53: positions of GPS coordinates (red X)

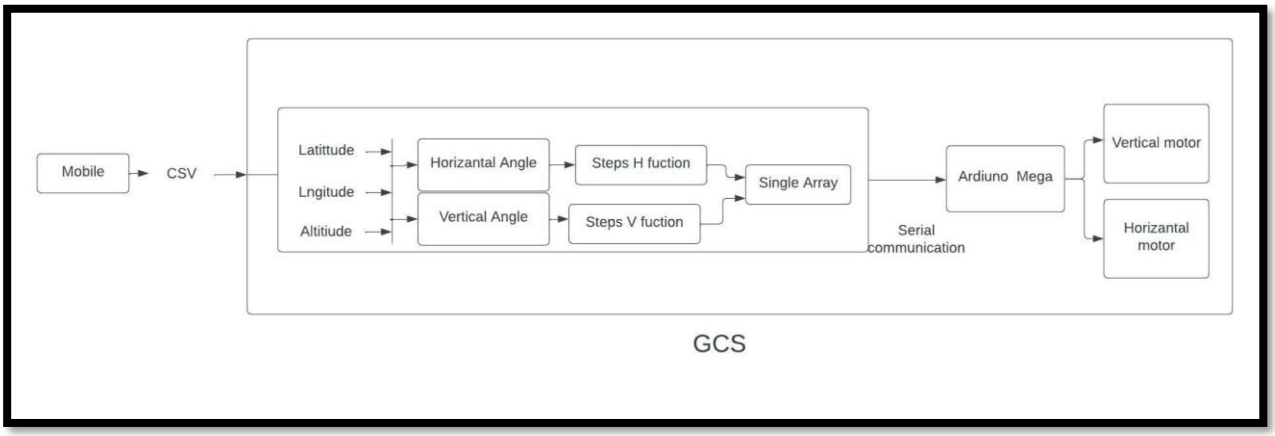


Figure 54: the system of live tracking experiment

At this task, we apply the first real experiment for the overall of our product The first step record the coordinates of the GPS for a specific position and then save it as CSV, but now we need to implement it in a realistic situation, for that we need to the coordinates at every 50 milli second to look like a real tracking file then apply it to the algorithms to calculate the steps of the motors, for setup moving of the directional antenna, the pressures done by three main phases: 1- calibration of the stepper motor at each start 2- construct the functions of the algorithm

3-calculate the steps of the motors 4- transfer the steps to Arduino for setup moving of the motors :

1- Calibration of the two stepper motors at the beginning, the calibration is done by using two IR sensors which are installed at the axis of the two motors this algorithm :

While (Output of IR1 !=1||Y Output of IR2 !=1)

  If (Output of IR1 !=1) :

  Moving the motor 1 →240 step

  If (Output of IR2 !=1) :

  Moving the motor 2 →-240 step

2- Calculating the elevation angle which done by applying thehaversine formula to calculate the horizontal distance, calculate the angle by applying the Pythagoras equation :

Distance N-S = ABS(Latitude2-Latitude1) × PI/180

Distance E-W = ABS(Longitude2-Longitude1) × PI/180

Distance Vertical = Altitude2 - Altitude1

Haversine =Sin^2(Distance N-S/2)+cos(Latitude1) ×cos(Longitude2) ×Sin^2(Distance E-W/2)

C=2 × asin(Square root (Haversine))

Distance =C × 6371 ×1000

Then Elevation angle = ArcTan (Distance Vertical / Distance)

3- Calculate the horizontal angle

Distance E-W = ABS(Longitude2-Longitude1)

y = sin(Distance E-W) ×cos(lat2)

x = cos(lat1) × sin(lat2) - sin(lat1) × cos(lat2) × cos(Distance E-W)

the Horizontal angle = ArcTan (y/x)

4- Calculate the steps of the vertical & horizontal motors

Steps of horizontal motor :

$$\frac{Horizantale\ angle}{360} \times 12500(the\ full\ steps\ of\ Horizantal\ motor)$$

Steps of vertical motor :

$$\frac{Vertical\ angle}{90} \times 3500(the\ full\ steps\ of\ vertical\ motor)$$

5- Transfer the steps of the motors to Arduino for setup moving of the motor

3.3.1 The tests

3.3.1.1 First test

The stepper motors move more than the last position takes it, which observes a problem from the serial communication issue, due to the differences in speed process between the PC and Arduino circuit, the solving of that problem adding a logic if condition and an array for saving the steps of the motors, so at each time the Arduino receives the steps the entry of that index will delete it simultaneously otherwise will keep it at the array.

3.3.1.2 Second test

After solving the issue of transmitting the stepper, there is still not accurate, and the directional antenna refers above the positions that we take it, after debugging the code, we notice the problem is from the function of calculating the steps which return float values, and the stepper read-only as an integer, and also sending the zeroes into a serial communication will make other problem issues, for that we solve it by rounding the function the output of the function, and apply that function into if condition to avoid zeroes values.

3.3.1.3 Third test

After solving the issue of the serial communication problems, it still the directional antenna does not refer exactly to the position, after debugging turns out the problem is from the speed of the motors, the observation was when slow the speed of the motor it came more accurate and better, the team assigns the speed of horizontal & horizontal motors at 170 steps at second.

So it is clear that the directional antenna refers to the positions of GPS coordinates successfully from building number 35 (English Language Institute) to the parking car of the engineering college then to the sports building, then at the end to parking cars at the science college, which moves it smoothly step by step. (show figures 56 to 59)

Figure 57: directional antenna refers to the building number 35

Figure 58: directional antenna refers to the parking of engineering college

Figure 56: directional antenna refers to the sport building

Figure 55: directional antenna refers to the parking car of science college

3.3.2 APPLY REAL LIVE TRACKING

This task will apply real live tracking as the customer want, so the main difference between the first and second task is the UDP communication is present in this experiment instead of a CSV file (GPS coordinates record it), but the algorithms and connection serial will still same because its success it from the previous task.

Figure 59: the tracker successfully track the transmitter

Figure 60: Successful track for next position

3.3.3 Apply real live tracking with different modes

This task will apply real live tracking but for a long time and with recapture algorithms, the recapture algorithm it designed to work as a contingency plan (when the connection lose) by applying an SVM formula this task was done in a large area at the parking of building number 35, which has a big large are of the line of sight.

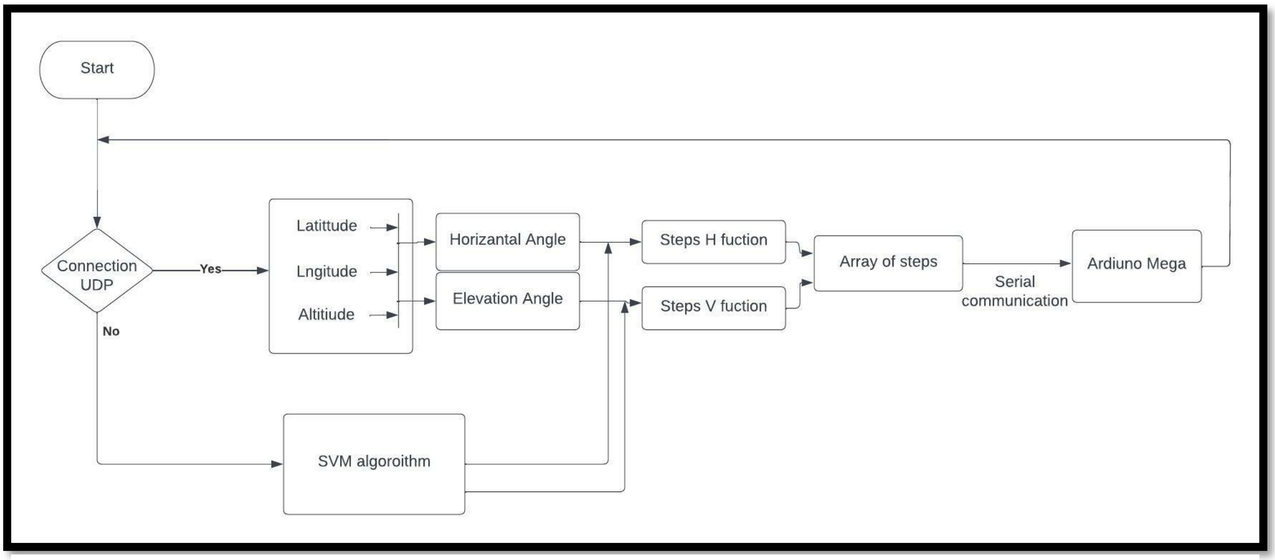


Figure 61: the flowchart of the third task

3.3.3.1 First test (Track mode)

For the first trial we apply live track normal mode, the team has been prepared three batteries to use for the long-period experiment, and the tracking done with different ranges was successful, except when the antenna track at the vertical axis the motor did not work properly, the team noticed the issue from the helical gear which was corroded, and there is need to print another one, for that the team members students to continue this experiment with fixed high of elevation angle until printing another gear.

3.3.3.2 Second test (Recapture mode)

At this trial we apply a recapture mode, which is very important when the tracker loses the signal of the transmitter, the algorithm of the recapture use SVM this formula is very popular and useful for predication, in our case we use it predicts the next place position according to the previous coordinates that save it before, on the software was work properly which take a different scenario and success it.

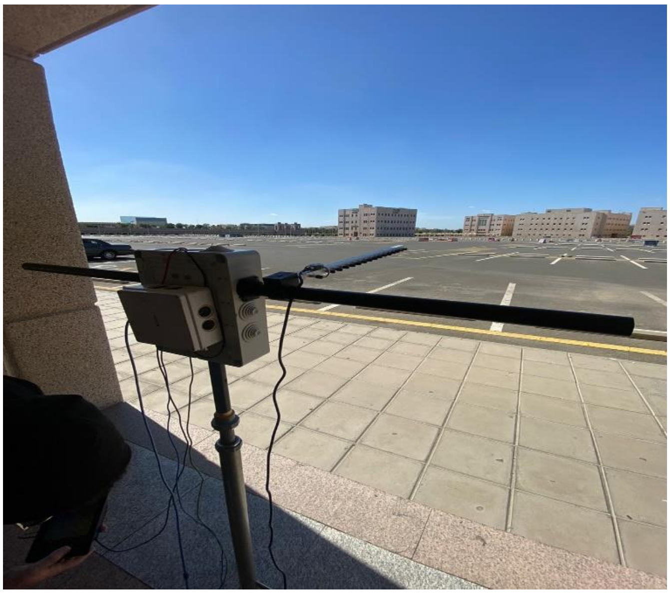


Figure 62: testing area of the experiment two

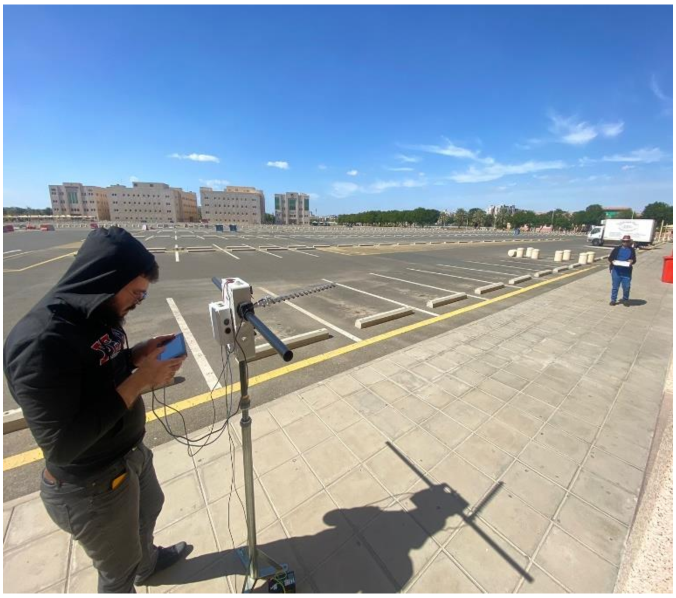


Figure 65: successful track at first mode

Figure 64: the antenna directly refer to the transmitter after applying recapture mode

Figure 63: The UDP connection lose

At figure 64 the connection of UDP is loose, then immediately the tracker switch to recapture mode, and applying an SVM algorithm, the transmitter took a curve path, and after applying this algorithm the antenna of the tracker successfully refers to the transmitter directly shown figure 65.

3.3.4 Apply real live tracking with different modes (2)

This experiment is complementary to the previous experiment, after fixing the problem issue of the vertical motor by printing another worm gear successfully, this experiment should satisfy all requirements of the customer.

3.3.4.1 First test (Track mode)

For the first trail, we apply live track normal mode, for this experiment, we add to the algorithm a track condition if the distance is less than 10 m no need to track it is useful because tracking at a low distance will not accurate and this range is enough for a high-quality video stream, the track done at multi positions, both the direction of the antenna vertically and horizontal successful track the transmitter.

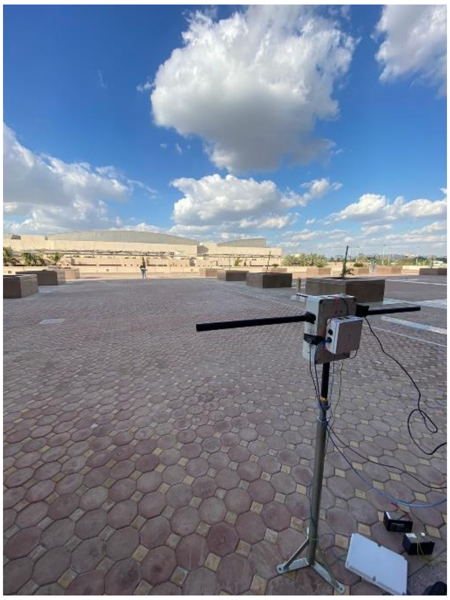


Figure 67: Successful track at position 1

Figure 66 successful track at position 2

5.4.2 Second test (Recapture mode)

At this trial we apply a recapture mode, by disconnecting the transmitter, so the GCS should track according to the prediction algorithm that choose it before is SVM, and to make it hard, the transmitter took a curve direction, the result was dazzling and successful show figure 71.

Figure 69 track at position 1

Figure 68 track at position 2 (UDP off)

CHAPTER – 4 IMPLEMENTATION

4.1 CONTROL OF THE MOTORS

Setup a suitable microcontroller for the two motors is very important, as known this will coordinate the instructions of the vertical & horizontal motor, moreover will it coordinates the rate quality of the communication, hence our product is real live tracking which mean live transmission of the data immediately.

4.1.1 First trial

To start our implementation we used a UNO Arduino the first experiments of the two motors according to the algorithms that upload into UNO Arduino, it was working properly, but for serial communication, it was not reliable, and flash memory was just (32kB) and static Ram is just 2kB which are not for our application, for that it is limited performance according to the project.

Figure 70: Ardiuno UNO

4.1.2 Second trial

Finding a highly efficient microcontroller now was the main thing, after deep searching according to the specific requirements demanded by the product, the choice was mega 2560 Arduino instead of UNO because the flash memory is 256 kB and static memory is 32 kB also When the program is up and running, the variables can be created and manipulated in Mega due to its SRAM space while it does not happen in Uno, also has the number of input pins is more than UNO, so the team members assigned to choose Arduino mega instead of UNO.

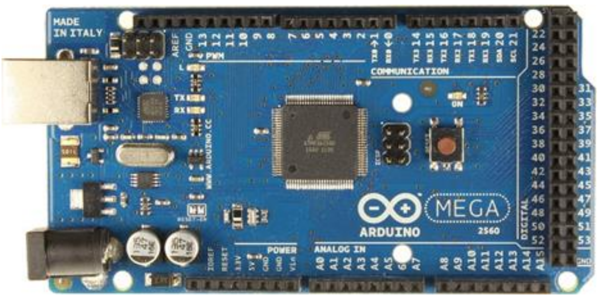


Figure 71: Mega Ardiuno

4.2 MECHANICAL GEARS

As known the product contains four gears, two axes, and two worm styles, which are all made by 3-D printers, choosing the type of gear material is very important, especially for the product dealing with different climates, and highly thermally radioactive materials.

4.2.1 First trial

axis and worm gears are made from carbon fiber, but after make the experiment and tests of the system during term 1 and summer, we notice the movement of the motors was not accurate and stuck at the same positions, especially the vertical motor due to the tooth of the gears are decay, for that the team assigned to print another gear but using another material that proper for the product.

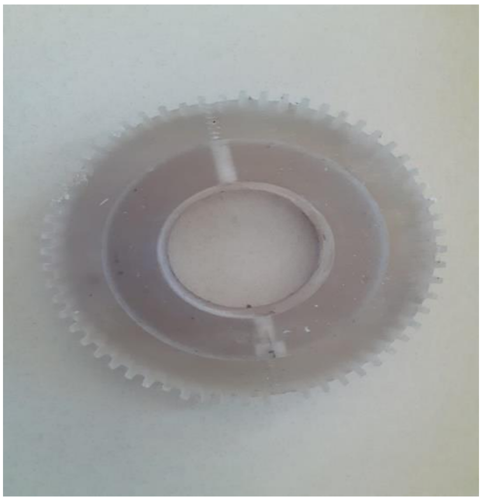


Figure 73: old axis gear

Figure 72: old worm gear

4.2.2 Second trial

After discussing with DR -ALABUDLI about the material of the gear he is specialized in mechanical engineering affairs, he suggests using a subsidized carbon fiber heat resistant

Figure 75: new axis gear

Figure 74: new worm gear

4.3 IR SENSORS

Calibration of the horizontal and vertical motors is very important, especially after the shutdown of the system, there were multi choices to achieve it, and one of them was using IR sensors to reset the axis of the motors, as known the IR sensors have many types and versions for that we do many tests to choose a reliable one for our product.

4.3.1 First trial

At the start of our test, we use a TCRT5000 Infrared, which has a high sensitivity for objects and detect immediately the objects, the test of that sensor was done by connecting with Arduino and printing them out at the serial, but unfortunately when we try to install at the GCS, was not proper with the mechanical structure of the stepper motors that designed a clip to deal as a label for the sensor at each time reach to IR the motor should stop moving and now is ready for work, for that it failed to choose this type.

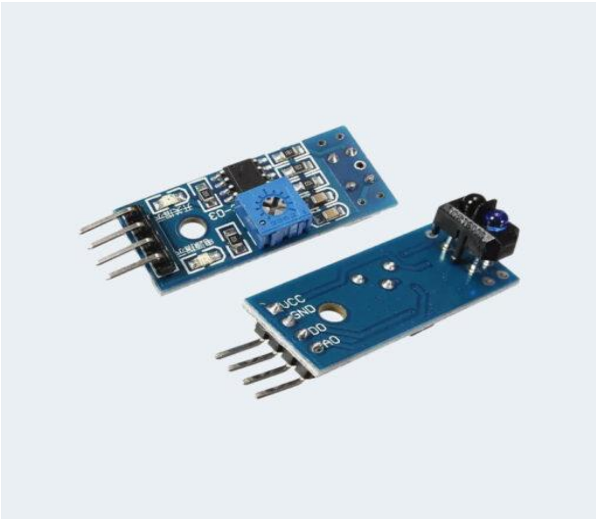


Figure 76: TCRT5000 Infrared

Figure 77: clip of the axis

4.3.2 Second trial

The old design of the tracker has an already IR sensor, but it removes during term 1 to renew all components of the electric circuits the IR was already had a ready design to deal with this type of clip of the axis, so we return it to the tracker this type of IR sensor is used as infrared counting sensor but it works properly with the design.

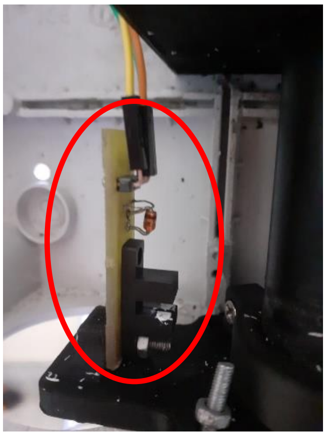


Figure 78: proper IR sensor with the clips of the axis

4.4 GPS TRACKING

GPS tracking can be used to track the movement of an antenna. By attaching a GPS tracking device to the antenna, the device can record the location of the antenna at regular intervals. This data can be used to track the angle of the antenna relative to its surroundings. For example, the GPS data could be used to determine the direction in which the antenna is pointed, or to track any changes in the angle of the antenna over time. By analyzing the GPS data, it is possible to understand the antenna's movement and orientation in real-time or to analyze its movement and orientation over a while.

4.4.1 First trial

The NEO-6M GPS module is a popular choice for adding GPS capabilities to a project, but it is important to understand how it works and how to properly use it. The NEO-6M module provides location information in the form of latitude and longitude coordinates, as well as altitude data. If the module is not providing coordinates, it could be due to several factors.

One possibility is that the module is not receiving a strong enough GPS signal. GPS signals can be disrupted by various factors such as tall buildings, trees, and atmospheric conditions. Make sure that the module has a clear view of the sky and is not obstructed by any physical barriers. It can also be helpful to move the module to a location with a better view of the sky, such as an open field or rooftop.

Figure 79: NEO-6M GPS

4.4.2 Second trial

Our team had been working on a mobile application using Matlab which aimed to collect GPS data and send it to the ground control station through UDP. However, we encountered an issue where the transmitted data became corrupted and was not displayed correctly at the ground control station. We attempted to resolve this issue as part of our senior project but were unable to find a satisfactory solution. We sought guidance from experts and tried various approaches, but were ultimately unable to resolve the issue. Despite our efforts, the transmitted data continued to be corrupted and not displayed correctly at the ground control station.

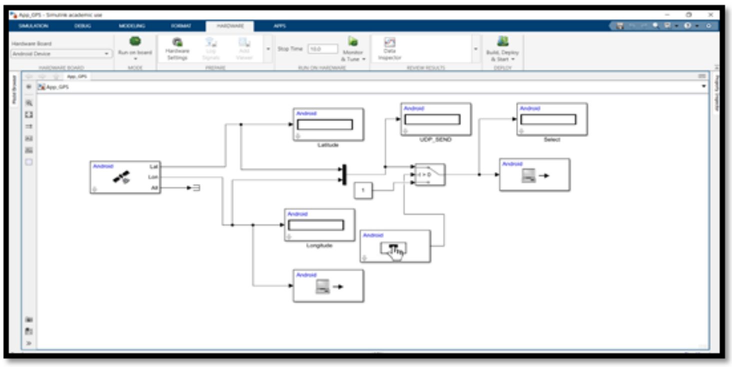


Figure 80: Matlab GPS app Diagram

4.4.3 Third trial

We had been using an IMU and GPS stream for our mobile application, instead of relying on Matlab. Our goal was to collect and transmit data from these sensors in real time to the ground control station, and we believed that using an IMU and GPS stream would allow us to achieve this more effectively. However, we encountered an issue where the GPS data being transmitted was not accurate enough for our needs. We attempted to resolve this issue as part of our project but were unable to find a satisfactory solution. We sought guidance from experts and tried various approaches, but were ultimately unable to improve the accuracy of the data being transmitted. Despite our efforts, the GPS data continued to be unreliable and did not meet the requirements of our project.

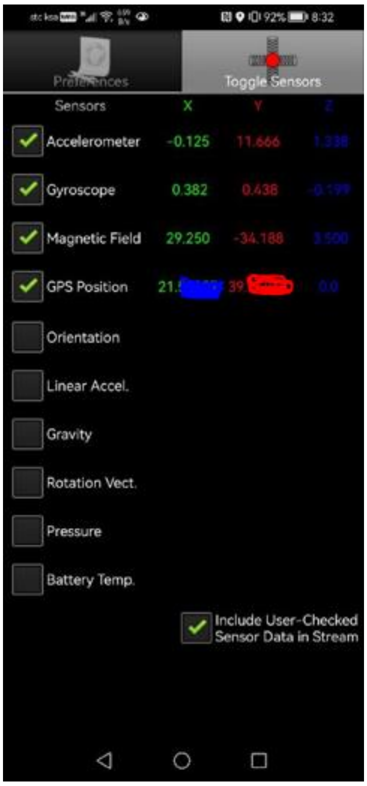


Figure: 81 IMU GPS Data

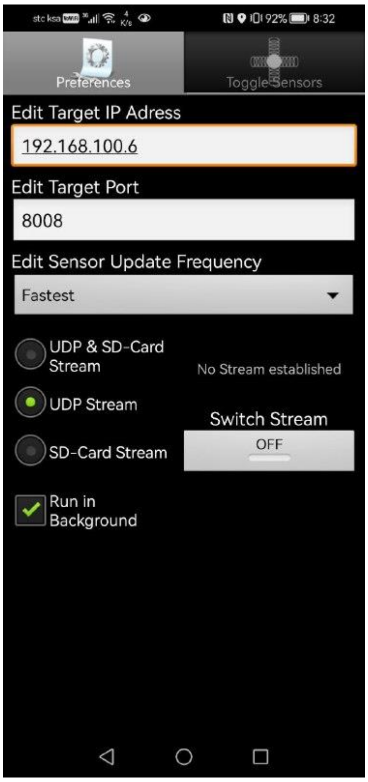


Figure: 82 IMU & GPS User Interface

4.4.4 Fourth trail

For our sensor project, we have developed a Flutter mobile application that is designed to track an antenna. The app collects GPS data and transmits it in real time to the ground station via a UDP stream. We believe that this is the best choice for our project as it allows us to accurately track the antenna and receive timely updates on its location. The Flutter platform was user-friendly and allowed us to easily develop the app, and the use of UDP streaming ensures that the data is transmitted efficiently and effectively. Overall, we are satisfied with our decision to use a Flutter app with a UDP stream for our sensor project, and we are confident that it will provide us with the necessary data and functionality.

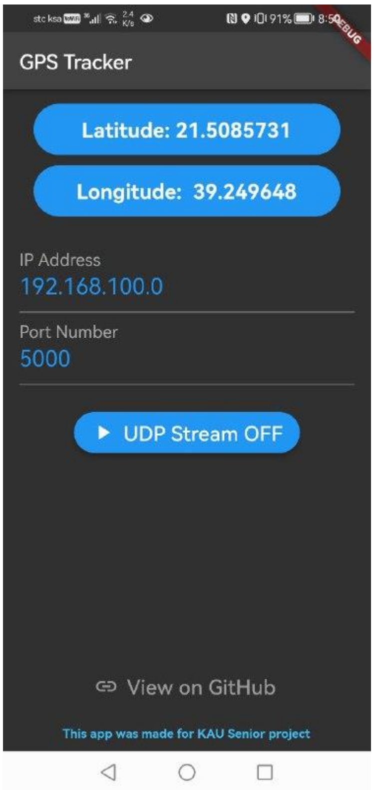


Figure 83: Flutter Mobile App

4.5 Altitude Track

One way to extract altitude data from a transmitter would be to use a GPS receiver on the transmitter side to determine its location. The GPS receiver can then use the location information, along with data from satellite signals, to calculate the altitude of the transmitter. This approach may be particularly useful if the transmitter is moving, as the GPS receiver can continuously update the altitude information as the transmitter moves. Alternatively, if the transmitter is stationary, a static GPS measurement can be taken to determine the altitude. It is also possible to use other methods, such as pressure sensors or accelerometers, to determine the altitude of the transmitter. These methods may be more suitable in certain situations, such as when the transmitter is inside a building or in an area with poor GPS reception.

4.5.1 First Trail

We attempted to use an IMU and GPS application to determine the altitude of the transmitter, but the readings were consistently inaccurate. This suggests that relying on this tool alone may not be sufficient for accurately measuring the transmitter's altitude. As a result, we may need to consider additional methods or techniques to obtain more reliable and precise altitude data.

4.5.2 Second Trail

Instead of using an IMU and GPS, we implemented a BME 280 sensor to measure the altitude of the transmitter. The readings from the BME 280 were significantly more accurate and reliable than those obtained using the IMU and GPS alone. This suggests that incorporating a BME 280 sensor into our measurement setup can greatly improve the accuracy and precision of our altitude data. As a result, we may want to consider using the BME 280 sensor as our primary method for determining the transmitter's altitude.

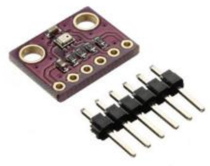


Figure 84: BME280 Sensor

4.6 MOTOR DRIVER

To select the best motor driver for two stepper motors in a ground control station for tracking, it is necessary to carefully evaluate the requirements of the application. This includes considering the voltage and current ratings of the motors, the desired speed and torque, and the operating temperature range. Additionally, it may be beneficial to consider the physical size and weight of the motor driver, as well as any additional features or functionality that may be useful for the application. It is also important to ensure that the chosen motor driver is compatible with the control system in use and has enough channels to drive both motors simultaneously. By taking these factors into account, it should be possible to identify a motor driver that meets the needs of the ground control station and enables the stepper motors to operate effectively.

4.6.1 First Trail

Initially, we utilized the L293D motor driver to control two stepper motors that had a rated current of 1.2 A. However, we encountered an issue with the L293D overheating during operation, which could potentially compromise the stability and reliability of the system. The overheating may have been caused by a variety of factors, such as insufficient cooling, high ambient temperatures, or excessive current drawn from the motors. To address this issue, we may need to consider alternative motor drivers or implement additional cooling measures to ensure the stable and reliable operation of the system.

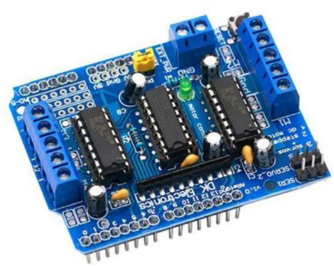


Figure 85: L293D Motor Driver

4.6.2 Second Trail

After encountering overheating issues with the L293D motor driver, we decided to replace it with the L298N Dual H-Bridge. This motor driver has proven to be effective in controlling our two stepper motors, with a rated current of 1.2 A, and has not experienced any overheating issues. As a result, we have decided to use the L298N Dual H-Bridge as our primary motor driver for the project. It has proven to be a stable and reliable choice that allows stepper motors to operate effectively.

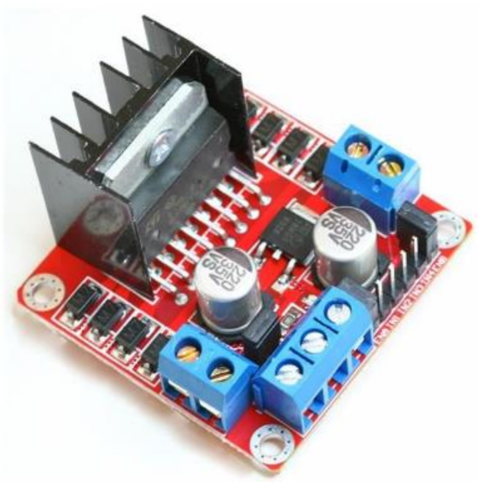


Figure 86: L298N Dual H-Bridge

4.7 RASPBERRY PI

For our ground station, we employed a Raspberry Pi as the main server for receiving and processing GPS data and a video stream. The Raspberry Pi's compact size and low power consumption made it an ideal choice for this application. It was able to effectively handle the incoming data and video stream, ensuring that the information was accurately transmitted to the necessary systems and devices. By using a Raspberry Pi as the primary server, we were able to efficiently operate the ground station and effectively track and monitor the transmitter.

4.7.1 First Trail

In our ground station, we utilized a Raspberry Pi 3 as a server to receive data from the transmitter and a video stream from an ESP-32 camera. However, we encountered a problem with this setup as the Raspberry Pi 3 lacks an LCD screen, which made it impossible to view the video in real time. This limitation hindered the effectiveness of the system and made it difficult to fully utilize the video stream. To address this issue, we may need to consider incorporating an external display or using a different device with an integrated LCD screen. Alternatively, we could explore other options for accessing the video stream, such as streaming it over the internet or saving it to a storage device for later viewing.

Figure 87: Raspberry Pi 3

4.7.2 Second Trail

To enhance the functionality and performance of our ground station, we decided to upgrade from a Raspberry Pi 3 to a Raspberry Pi 4. The Raspberry Pi 4 offered improved processing power and additional features, including an integrated LCD screen. This allowed us to easily view the video stream in real-time, which was not possible with the Raspberry Pi 3 due to its lack of an LCD screen. The use of the Raspberry Pi 4 and its built-in LCD screen greatly improved the ease of use and monitoring capabilities of the ground station. The enhanced performance of the Raspberry Pi 4 also enabled us to process and manage the incoming data and video stream.

Figure 88: Raspberry Pi 4

4.8 FINAL PRODUCT

In the end, to make sure that the tracking antenna is working properly and without any problems, and even after making sure that all the parts are added and all the algorithms are working, we had to make sure that the last test was done to make sure that the algorithms, which are the main part of the project, work. Installing the antenna at one fixed point, taking its coordinates, determining the first point for the transmitter, and tracking the transmitter begins, provided that there is nothing that hinders cutting the signal between the antenna and the transmitter. The signal is often strong and easy to track, but in the event of its interruption, the prediction algorithm that we talked about above will work, as it tries to capture the signal again.

Figure 89: Ground Station

Figure 90: Ground Station 2

Figure 91: Ground Station

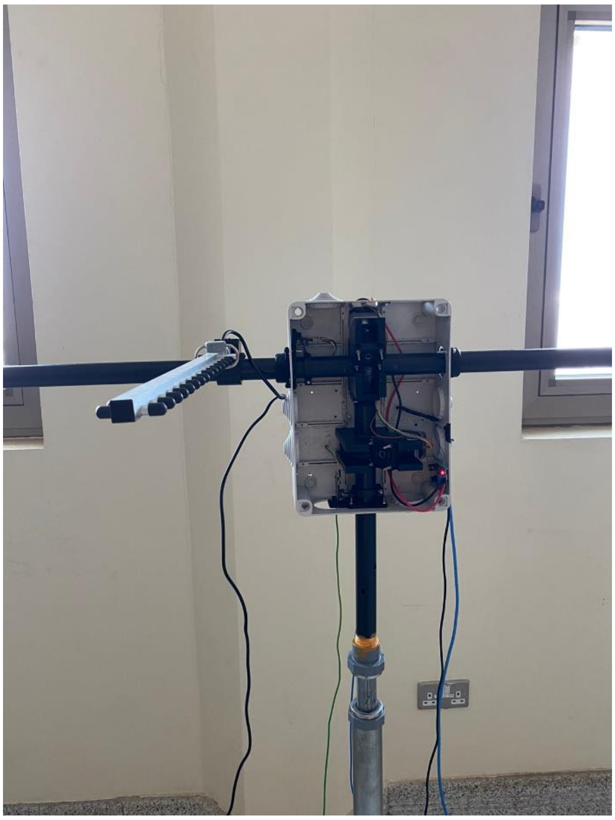


Figure 93: Ground Station 3

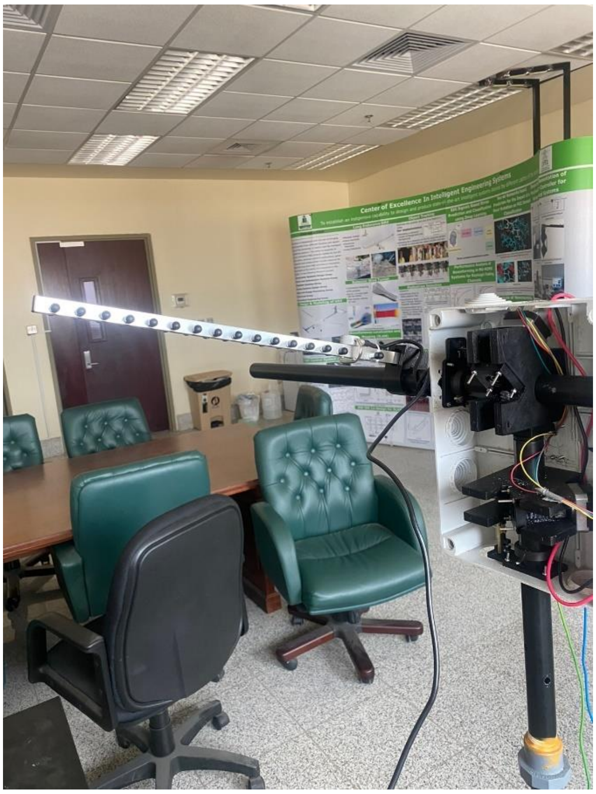


Figure 92: Ground Station 4

Figure 95: Ground Station 5

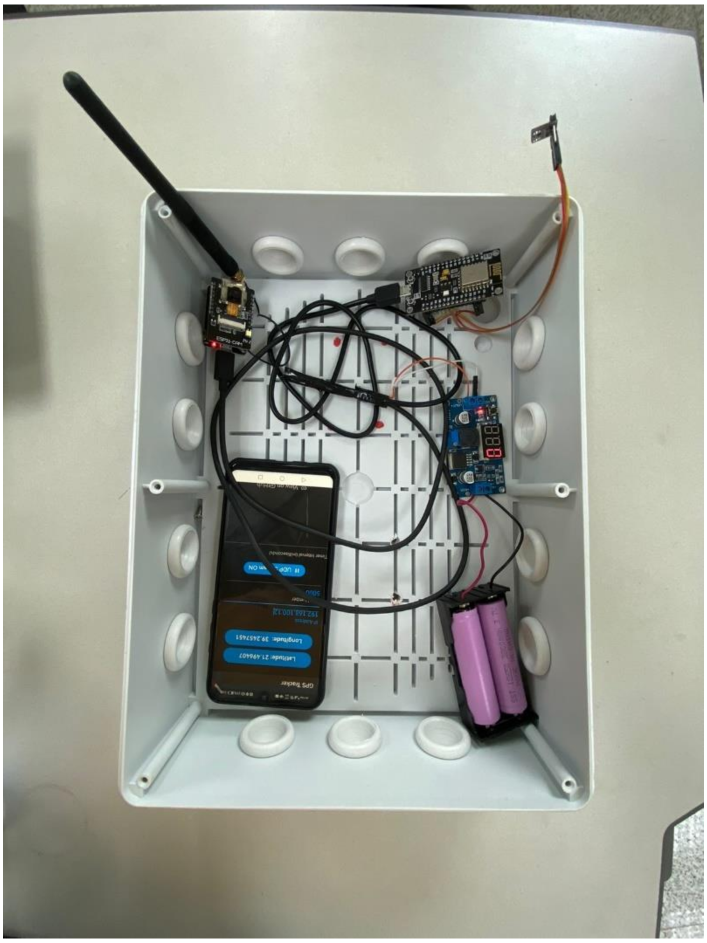


Figure 94: Trnsmmiter Circut

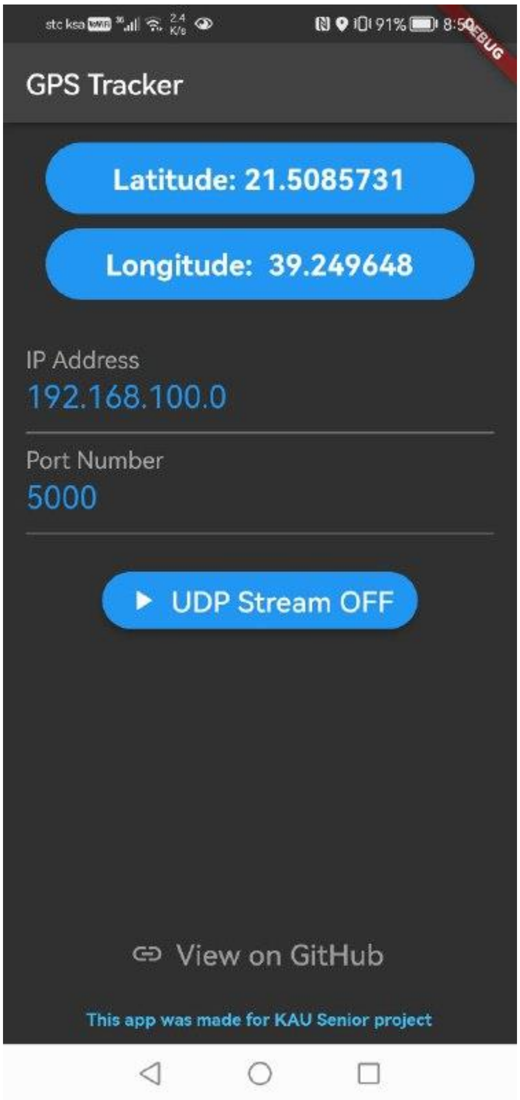


Figure 96: Mboile application for GPS Track

CHAPTER – 5 RESULTS, DISCUSSION, AND CONCLUSIONS

5.1 RESULTS AND DISCUSSION

5.1.1 Barometer sensor

First, to track the signal of the transmitter, we must have its coordinates. These coordinates are latitude and longitude, with altitude relative to the transmitter. The altimeter is based on the transmitter's height above sea level. In the beginning, we relied on measuring the height using phone applications, which were not accurate with us in measuring the height and were giving us different numbers for the same place, so we could not get accurate results for the altitude, so we touched on measuring the height of the transmitter with a barometer sensor to give us accurate results Calculates the altitude around sea level for the transmitter. Summary of this sensor, it is a sensor that detects atmospheric pressure and with which altitude can be known. The barometer sensor gives us a measure of the height of the transmitter, and the sensor depends on the air pressure around it, which means that the height varies according to the air pressure around it, and this is what makes it very accurate in the measurement process. The obstacle to this sensor may be the presence of strong winds, which leads to fluctuations in the height measurement, but this rarely happens. We were able to achieve good and accurate readings by doing several tests that we ran on the sensor, and as shown in the image below, the result of the readings for this sensor.

```
 51.49
Approx altitude = 51.46 m

 51.46
Approx altitude = 51.49 m

 51.49
Approx altitude = 51.48 m
```

Figure 97: Barometer sensor

5.1.2 Prediction Algorithm

discussing the use of an algorithm to find out the direction of the sender. This algorithm is based on signal loss from the transmitter. After the transmitter loses the signal, the prediction algorithm predicts the direction of the transmitter based on the previous coordinates (latitude, longitude, and altitude). We've touched on using the Kalman filter in prediction, but we've run into the problem that it gives us results that are too far away. When we tested the filter, we found that it needs to take 12 values or more to give us the result we want. For this, the Kalman filter relies on a large number of preset values to predict a nearby location. For this purpose, we used the standard deviation equation, and its results were very accurate and close to predicting the path of the transmitter. Whether it is a longitudinal or circular path. By comparing the two, we find that both can predict correct numbers, but the problem was in the accuracy that we wanted. The following table shows you the comparison between the two using the previous coordinates of the sites.

Table 23: Coordinates Tabel

<table>
<tr><th>#</th><th colspan="4">Coordinates</th></tr>
<tr><td>1st</td><td colspan="2">21.496927153241973</td><td colspan="2">39.24467613052363</td></tr>
<tr><td>2nd</td><td colspan="2">21.49695820166792</td><td colspan="2">39.24490415694486</td></tr>
<tr><td>3rd</td><td colspan="2">21.49699183745521</td><td colspan="2">39.24507100554577</td></tr>
<tr><td>4th</td><td colspan="2">21.497466002529563</td><td colspan="2">39.247517420613654</td></tr>
<tr><td>5th</td><td colspan="2">21.49745194943539</td><td colspan="2">39.24779990183834</td></tr>
<tr><td>Algorithm</td><td colspan="2">Kalman Filter</td><td colspan="2">Standard Deviation</td></tr>
<tr><td>Result</td><td>23.836669921875</td><td>43.5189323425293</td><td>21.497583148483745</td><td>39.24858084466702</td></tr>
</table>

After the comparison that we made in the table above, we note the result for both algorithms, and by taking five prior coordinates, we find that Kalman gave us a very far coordinate because it depends on having more than 12 prior coordinates to give us the result we want, while the standard deviation algorithm gave us a good result, which is what we wanted.

The images below show you an example of how the standard deviation algorithm works by giving it latitude and longitude coordinates and giving it random altitude values. The altitude was confirmed after the experiment.

Figure 98: first location

Figure 99: Second location

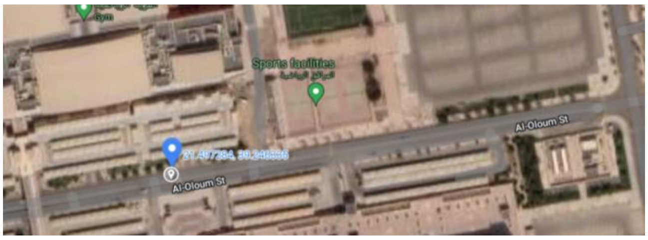


Figure 100: Third location

Here you will see the result of predicting the path of the sender. And use the result of the new coordinates of the transmitter.

```
[21.497312255695164, 39.246601350565385, 65.0]

Process finished with exit code 0
```

Figure 101: GPS Data

Figure 102: GPS Location

5.1.3 obstacles

The antenna succeeded in tracking the signal of the transmitter and succeeded in the prediction process when the signal was lost, and the only obstacle in the tracking process was the presence of a delay in tracking the signal, this causes a delay in the movement of the antenna towards the transmitter, and the delay also occurs when predicting the location of the transmitter. It is not possible to pick up a signal from the transmitter clearly in the presence of this delay because it may cause continuous interruption of the signal, so the solution to this was to receive the coordinates quickly so that we can receive a signal from the transmitter clearly and not interrupt it quickly. Also, one of the obstacles is the batteries, because we depend on batteries a great deal. In the first experiment, our obstacle was because of the low current.

5.1.4 Accuracy of the algorithm software

Figure 103: Test positions

Measuring the accuracy of the algorithm and real information is very important, this is done by taking the values from the output of the function and compared with values of the coordinates of the GPS, the values are taken from the last

experiment (4), at this it assigns by (R/A) R is realistic which calculates by taking the
coordinates of the GPS from google map, and A means the values the tack it from our system.

Position	Distance(R/A)		Horizontal angle(R/A)		Vertical angles (R/A)		Distance error(%)	Horizontal error(%)
X1	18.25	19	-65.7	-65.8	15	15.5	0.273224044	0.152207002
X2	20	20.8	35.32	35.3	15	15.3	0.497512438	0.056625142
X3	38.02	38.5	-25.21	-25.3	16	16.2	0.026308866	0.35700119
X4	38.19	38.2	24.29	24.31	16	16.1	0.02617801	0.082338411
X5	28.3	28.2	-4	-3.9	15	15.1	0.354609929	2.5
X6	88.12	88.14	12	12.3	15.3	15.3	0.022691173	2.5
X7	43.3	43.31	32.12	32.2	15.9	15.8	0.023089356	0.249066002
X8	11.12	11.11	92.2	92.3	15.6	15.7	0.090009001	0.10845987
X9	20	20.1	88	87.8	16.2	16.21	0.497512438	0.227272727
X10	41.21	41.2	27	27.6	16.3	16.33	0.024271845	2.222222222

Table 24: Output of the algorithm of the accuracy

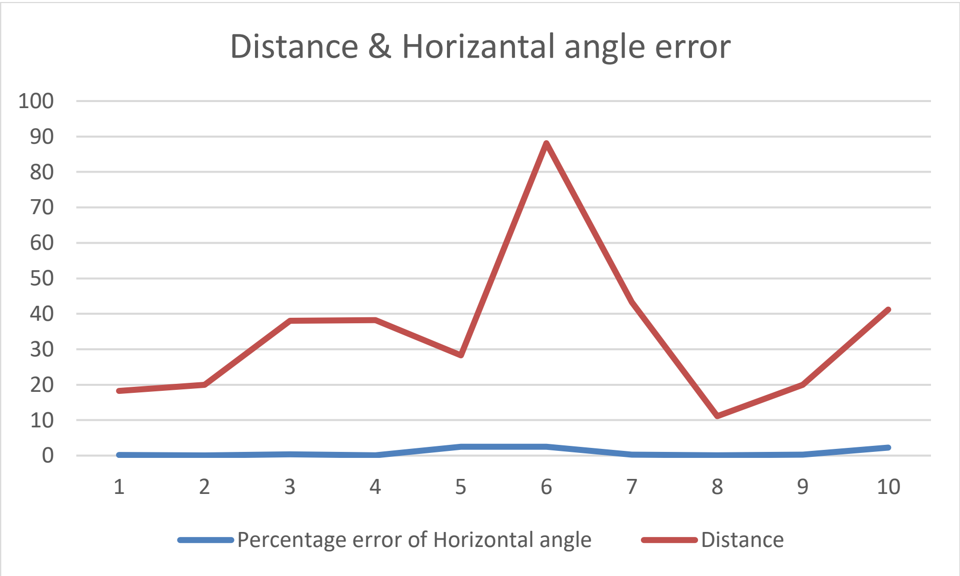


Figure 104: the relationship between the distance and percentage at the horizontal angle

At this, it clarifies the relationship between the real distance and horizontal angle error, in which there is a slight increase at positions but it satisfied the requirements of limitation of the error, reaching to results will give an accurate step of the motor.

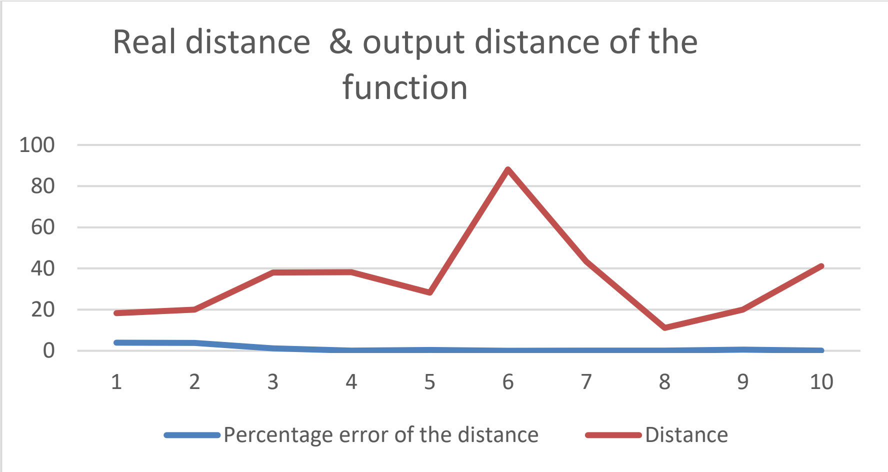


Figure 105: the relationship between real distance and output distance of the function

As shown in this figure it is clear that when the distance near the ground station the percentage error increase, for our main algorithm the team put a simple condition that the track done after 20 M from the tracker due to the error, which means the algorithm of GPS is not accurate from near places, about elevation

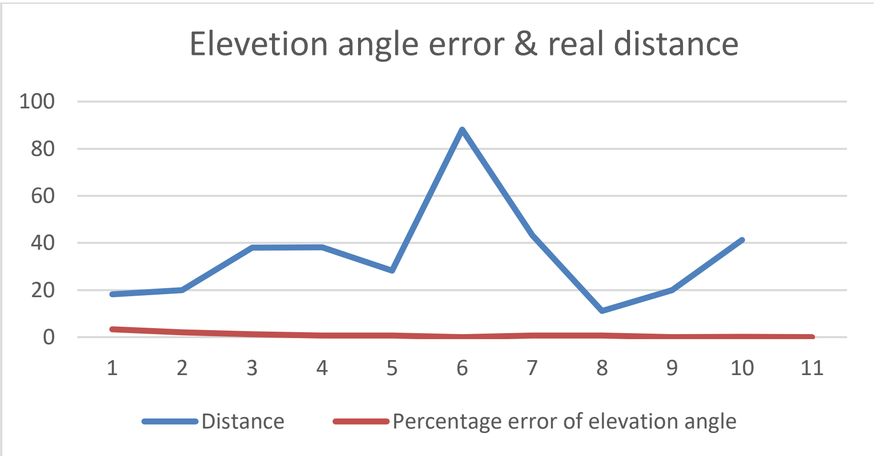


Figure 106: the relationship between real distance and output of elevation angle function

This figure is calorie the relationship between the percentage error of elevation angle and real distance, it is clear that the error is increasing at near distance from the tracker due to the GPS algorithm which is not accurate from a near distance, but increasing the distance it gives more accurate, anyway the values of the error are safety for our system, and we ignore the issue the near distance by adding a simple condition that the track only after 28 M, less than 28 M the video stream of the transmitter could able a high quality without any issue.

5.2 EVALUATION OF SOLUTIONS

When performing the solutions for the final product, it is time to analyze technical aspects and the environmental impact, financial also, these discussions are very important for making a quick review of the product from different angles.

5.2.1 Technical Aspects

About the technical aspect of the final product, it satisfied the main requirements of the customer and the final product is viewed and accepted, the tracker station is now able to track the transmitter by transferring a high-quality video, and it is portable and it uses low power consumption, with a fixed place of the ground station as customer need, but the range of the tracking less than 2 km due to the quality of the antenna, the design of the antenna it was not from our tasks to solve it just by same has same specifications but another brand, for our project the customer need to install a specific application at the mobile phone then put with the transmitter, which could in the future replace with a high technology GPS module instead of mobile phone, otherwise the product is highly efficient and the algorithms are deal with all contingency situations like recapture if the signal of the transmitter loses

5.2.2 Environmental Impacts

There are positive and negative environmental factors and effects to every project, but the negative environmental effects must be reduced, as they may harm the environment. In this part, we will discuss the environmental effects of the project, which would affect community service and help raise and develop the quality of life.

5.2.2.1 Battery

Many batteries are made of lead. There are negative effects of this substance, including that it causes a problem to the environment, which leads to an impact on human health. This is what will make us careful in its use.

5.2.2.2 ESP32

One of the components of ESP32 is that it is in the form of a PCB with a small amount of copper in it. This copper can be extracted, recycled, or used instead of mining copper ore. PCBs also contain semiconductors and can be recycled and used.

5.2.2.3 Camera

Cameras are often made up of a variety of components, each with its chemical properties. First, is the glass, which is the main part of the camera, and consists of a material (CO2) to form it. Also, one of the advantages of glass is that it can be recycled without losing any of its properties. The cameras also contain PCBs, which are made of copper and semiconductors, and copper can be built and used in a Variety of Applications The rest of the parts consist of copper, aluminum, and plastic and can also be used in a variety of applications.

5.2.2.4 Radiation

We know that the radiation is emission radiation of electromagnetic waves, about the human effect, is dependent on the amount of radiation received, and the type of that radiation, and the manner, length of time exposed, for our product deal with a gain of 25 dbi narrow beam radiation antenna, 2.4 GHz which not consider as harmful for the human according to the world health organization.

5.2.2.5 Switch

The switches differ from each other, and most are made of actual materials. The materials mustn't be corrosive, because corrosion will result in the accumulation of insulating oxides, and this may cause harm to humans, and also will prevent the switch in the switch. For this, corrosion-resistant connecting materials are selected. We will choose a switch with good specifications because we will not want to resort to changing it in a short period.

5.2.2.6 Stepper motor

Inside the stepper motors, there is a magnet trapped in the middle of the rotor which helps or causes axial voltage and helps the motor to rotate. Wire coils form the stator in the various phases of the motor. But there are no parts harmful to the environment and humans.

5.2.3 Safety Aspects

Regarding the safety of this product is moving the antenna could be harmful if it bumped into anybody near the ground station, for that keeping 3 M, also the ground should set in stable flat ground, the electronic components of the ground station is sensitive to the water for that do not use it during rainy weather, also the user should use the recommended battery 12 V to the all the circuits at the ground station tracker.

5.2.3.1 Chemical risk

In general, batteries are used in several kinds of projects. Our project depends on the power supply, and we used the battery as a power supply, there is a risk from using this battery and this may impact human health and nature, Use of acids materials, corrosive electrolytes, and highly ignitable explosive materials became an issue for human health impact and environment. The result of this impact also depends on the size of the battery, also temperatures have a significant impact on battery performance. In our project, we used almost two kinds of batteries small and big. We're very careful when we make tests of our project outside the building because of the temperature of the weather. We must take care of the liquid materials resulting from the batteries.

5.2.3.2 Electrical risk

Electrical Circuits:

As we know in any project there are electrical circuits in which there must be electrical safety. Electricity can lead to severe human damage, injuries, burns, damage to property or damage to the entire project. There must be safe from these damages, which can be avoided by doing periodic maintenance of the electrical circuit of the project.

Electrical Wires:

We must be careful not to touch or approach the wires in the electrical circuits, because it may lead to burns or damage to the same project. The wires are made of metals that contain free electrons, that is, they are good conductors of electric current. This can be avoided by insulating metals so that the electric current does not leak when touching the body of the person who uses it and causing harm.

5.2.3.3 Mechanical Energy Risk

Motors:

The motors in our project are operated by electric power, and when operating these motors, there must be an element of risk. This motor can lead to project damage or environmental damage in general caused by excess power (overload) on the motor. Care must be taken to control the electric power supplied to the motors.

5.2.4 Financial Aspects

This table will define the cost of each essential part of the final product, here the table is done in five columns the first one defines the component for each part and the quantity, then the price for each then the total price which includes shipment, and finally the store of the component including the address of the website if it is electronic store in the references.

Table 25: Project cost analysis

Components	Quantity	Price (SR)	Total(SR)	Shop/Website
ESP32 cam`	1	19	26	AliExpress
Yagi antenna	1	63	71	AliExpress
Arduino Mega	1	60	60	amazon.sa
Stepper motors	2	50	100	AliExpress
Drivers	2	33	66	amazon.sa
Plastic box	1	90	100	Banggood.com
IR sensor	2	13	26	AliExpress
Printed gear	1	15	15	Manufacturing Club
Raspberry Pi 4	1	730	730	(amazon.sa)
Screen	1	215	215	(amazon.sa)
DC-DC circuit	2	41	82	(amazon.sa)
Battery 12 V	1	107	107	(amazon.sa)
Mobile phone	1	380	380	AliExpress
ESP8266	1	42	42	(amazon.sa)
BME280 sensor	1	35	35	|Qariya.net متجر القرية| BME280
Battery 4 V	2	44.25	70	Ali baba
Total (SR)	2125			

5.2.5 Social Impacts

As we know, our project is a robotic system to track the transmitter, hence extending the range of control of any transmitter from wide distances, which helps to solve a lot of problems in any applications dealing with the transmitters, for example In the media field for video transmitting especially in hard to reach places such as in football studio, cover some natural places, etc., and in army fields that there are a lot of applications need to control the transmitter from a far way like border control, it is hard to do it without this product for the control the transmitter, but in another side of the coin it possible to use in illegal applications which were hard to do it in the past, like jamming and hacking device deal any transmitter within the range of the station.

5.3 CONCLUSIONS

The need for directional tracking antennas has long been a topic of interest in the field of communication technology. These antennas are used to track and communicate with transmitters located at long distances, making them an important tool for a variety of applications such as military, aviation, and satellite communication. In our project, we set out to design and develop a prototype of a directional tracking antenna that would be able to accurately track a transmitter from a long distance away.

To solve this problem, we utilized a variety of techniques including signal processing, and antenna design, Through careful experimentation and analysis, we were able to achieve a high level of accuracy in our prototype, making it a promising solution for tracking transmitters from long distances.

In the final stages of our project, we were able to demonstrate the effectiveness of our prototype in a variety of different scenarios, showing that it was capable of accurately tracking a transmitter even under challenging conditions. Overall, our project was a success and we were able to make significant progress toward the development of a practical and reliable directional tracking antenna.

In terms of future improvements, there are a few recommendations we would make to take our prototype to the next level and bring it to market as a final product. One potential avenue for improvement would be to optimize the antenna design and signal processing algorithms to increase the accuracy and range of the tracking system. Additionally, further testing and evaluation would be necessary to ensure the reliability and robustness of the system in a variety of different environments and scenarios.

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APPENDIX – A: VALIDATION PROCEDURES

EE499

Senior Project

Term Project

Report-6_ValidationExperiments _S22_Team-03

Team 3

Advisor Name

Dr. Mohammed Belal

Advisor Name

Date: 1/12/2022

Mem	Name	ID
M1	Ammar Yaser	1768459

Contents

Introduction :

The design of tracking directional antenna, stating by choosing which method that I choose for know the location of the transmitter, we assign to find the location of the transmitter according to GPS coordinates which consider more reliable and efficient, but we need now to calculate the horizontal angle between two locations also the elevation angle but are important for setting up moving off the horizontal and vertical motors of the tracker station.

Elevation angle algorithm :

Implementing an algorithm for calculating the elevation angle between the ground station and transmitter and the distance between each, which are very important to set up moving of vertical motor for directional antenna and is done by applying the haversine formula :

Distance N-S = (Latitude2-Latitude1) × PI/180

Distance E-W = (Longitude2-Longitude1) × PI/180

Distance Vertical = Altitude2 - Altitude1

Haversine =Sin^2(Distance N-S/2)+cos(Latitude1) ×cos(Longitude2) ×Sin^2(Distance E-W/2)

C=2 × asin(Square root (Haversine))

Distance =C × 6371 ×1000

Then Elevation angle = ArcTan (Distance Vertical / Distance)

Horizontal angle algorithm :

Implementing the algorithm of the horizontal to calculate the angle between two coordinates ground station and transmitter GPS, which is important for setting up moving of horizontal motor, and then apply it :

Distance E-W = (Longitude2-Longitude1)

y = sin(Distance E-W) ×cos(lat2)

x = cos(lat1) × sin(lat2) - sin(lat1) × cos(lat2) × cos(Distance E-W)

the Horizontal angle = ArcTan (y/x)

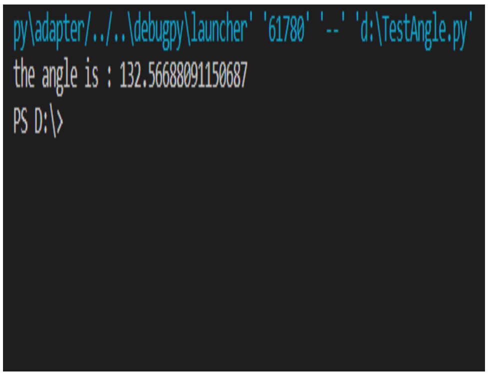

Figure 107 the output of the function

Figure 108 Successful measuring of the angle between Jamaa store to Andulisia hospital (clock wise).

Figures 107 & 108 successfully measured the angles between two coordinates of GPS, which we use Google Maps to check.

Calibration of the steps of the stepper motor and the output of the function :

We know that the output of our functions is in degrees, another side of the coin is the motors moving according to steps, I and M2 we calculate the full movement of the horizontal motor to move it as 180 degrees, and the same thing vertical angle as 90 degrees, the equation of the calibration of the steps of the motor and output degrees of horizontal & vertical angle :

Steps of horizontal motor :

$$\frac{Horizantale\ angle}{360} \times 12500(the\ full\ steps\ of\ Horizantal\ motor)$$

Steps of vertical motor :

$$\frac{Vertical\ angle}{90} \times 3500(the\ full\ steps\ of\ vertical\ motor)$$

Now after applying these algorithms successfully now time for testing for real tracking, but one thing important is the differences between steps why ? as example when you take the first coordinates angle let is say 60 degrees then the drone will move to the next place to 70 degrees the directional antenna should set up the moving of horizontal motor as 10 degrees, but if you give it directly without differences it will move for huge distance very far from the direction of the transmitter.

Applying the algorithm by single stream array

Now time for testing the algorithm in the real case, so the receiver will receive the coordinates as a single array from the transmitter (latitude, longitude, altitude) as :

coordinates=[21.49593857365895,39.24316040651554,20,21.497810370746773, 39.24724450655052,30,21.496637096193083,39.2491611679268,10]

it consists of the coordinates for 3 locations (English Language Institute, college engineering Parking car, parking cars of college sciences) :

```
In [6]: runfile('D:/safeSenior/TestAngle_Live.py', wdir='D:/safeSenior')
Current process :
the horizantal angle is  100.96669732528758
the vertical angle is  -6.31001308997124
the destance is  271.30189529127193
the numbers of steps is : (3506, 245)

Current process :
the horizantal angle is  -42.76180748765124
the vertical angle is  -5.129908298758927
the destance is  222.78214057088996
the numbers of steps is : (-4991, -46)

Current process :
the horizantal angle is  -85.10963133015058
the vertical angle is  -6.426336667214573
the destance is  355.1343158516424
the numbers of steps is : (-1470, 50)
```

Figure 109 Successful output of testing the algorithm

Figure 3, is the output of results from single array coordinates, after that now time for testing the system overall :

Testing the system overall

Our progress start by tacking the coordinates of GPS from the Preparatory year buildings then the college of engineering parking to the college of Science parking, the coordinates were tacked for each milli second for more accuracy, then saves in a CSV file, and my workspace(Live tracking code) will receive these data and append it in a single array which contains respectively the

latitude and longitude and altitude, then apply all algorithms then record the steps of horizontal and vertical motors to send it to the Arduino for setting the moving of motors

Phase one (software)

A	B	C
21.49708	39.24387	73.8
21.49708	39.24387	65.9
21.49726	39.24383	70.6
21.49746	39.24379	71.7
21.49783	39.24367	66.5
21.49801	39.24364	61.4
21.49801	39.24364	57
21.49838	39.2436	51.3
21.49873	39.24397	44.6

Figure 111 sample of coordinates GPS

A	B
2325.822	-252.522
-163.698	-17.585
-154.6	2.582
-221.521	59.76
-100.817	47.268
-91.577	34.206

Figure 110 sample of the output steps

As shown in figure 3 our data set is a group of coordinates of GPS, which is tacked from mobile; phone record the coordinates of GPS at each milli second, then at figure 4 we see the output of the steps calculated by the algorithms that we discussed before.

Figure 112 recording the coordinates of GPS

Recoding the coordinates of GPS is done by installing a program into a mobile phone called IMU sensor, and establishing a code in the laptop to receive the data from a mobile phone, via an access point which was the ESP32 microcontroller.

Phase two (practical testing) :

After testing the algorithms in the software, now time to implement them at the ground station the main task now is to transfer the steps of the motors vertically and horizontally to the main unit (Arduino) from the computer at the beginning of the moving of motors was not accurate, and there is an additional Steps which more than I need, the team thought from a serial communication issue between the computer and Arduino, but the problem was from the setting of motors which read only integers not float, so immediately I convert the steps of two motors to integers.

A	B
2326	-253
-164	-18
-155	3
-222	60
-101	47
-92	34
-90	10

Figure 113 the steps of the stepper at the integer form

Figure 9directional antenna refers to the primary year building

Figure 10 directional antenna refers to the parking of engineering college

Figure 11directional antenna refers to the sport building

Figure 12 directional antenna refers to the scenes parking car

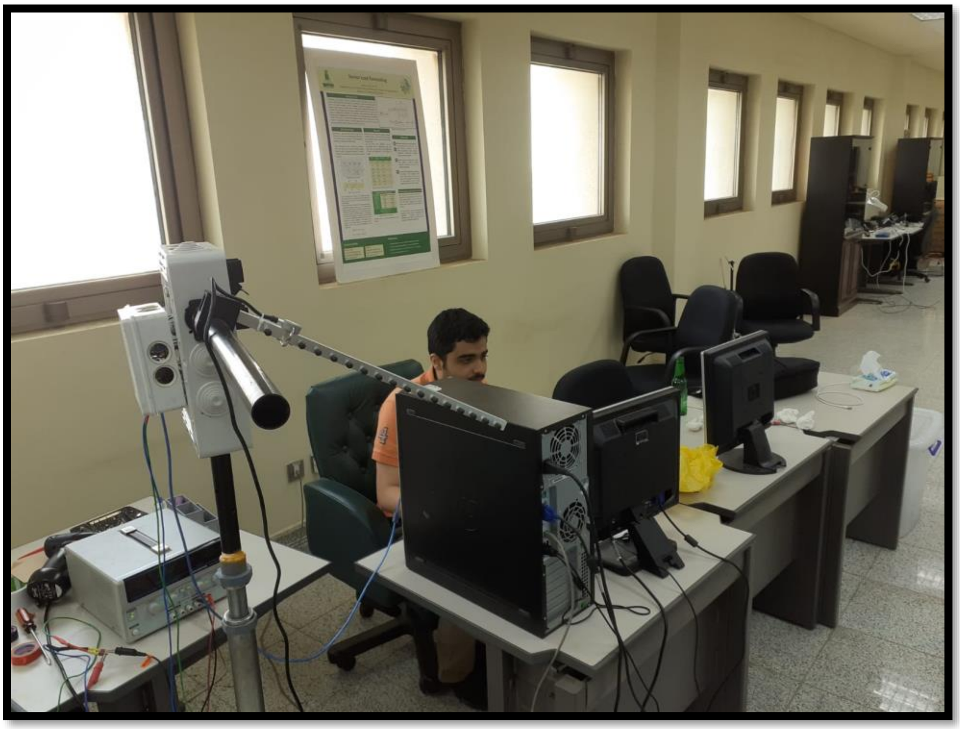

Figure 13 the station of the tracking antenna project during test

As we notice from figures 9 to 12, a successful tracking of the coordinates of GPS, actually was not from the first time, transferring the steps to the Arduino was not simple, especially the serial communication protocol, and debugging the errors during the transfer of the data.

Conclusion :

After successfully testing the algorithms in the software, and in the practical the rest is applied with the transmitter to test the real live tracking and measure the maximum distance of the directional antenna, which may face a lot of problems during these experiments.

12/1/2022

King Abdulaziz University
Faculty of Engineering
Department of Electrical and Computer Engineering

Senior Design Project EE499
Design of Tracking Directional Antenna

Report-6 _Validation Experiments _S22_Team-03

Team-3		
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Introduction

This experiment was for testing the tracking mechanism of the Design of the Tracking Directional Antenna so here is this report will preview the process while testing the track and the process that got through until getting into the tracking function each step will explain and preview the tools that were used this section of the report will only show the tasks of member 2.

Body

Tools

The tools that were used for this experiment:

- 1 stepper motor (Nema 17) 1 A, 12 V for each.
- 12 V battery.
- 2 motor driver module L298N.
- Arduino Mega
- 1 transmitter (ESP32 cam) 5 V.
- Mobile phone for GPS coordinates.
- Raspberry Pi 2 (5 V).
- Wires.
- DC-DC converter.
- Two batteries 3.7 V.
- 2 IR sensors.

Circuit Schematic

The input of 12 V from the battery will feed the two motor drivers one driver will output 5 V and pass it to the Mega Arduino on the other side, DC-DC converter is connected to a 12 V battery, so it will convert the 12 volts to 5 and pass to the raspberry pi, later the raspberry pi will connect serially with the Arduino to pass values into the Arduino.

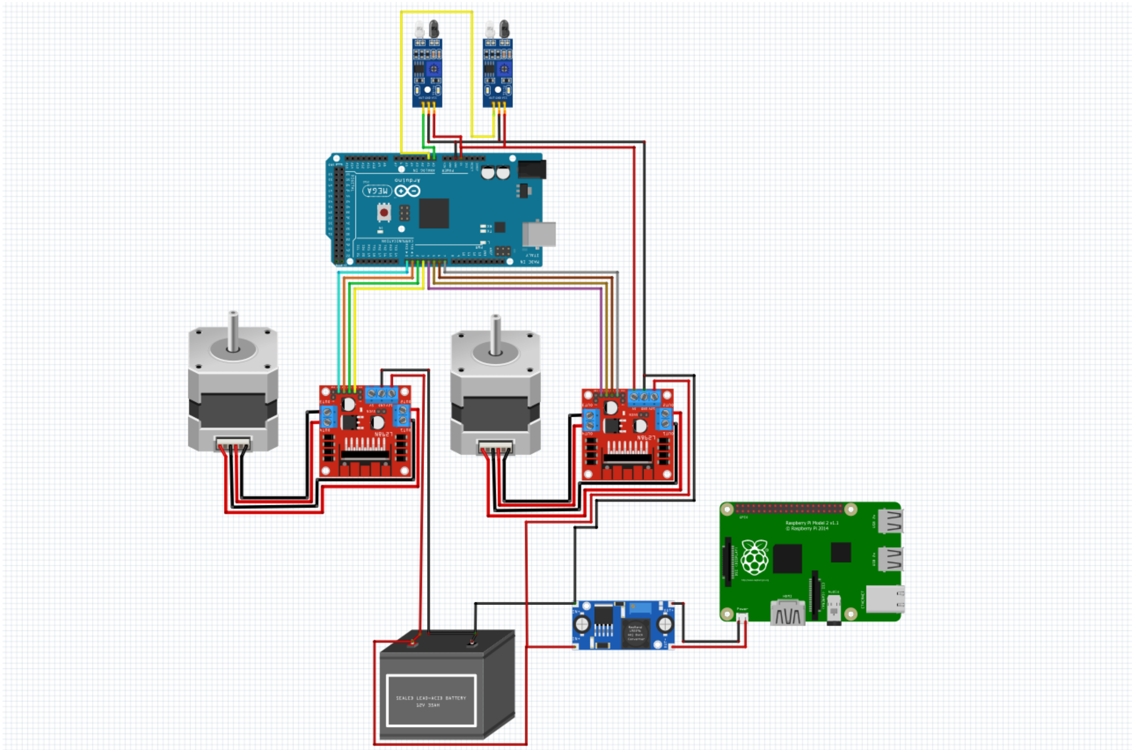


Figure 114: Circuit schematic

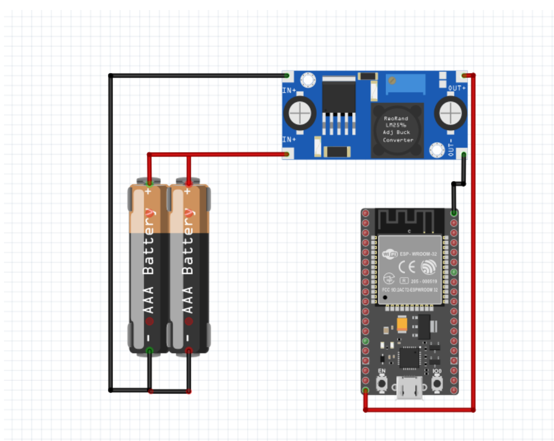


Figure 115: Transmitter Circuit

This is the ESP32 cam circuit, a 7.4 V power supply connected to a DC-DC converter to power up the ESP32.

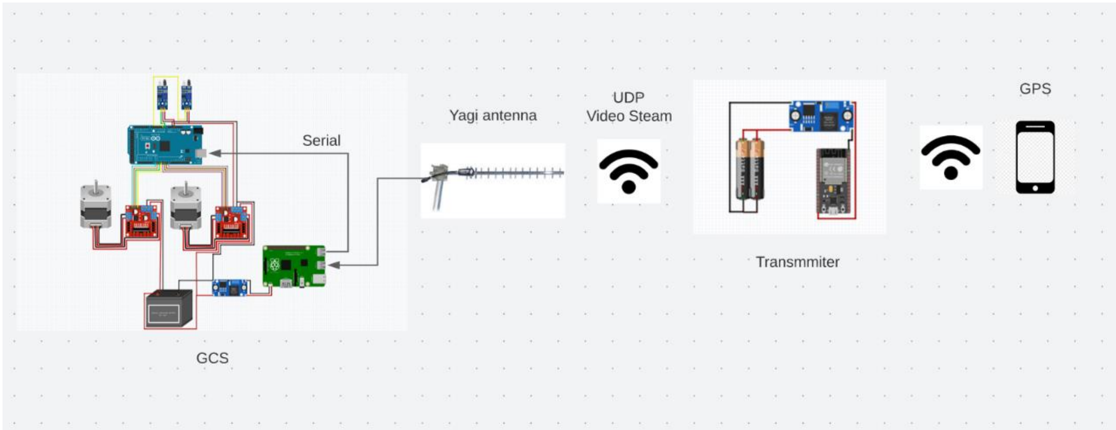


Figure 116: Overall system

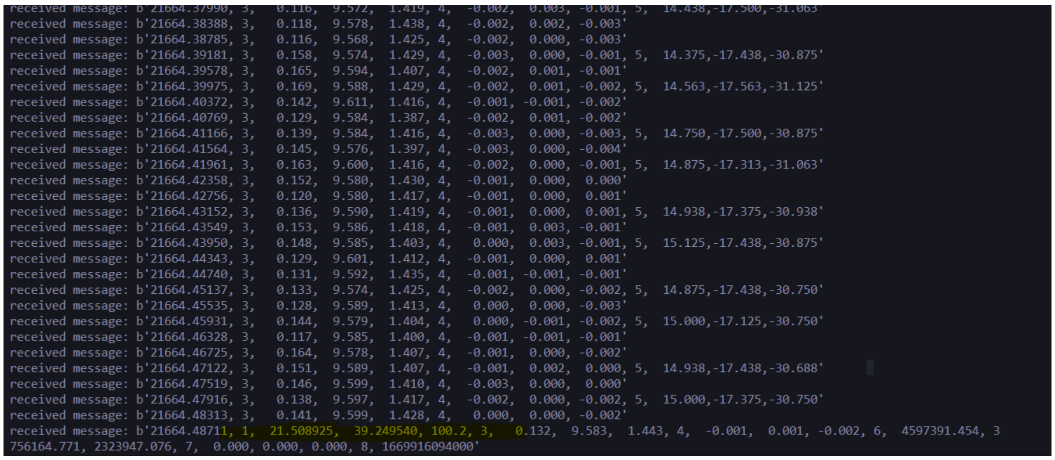
After finishing connecting all the circuits in the GCS and transmitter side now it's time for testing and starting to do some real work to test the design functionality so the first thing was done on the software side work plan section will show the whole step that was done until this time.

Work Plan

1. The first thing needed is to take the GPS coordinates from the mobile phone and send it to the GCS (Rasberry pi) through the transmitter which is the access point of the WIFI.
2. In the Rasberry, pi will implement UDP communication to receive the packet from the mobile phone the protocol that will be used is UDP.
3. Collect the GPS coordinates and save them in a CSV file.
4. Use 2 IR sensors for the calibration of the motor to set the angle for its default value.
5. After doing the math calculations in the raspberry pi for obtaining the number of steps, the raspberry pi will establish a serial communication.
6. Receiving the data in the Arduino from the raspberry pi and moving the motor.
7. After this whole process that what we got is, the need to successfully track the transmitter, take the coordinates of the ground control station(GCS), and make it constant, using this value will calculate the angle between that two-point later will covert this angle into several steps so it will start the tracking process.

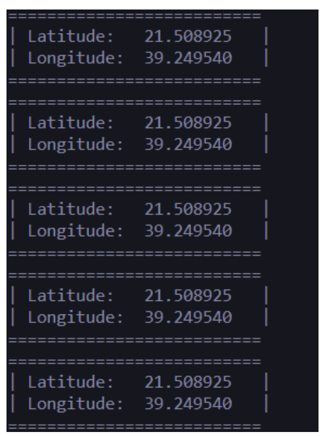
Data collection

While doing this experiment data collection is needed to make sure that the functionality of the prototype is work as planned so starting to preview the dataset that was collected through the process.



```
received message: b'21664.37990, 3,   0.116,  9.572,  1.419, 4,  -0.002,  0.003, -0.001, 5,  14.438,-17.500,-31.063'
received message: b'21664.38388, 3,   0.118,  9.578,  1.438, 4,  -0.002,  0.002, -0.003'
received message: b'21664.38785, 3,   0.116,  9.568,  1.425, 4,  -0.002,  0.000, -0.003'
received message: b'21664.39181, 3,   0.158,  9.574,  1.429, 4,  -0.003,  0.000, -0.001, 5,  14.375,-17.438,-30.875'
received message: b'21664.39578, 3,   0.165,  9.594,  1.407, 4,  -0.002,  0.001, -0.001'
received message: b'21664.39975, 3,   0.169,  9.588,  1.429, 4,  -0.002,  0.001, -0.002, 5,  14.563,-17.563,-31.125'
received message: b'21664.40372, 3,   0.142,  9.611,  1.416, 4,  -0.001, -0.001, -0.002'
received message: b'21664.40769, 3,   0.129,  9.584,  1.387, 4,  -0.002,  0.001, -0.002'
received message: b'21664.41166, 3,   0.139,  9.584,  1.416, 4,  -0.003,  0.000, -0.003, 5,  14.750,-17.500,-30.875'
received message: b'21664.41564, 3,   0.145,  9.576,  1.397, 4,  -0.003,  0.000, -0.004'
received message: b'21664.41961, 3,   0.163,  9.600,  1.416, 4,  -0.002,  0.000, -0.001, 5,  14.875,-17.313,-31.063'
received message: b'21664.42358, 3,   0.152,  9.580,  1.430, 4,  -0.001,  0.000,  0.000'
received message: b'21664.42756, 3,   0.120,  9.580,  1.417, 4,  -0.001,  0.000,  0.001'
received message: b'21664.43152, 3,   0.136,  9.590,  1.419, 4,  -0.001,  0.000,  0.001, 5,  14.938,-17.375,-30.938'
received message: b'21664.43549, 3,   0.153,  9.586,  1.418, 4,  -0.001,  0.003, -0.001'
received message: b'21664.43950, 3,   0.148,  9.585,  1.403, 4,   0.000,  0.003, -0.001, 5,  15.125,-17.438,-30.875'
received message: b'21664.44343, 3,   0.129,  9.601,  1.412, 4,  -0.001,  0.000,  0.001'
received message: b'21664.44740, 3,   0.131,  9.592,  1.435, 4,  -0.001, -0.001, -0.001'
received message: b'21664.45137, 3,   0.133,  9.574,  1.425, 4,  -0.002,  0.000, -0.002, 5,  14.875,-17.438,-30.750'
received message: b'21664.45535, 3,   0.128,  9.589,  1.413, 4,   0.000,  0.000, -0.003'
received message: b'21664.45931, 3,   0.144,  9.579,  1.404, 4,   0.000, -0.001, -0.002, 5,  15.000,-17.125,-30.750'
received message: b'21664.46328, 3,   0.117,  9.585,  1.400, 4,  -0.001, -0.001, -0.001'
received message: b'21664.46725, 3,   0.164,  9.578,  1.407, 4,  -0.001,  0.000, -0.002'
received message: b'21664.47122, 3,   0.151,  9.589,  1.407, 4,  -0.001,  0.002,  0.000, 5,  14.938,-17.438,-30.688'
received message: b'21664.47519, 3,   0.146,  9.599,  1.410, 4,  -0.003,  0.000,  0.000'
received message: b'21664.47916, 3,   0.138,  9.597,  1.417, 4,  -0.002,  0.000, -0.002, 5,  15.000,-17.375,-30.750'
received message: b'21664.48313, 3,   0.141,  9.599,  1.428, 4,   0.000,  0.000, -0.002'
received message: b'21664.48711, 1,  21.508925,  39.249540, 100.2, 3,   0.132,  9.583,  1.443, 4,  -0.001,  0.001, -0.002, 6,  4597391.454, 3
756164.771, 2323947.076, 7,  0.000, 0.000, 0.000, 8, 1669916094000'
```

Figure 117: receiving GPS through UDP



```
=========================
| Latitude:    21.508925   |
| Longitude:  39.249540   |
=========================
=========================
| Latitude:    21.508925   |
| Longitude:  39.249540   |
=========================
=========================
| Latitude:    21.508925   |
| Longitude:  39.249540   |
=========================
=========================
| Latitude:    21.508925   |
| Longitude:  39.249540   |
=========================
=========================
| Latitude:    21.508925   |
| Longitude:  39.249540   |
=========================
```

Figure 118: check GPS values

Before doing the calculations and processing them, it's better to double-check that the values that are received the correct.

Figure 119: First test

As shown in the figure above the first test, after collecting all those GPS coordinates and extracting the number of the steps now to make sure we need to see how the GCS will react and it must follow this pass shown in the figure.

Figure 120: During the first Test

21.49716	39.24969	39.6
21.49716	39.24969	39.6
21.49716	39.24969	39.6
21.49766	39.2496	43.7
21.49766	39.2496	43.7
21.49769	39.2496	43.7
21.49769	39.2496	43.7
21.49772	39.24959	43.6
21.49772	39.24959	43.6
21.49772	39.24959	43.6
21.49772	39.24959	43.6
21.49772	39.24959	43.6
21.49772	39.24959	43.6
21.49772	39.24959	43.6
21.49772	39.24959	43.6
21.49786	39.24958	44.2
21.49786	39.24958	44.2
21.49786	39.24958	44.2
21.49786	39.24958	44.2

Figure 121: Some of The GPS coordinates

2326	-253
-164	-18
-155	3
-222	60

Figure 122: Some of the steps

Figure 123: implement the first experiment

This photo was taken during the tracking process for the above data set, and it was very successful.

Discussion

So while implementing this experiment we face many difficulties to make it successful works, most of the time in the communication part between the transmitter and the GCS data was received and corrupted, after including the data checksum problem was solved, also the serial communication side was very difficult because there was a difference in the speed between the raspberry pi and mega Arduino so there was a lot of reading behind this to learn how to implement the serial communication in the right way later it reveals that the problem was on the delay.

Conclusion

So, after fishing, this experiment now time to work on the communication between the transmitter and GCS while video streaming and also how the algorithm will work during video streaming, one more thing is to test the range of the antenna if it can exceed most 2 Km, but until this moment the progress goes as planned.

12/1/2022

King Abdulaziz University
Faculty of Engineering
Department of Electrical and Computer Engineering

Senior Design Project EE499
Design of Tracking Directional Antenna

Report-6 _Validation Experiments _S22_Team-03

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Dr. Muhammed Bilal

SDP Convener
Prof. Khalid Munawar

Introduction

Every successful project has tasks that require the student to solve issues. In this report, I am going to discuss my tasks of the project which started writing assignments and planning for the project. I will go over each aspect of my tasks and cover its details. This report presents my completed tasks, in which I applied what I learned during my academic career at the university

Tasks

1- As we know, our project aims to track drones with an antenna. The antenna enables the drone to be tracked in the horizontal or vertical direction. But it is important to have a GPS device to track the drone. It is assumed that there is an algorithm used for the success of the tracking process, and this is what we will use with this algorithm that enables us to predict the location of the drone. This algorithm will make it easier for us to track the drone by reducing the tracking time of the antenna. This algorithm depends on tracking the GPS device in the drone by knowing the latitude and longitude as well as the first location of this GPS.

2- We tested the tracking antenna to see how well the antenna could track the drone by taking more than one location outside the university building and storing it in a file and testing it on the antenna. In this task, my task is to read a file that contains more than one location (latitude and longitude) and apply an antenna tracking algorithm to track all locations stored within the file.

```
<_csv.reader object at 0x0000016BACB87C40>
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
['21.49533', '39.24415', '49.9']
```

Conclusion

And after completing my previous tasks, I am now going to search for my next task, which is centered on finding the height sensor it is connected to the ESP32-cam and through it, the data is sent to the Raspberry Pi.

APPENDIX – B: SELF ASSESSMENT CHECKLIST

E: Exemplary, **S:** Satisfactory, **D:** Developing, and **U:**Unsatisfactory.

Student Outcome (SO)	Key Performance Index (KPI)	Self-assessment (E, S, D, or U)		
		M1	M2	M3
1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	1.1. Problem Identification	E	E	E
	1.2. Problem formulation	E	E	S
	1.3. Problem solving	S	E	S
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	2.1. Design Problem Definition	E	S	E
	2.2. Design Strategy	S	E	D
	2.3. Conceptual Design	E	S	S
3. an ability to communicate effectively with a range of audiences	3.1. Effective Written Communication	S	D	E
	3.2. Effective Oral Communication	E	S	E
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	4.1. Recognition of Ethical and Professional Responsibility	E	E	E
	4.2. Consideration of Impact of Engineering Solutions	S	S	S
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	5.1. Effective Team Interactions	E	E	D
	5.2. Use of Project Management Techniques	S	D	D
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	6.1. Developing Appropriate Experiment	S	S	D
	6.2. Conducting Appropriate Experiment	E	E	S
	6.3. Analysis and interpretation of Experiment Data and Drawing Conclusions	E	S	E
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	7.1. Effective Access of information	S	E	S
	7.2. Ability to learn and apply new knowledge independently	S	E	S