Misr University for Science and Technology Faculty of Engineering

Department of Electronics and Communication Engineering

B. Sc. Final Year Project

PROJECT TITLE

A Standalone Jammer System Against Drones Utilizing AI For Detection Enhancement

Presented By

ANAS MOHAMED IBRAHIM MUSTAFA	80747
ADEL MAHMOUD MOHAMED	91620
MAHMOUD TALAAT FARAG	91621
MOHAMED ABDALRADY EBRAHIM	91636
PASSANT NAGI MOURICE GHATTAS	91255
RANA ADEL MOHAMED MASRY	91300
MERNA BAHER BADRY FAYEK	91400
RAWAN MAHMOUD ABDELBADIE	91630

***Supervisor/ Prof. Dr*. Mamdouh Gouda**

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DECLARATION

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Bachelor of Science in *(insert title of degree for which registered)* is entirely my own work, that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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Date: Day, xx Month Year.

ACKNOWLEDGMENT

We would like to express our sincere gratitude and appreciation to **Professor Dr. Mamdouh Gouda** *for his invaluable guidance and support throughout the graduation project.*

His experience and dedication have been instrumental in shaping our ideas and guiding us towards successful completion. We would also like to extend our deepest thanks to our family and friends for their unwavering encouragement and understanding.

Their continued support has been a source of motivation and strength during difficult times. Our team would like to acknowledge the contributions of every individual who has played a role in our project, whether big or small. Everyone's input, feedback, and assistance have been critical to achieving our goals.

Finally, we would like to express our gratitude to our fellow team members for their hard work, cooperation, and commitment. Our collective efforts and shared vision have been the driving force behind our project achievements. Thanks again to **Professor Dr. Mamdouh Gouda***, our families, friends, and everyone who participated in the graduation project. Your support and belief in us has made a huge difference, and we are truly grateful for the opportunity to work alongside such exceptional individuals.*

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Overview of the S-A-J system

<u>Presented by/</u>

A. ANAS MOHAMED IBRAHIM MOUSTAFA 80747
B. ADEL MAHMOUD MOHAMED 91620
C. MOHAMED ABDALRADY EBRAHIM 91636

1.1 Introduction

As unmanned aerial vehicles (UAVs) are becoming more accessible and easier to use, the need for a reliable and easy to deploy monitoring solution has become the subject of great importance in defense, security, and commercial sectors. While these aerial platforms bring numerous benefits, they also pose new challenges in terms of security and privacy. To counter the potential threats posed by UAVs, this graduation project book focuses on the development of standalone jamming systems utilizing helical antennas, specifically designed to operate within the frequency range of Global Navigation Satellite Systems (GNSS).

GNSS, encompassing global satellite systems such as GPS, GLONASS, and Galileo, plays a vital role in providing precise positioning, navigation, and timing services for a multitude of applications. However, the increasing prevalence of UAVs has raised concerns about their misuse, prompting the need for effective countermeasures against unauthorized drone operations. By leveraging the unique capabilities of helical antennas and operating within the GNSS frequency range, standalone jamming systems can neutralize UAVs while minimizing interference with legitimate GNSS signals.

The primary objective of this graduation project is to design, develop, and evaluate a standalone jamming system capable of effectively countering UAVs within the GNSS frequency range using helical antennas. Throughout the following chapters, we will explore the fundamental principles of helical antenna design and the specific challenges associated with operating within the GNSS frequency range. Additionally, we will investigate the legal and ethical considerations surrounding the use of jamming technology to ensure responsible deployment.

To achieve our goals, this project will integrate theoretical knowledge with practical experimentation. Through extensive research and analysis, we will gain a comprehensive understanding of the operating principles behind helical antennas and the potential impact of jamming on GNSS systems. Furthermore, we will develop and test a prototype standalone jamming system, evaluating its effectiveness in neutralizing UAVs while minimizing disruption to legitimate GNSS signals.

This graduation project book not only aims to contribute to the field of UAV security but also to foster discussions on responsible implementation and regulation of jamming systems within the GNSS frequency range. By exploring the capabilities of helical antennas and their integration into standalone jamming systems, we hope to offer insights into the development of effective countermeasures against unauthorized drone activities while ensuring the preservation of legitimate GNSS services.

Throughout the chapters that follow, we will embark on an exploration of helical antennas, GNSS frequency range considerations, and the design intricacies of standalone jamming systems targeting UAVs. By the culmination of this project, we envision a robust and responsible solution that protects airspace and maintains the integrity of GNSS services, contributing to the overall security and privacy of our increasingly interconnected world.

1.2 GNSS Spectrum Allocations

Today, all global satellite navigation systems use carrier frequencies in the L−band (1−2 GHz), regional systems use the S−band (2−4 GHz). Several GNSS service providers are considering the future addition of navigation signals in C−band (4−8 GHz).A multiple GNSS systems solution (integrated receivers) is beneficial in signal-obstructed areas such as urban canyons where the visibility of satellites is limited or when the user's receiver is not ideally located on the object being positioned, e.g., inside a car or bag. A multiple frequencies solution will be most useful for improving position accuracy when signal visibility is less of a concern.

The International Telecommunications Union (ITU) allocates the global radio spectrum as well as satellite orbits. GNSS operates in frequency bands allocated to the Radionavigation Satellite Service (RNSS). RNSS is not considered a safety service, unlike services directly allocated to aeronautical use, such as the Aeronautical Radio Navigation Service (ARNS), which is used by terrestrial navigation aids. This is because GNSS supports many different users and applications – not all of which are considered safety services. However, the aviation use of GNSS, based on published standards in ICAO Annex 10, is considered a safety service, meaning that additional precautions are taken to ensure interference free operation.

The ITU have allocated the following L-band frequencies to GNSS (bold are aeronautically used):

- GPS, the center frequencies are 1575.42 MHz (L1), 1227.6 MHz (L2) and 1176.45 MHz (L5).
- GLONASS operates as frequency divisional multiple access (FDMA) and there are two operational center frequencies 1602 MHz (L1) and 1246 MHz (L2) and at 1207.14 MHz (L3). GLONASS over this decade will also introduce Code Divisional Multiple Access (CDMA) similar to GPS.
- GALILEO has a range of frequencies assigned in the L-band as follows:
- E2 – L1 – E1 – Centre frequency 1575.42 MHz (band from 1559MHz – 1591MHz).
- E5A – Centre frequency 1176.45 MHz (band from 1164 MHz – 1188 MHz).

- E5B - Centre frequency 1207.14 MHz (band from 1188 MHz – 1215 MHz).
- E6 – Centre frequency 1278,75 MHz (band from 1260 MHz – 1300 MHz).

Note that while SBAS reference stations make use of signals on the L2 frequency, this is not a recognized aeronautical use. This is why aviation use of GNSS will migrate to use only L1 and L5 frequency bands in the future.

Compatibility and interoperability between different GNSS systems (core satellite constellations and augmentation systems) are managed by the United Nations International Committee on GNSS (UN ICG). Signaling techniques such as CDMA (Code Division Multiple Access), orthogonality, and subcarriers (Binary Offset Code or BOC modulation) are used to allow operation of multiple GNSS system within the RNSS frequency band allocation while limiting inter-system interference to acceptable levels.

Because GNSS is used by many different users, aviation use of GNSS may be subject to collateral interference, such as intentional interference which was not intended to impact aviation operations. Therefore, specific mitigation measures are needed to help ensure an interference free environment and enable timely and efficient reactions when interference is reported. Further guidance on this topic can be found in the ICAO GNSS Manual, Doc 9849, and the ICAO Manual on Testing of Radio Navigation Aids, Doc 8071, Volume 2 on GNSS.

1.2.1 Satellite system:

A satellite navigation or satnav system is a system that uses satellites to provide autonomous geo positioning. A satellite navigation system with global coverage is termed global navigation satellite system (GNSS). As of 2024, four global systems are operational: the United States's Global Positioning System (GPS), Russia's Global Navigation Satellite System (GLONASS), China's BeiDou Navigation Satellite System, and the European Space Agency's Galileo.

Regional navigation satellite systems in use are Japan's Quasi-Zenith Satellite System (QZSS), a GPS satellite-based augmentation system to enhance the accuracy of GPS, with satellite navigation independent of GPS scheduled for 2023, and the Indian

Regional Navigation Satellite System (IRNSS) or NavIC, which is planned to be expanded to a global version in the long term.

Satellite navigation allows satellite navigation devices to determine their location (longitude, latitude, and altitude/elevation) to high precision (within a few centimeters to meters) using time signals transmitted along a line of sight by radio from satellites. The system can be used for providing position, navigation or for tracking the position of something fitted with a receiver (satellite tracking). The signals also allow the electronic receiver to calculate the current local time to a high precision, which allows time synchronization. These uses are collectively known as Positioning, Navigation and Timing (PNT). Satnav systems operate independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the positioning information generated.

Global coverage for each system is generally achieved by a satellite constellation of 18–30 medium Earth orbit (MEO) satellites spread between several orbital planes. The actual systems vary, but all use orbital inclinations of >50° and orbital periods of roughly twelve hours (at an altitude of about 20,000 kilometers or 12,000 miles).

1.2.1.1 Classification:

GNSS systems that provide enhanced accuracy and integrity monitoring usable for civil navigation are classified as follows:

GNSS-1 is the first generation system and is the combination of existing satellite navigation systems (GPS and GLONASS), with Satellite Based Augmentation Systems (SBAS) or Ground Based Augmentation Systems (GBAS).[5] In the United States, the satellite-based component is the Wide Area Augmentation System (WAAS); in Europe, it is the European Geostationary Navigation Overlay Service (EGNOS); and in Japan, it is the Multi-Functional Satellite Augmentation System (MSAS). Ground-based augmentation is provided by systems like the Local Area Augmentation System (LAAS).

GNSS-2 is the second generation of systems that independently provide a full civilian satellite navigation system, as shown by the European Galileo positioning system. These systems will provide the accuracy and integrity monitoring necessary for civil navigation, including aircraft. Initially, this system consisted of only Upper L Band *frequency sets (L1 for GPS, E1 for Galileo, and G1 for GLONASS). In recent years, GNSS systems have begun activating Lower L Band frequency sets (L2 and L5 for GPS, E5a and E5b for Galileo, and G3 for GLONASS) for civilian use; they feature higher aggregate accuracy and fewer problems with signal reflection. As of late 2018, a few consumer-grade GNSS devices are being sold that leverage both. They are typically called "Dual band GNSS" or "Dual band GPS" devices.*

By their roles in the navigation system, systems can be classified as:

There are four core satellite navigation systems, currently GPS (United States), GLONASS (Russian Federation), Beidou (China) and Galileo (European Union).

Global Satellite-Based Augmentation Systems (SBAS) such as OmniSTAR and StarFire.

Regional SBAS including WAAS (US), EGNOS (EU), MSAS (Japan), GAGAN (India) and SDCM (Russia).

Regional Satellite Navigation Systems such as India's NAVIC, and Japan's QZSS.

Continental scale Ground Based Augmentation Systems (GBAS) for example the Australian GRAS and the joint US Coast Guard, Canadian Coast Guard, US Army Corps of Engineers and US Department of Transportation National Differential GPS (DGPS) service.

Regional scale GBAS such as CORS networks:

Local GBAS typified by a single GPS reference station operating Real Time Kinematic (RTK) corrections.

As many of the global GNSS systems (and augmentation systems) use similar frequencies and signals around L1, many "multi-GNSS" receivers capable of using multiple systems have been produced. While some systems strive to interoperate with GPS as well as possible by providing the same clock, others do not.

1.2.1.2 Principles:

Further information: GPS § Principles, and GPS § Navigation equations

Part of an orbiting satellite's broadcast includes its precise orbital data. Originally, the US Naval Observatory (USNO) continuously observed the precise orbits of these satellites. As a satellite's orbit deviated, the USNO sent the updated information to the *satellite. Subsequent broadcasts from an updated satellite would contain its most recent ephemeris. Modern systems are more direct. The satellite broadcasts a signal that contains orbital data (from which the position of the satellite can be calculated) and the precise time the signal was transmitted. Orbital data include a rough almanac for all satellites to aid in finding them, and a precise ephemeris for this satellite. The orbital ephemeris is transmitted in a data message that is superimposed on a code that serves as a timing reference. The satellite uses an atomic clock to maintain synchronization of all the satellites in the constellation. The receiver compares the time of broadcast encoded in the transmission of three (at sea level) or four (which allows an altitude calculation also) different satellites, measuring the time-of-flight to each satellite. Several such measurements can be made at the same time to different satellites, allowing a continual fix to be generated in real time using an adapted version of trilateration: see GNSS positioning calculation for details.*

Each distance measurement, regardless of the system being used, places the receiver on a spherical shell at the measured distance from the broadcaster. By taking several such measurements and then looking for a point where they meet, a fix is generated. However, in the case of fast-moving receivers, the position of the signal moves as signals are received from several satellites. In addition, the radio signals slow slightly as they pass through the ionosphere, and this slowing varies with the receiver's angle to the satellite, because that changes the distance through the ionosphere. The basic computation thus attempts to find the shortest directed line tangent to four oblate spherical shells centered on four satellites. Satellite navigation receivers reduce errors by using combinations of signals from multiple satellites and multiple correlators, and then using techniques such as Kalman filtering to combine the noisy, partial, and constantly changing data into a single estimate for position, time, and velocity.

Einstein's theory of general relativity is applied to GPS time correction, the net result is that time on a GPS satellite clock advances faster than a clock on the ground by about 38 microseconds per day.

1.2.1.3 Applications:

The original motivation for satellite navigation was for military applications. Satellite navigation allows precision in the delivery of weapons to targets, greatly increasing their lethality whilst reducing inadvertent casualties from mis-directed weapons. (See Guided bomb). Satellite navigation also allows forces to be directed and to locate themselves more easily, reducing the fog of war.

Now a global navigation satellite system, such as Galileo, is used to determine users location and the location of other people or objects at any given moment. The range of application of satellite navigation in the future is enormous, including both the public and private sectors across numerous market segments such as science, transport, agriculture, insurance, energy, etc.

The ability to supply satellite navigation signals is also the ability to deny their availability. The operator of a satellite navigation system potentially has the ability to degrade or eliminate satellite navigation services over any territory it desires.

1.2.2 The performance of GNSS is assessed using four criteria:

- ***Accuracy****: the difference between a receiver's measured and real position, speed or time.*
- ***Integrity****: a system's capacity to provide a threshold of confidence and, in the event of an anomaly in the positioning data, an alarm.*
- ***Continuity****: a system's ability to function without interruption.*
- ***Availability****: the percentage of time a signal fulfils the above accuracy, integrity, and continuity criteria.*

This performance can be improved by regional satellite-based augmentation systems (SBAS), such as the European Geostationary Navigation Overlay Service (EGNOS). EGNOS improves the accuracy and reliability of GPS information by correcting signal measurement errors and by providing information about the integrity of its signals.

1.3 Using GNSS jamming and spoofing to combat drones

The risk from drones is undoubtedly increasing. So how do you bring down a drone and, more to the point, how do you bring down a drone safely without endangering people, objects or infrastructure?

One method that's often cited is attacking the drone's GNSS receiver, by jamming or spoofing. Many drones can be programmed with a pre-determined flight path, and use GPS (or another global navigation satellite system, like Russia's GLONASS, Europe's Galileo or China's BeiDou) to navigate along that path.

It follows that disrupting the drone's ability to receive and process GNSS signals will prevent the drone from being able to navigate as its dispatcher intended.

How it works

The two basic options are jamming and spoofing. Jamming involves flooding the GNSS receiver with Radio Frequency Interference at the same frequencies as the GNSS signals so it can no longer distinguish GNSS signals, while spoofing involves broadcasting a false GNSS signal at the receiver, with the fooling the drone into believing it's somewhere else.

Both methods can work to disable a drone, but only in certain circumstances. For a start, not all drones use GNSS to navigate some are radio-controlled by an operator on the ground. And drones that do navigate using GNSS may not use GPS for the purpose – or they may use GPS on a different frequency from the one the jammer or spoofer is targeting. A drone that navigates using the Russian GLONASS system may be less susceptible to a GPS-only jammer or spoofer, for example. In fact, many modern receivers are capable of processing signals from multiple GNSS constellations on multiple.

1.3.1 Interference techniques

1. **Jamming**:

consists of emitting RF signals with specific properties and higher power than the target signal to overpower the GNSS signals receiver causing the total or partial block of the reception of the latter one. There is a type of jamming called ‘’meaconing” that is only needed to tune into the accurate GNSS signals, record them, and then retransmit them after an unavoidable delay and more power to confuse the receiver. It is essential to highlight that there is no control over the variables, time, and position, which it calculates To simplify, ***jamming causes the receiver to die.*** *The inhibitor system causes side effects on other systems too.*

2. **Spoofing:**

is the provision of GNSS-like signals locally transmitted and coded to fool the receiver. A device sends a movement analogous to the satellite signal, but which higher power, so the **GNSS receives the false signal instead of the real one**; in such a manner, it calculates an incorrect position or an incorrect time variable. There is a type of spoofing called a ‘’carry-off attack’ that is caused by broadcasted signals synchronized with genuine signals observed by the target receiver. The power of the counterfeit signals is gradually increased, so that, the **GNSS receiver tracks the false signals which can be manipulated** giving a different location to the provided by genuine signals, to simplify, **spoofing causes the receiver to lie being this attack** more complex than a jamming attack.

1.3.2 The pros and cons of jamming

The two interference methods, jamming is less sophisticated and easier to do. It also works well. Even low-powered jammers of the kind often used by commercial drivers to stop their employer tracking their vehicle's movements are effective at drowning out GNSS signals to a range of several hundreds of meters. And there lies one of the many problems with using GNSS jamming to defend against drones. Because they're effective over a wide range, GPS jammers are illegal in most countries, as is the act of deliberately interfering with navigation signals.

Any UK organization that wanted to jam GNSS to defend against drones would have to obtain government permission (as indeed it seems Gatwick did for the December incident). It should also notify GNSS users in the area that they may experience disruption to the signal at certain times. Getting the right permissions at the right time could be a bureaucratic nightmare—but being prosecuted for unauthorized jamming isn't an appealing scenario either. While the military-grade jammers likely to be used for drone defense are directional effectively radio guns they still have the potential to disrupt anything in their range. That creates significant risks for airport infrastructure that relies on GNSS, such as modern landing systems and air traffic control systems.

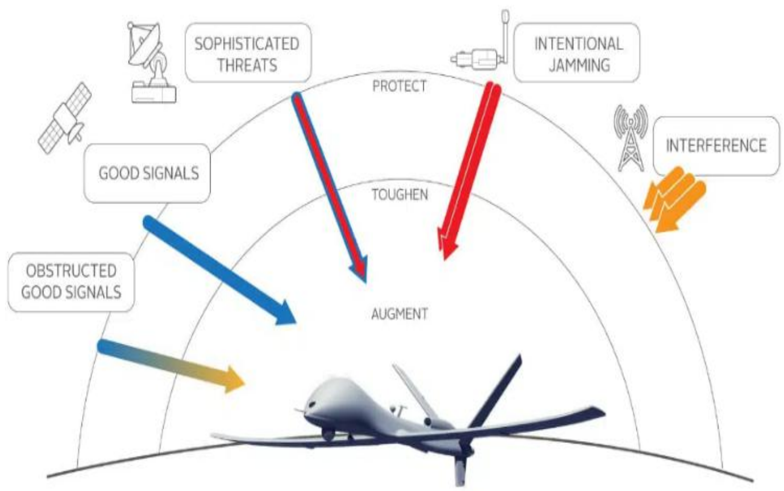


Figure 1.3.2: The pros and cons of jamming

Chapter 2 **AI & Software system**

Presented by/

D. RANA ADEL MOHAMED MASRY 91300
E. MERNA BAHER BADRY FAYEK 91400

1. Artificial Intelligence:

2.1 Introduction:

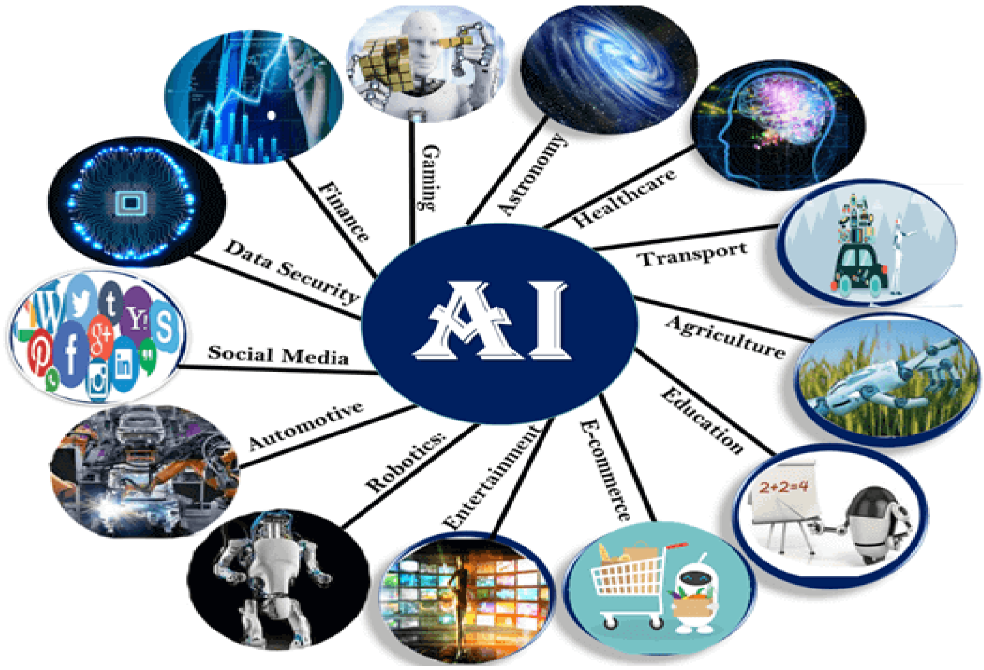
Artificial intelligence (AI) is the ability of machines to replicate or enhance human intellect, such as reasoning and learning from experience. Artificial intelligence has been used in computer programs for years, but it is now applied to many other products and services. For example, some digital cameras can determine what objects are present in an image using artificial intelligence software. In addition, experts predict many more innovative uses for artificial intelligence in the future, including smart electric grids.

AI uses techniques from probability theory, economics, and algorithm design to solve practical problems. In addition, the AI field draws upon computer science, mathematics, psychology, and linguistics. Computer science provides tools for designing and building algorithms, while mathematics offers tools for modeling and solving the resulting optimization problems.

Although the concept of AI has been around since the 19th century, when Alan Turing first proposed an "imitation game" to assess machine intelligence, it only became feasible to achieve in recent decades due to the increased availability of computing power and data to train AI systems.

To understand the idea behind AI, you should think about what distinguishes human intelligence from that of other creatures – our ability to learn from experiences and apply these lessons to new situations. We can do this because of our advanced brainpower.

Figure 2.1 AI



2.2 Different fields under AI:

Artificial Intelligence is the most trending field of computer science. However, with all the new technology and research, it's growing so fast that it can be confusing to understand what is what. Furthermore, there are many different fields within AI, each one having its specific algorithms. Therefore, it's essential to know that AI is not a single field but a combination of various fields.

Artificial Intelligence (AI) is the general term for being able to make computers do things that require intelligence if done by humans. AI can be broken down into two major fields, Machine Learning (ML) and Neural Networks (NN). Both are subfields under Artificial Intelligence, and each one has its methods and algorithms to help solve problems.

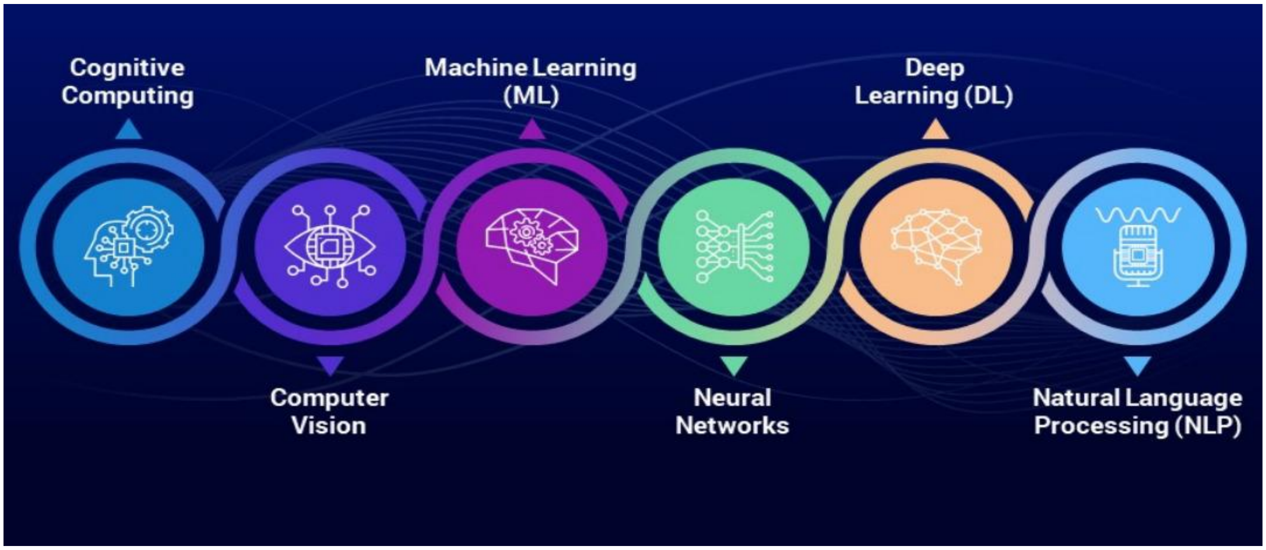


Figure 2.2 Fields of AI

2.3 Machine learning:

Machine Learning (ML) makes computers learn from data and experience to improve their performance on some tasks or decision-making processes. ML uses statistics and probability theory for this purpose. Machine learning uses algorithms to parse data, learn from it, and make determinations without explicit programming.

Machine learning algorithms are often categorized as supervised or unsupervised. Supervised algorithms can apply what has been learned in the past to new data sets; unsupervised algorithms can draw inferences from datasets. Machine learning algorithms are designed to strive to establish linear and non-linear relationships in a given set of data. This feat is achieved by statistical methods used to train the algorithm to classify or predict from a dataset.

2.4 Deep learning (DL):

Deep learning is a research field in ML and originates from artificial neural network (NN) studies. Multilayer perceptron (MLP) is a deep learning structure.

*Deep learning uses higher level features derived from the lower level features to form a hierarchical representation. Deep learning aims to establish neural networks that simulate the human brain to analyze and interpret data, such as images, voice, and text***.**

Deep learning will witness all possible human characteristics and behavioral databases and will perform supervised learning. This process includes:

- *Detection of different kinds of human emotions and signs.*
- *Identify the human and animals by the images like by particular signs, marks, or features.*
- *Voice recognition of different speakers and memorize them.*
- *Conversion of video and voice into text data.*
- *Identification of right or wrong gestures, classify spam things, and fraud cases (like fraud claims)*

2.5 Neural networks:

Neural networks are inspired by biological neurons in the human brain and are composed of layers of connected nodes called "neurons" that contain mathematical functions to process incoming data and predict an output value. Artificial neural network learns by example, similarly to how humans learn from our parents, teachers, and peers. They consist of at least three layers: an input layer, hidden layers, and an output layer. Each layer contains nodes (also known as neurons) which have weighted inputs that compute the output.

2.6 How does AI work?

If AI is a complex but necessary technology, how does it work?

To put it simply, AI works by combining large data sets with intuitive processing algorithms. AI can manipulate these algorithms by learning behavior patterns within the data set.

It's important to understand that AI is not just one algorithm. Instead, it is an entire machine learning system that can solve problems and suggest outcomes.

Let’s look at how AI works step-by-step.

1. Input

The first step of AI is input. In this step, an engineer must collect the data needed for AI to perform properly.

Data does not necessarily have to be a text input; it can also be images or speech. However, it’s important to ensure the algorithms can read inputted data.

It’s also necessary to clearly define the context of the data and the desired outcomes in this step.

2. Processing

The processing step is when AI takes the data and decides what to do with it. While processing, AI interprets the pre-programmed data and uses the behaviors it has learned to recognize the same or similar behavior patterns in real-time data, depending upon the particular AI technology.

3. Data Outcomes

After the AI technology has processed the data, it predicts the outcomes. This step determines if the data and its given predictions are a failure or a success.

4. Adjustments

If the data set produces a failure, AI technology can learn from the mistake and repeat the process differently. The algorithms’ rules may need to be adjusted or changed to fit the data set.

Outcomes may also shift during the adjustment phase to reflect a more desired or appropriate outcome.

5. Assessments

Once AI has finished its assigned task, the last step is assessment. The assessment phase allows the technology to analyze the data and make inferences and predictions. It can also provide necessary, helpful feedback before running the algorithms again.

AI is extremely beneficial in business. However, choosing the right AI technology for your business needs is important.

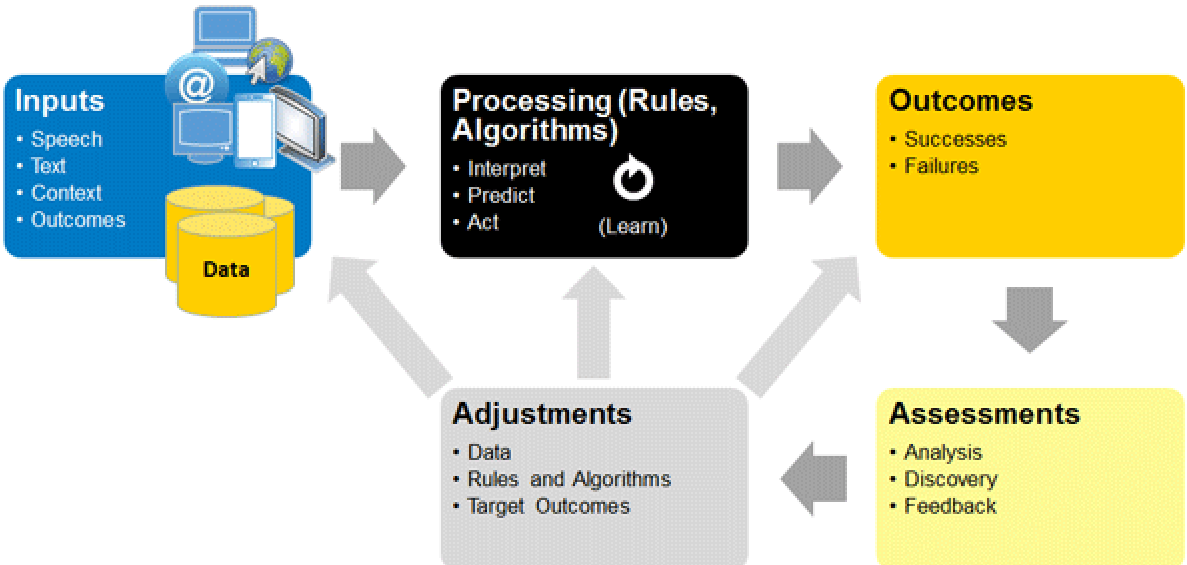


Figure 2.3 Steps of AI

2.7 Application Fields of AI:

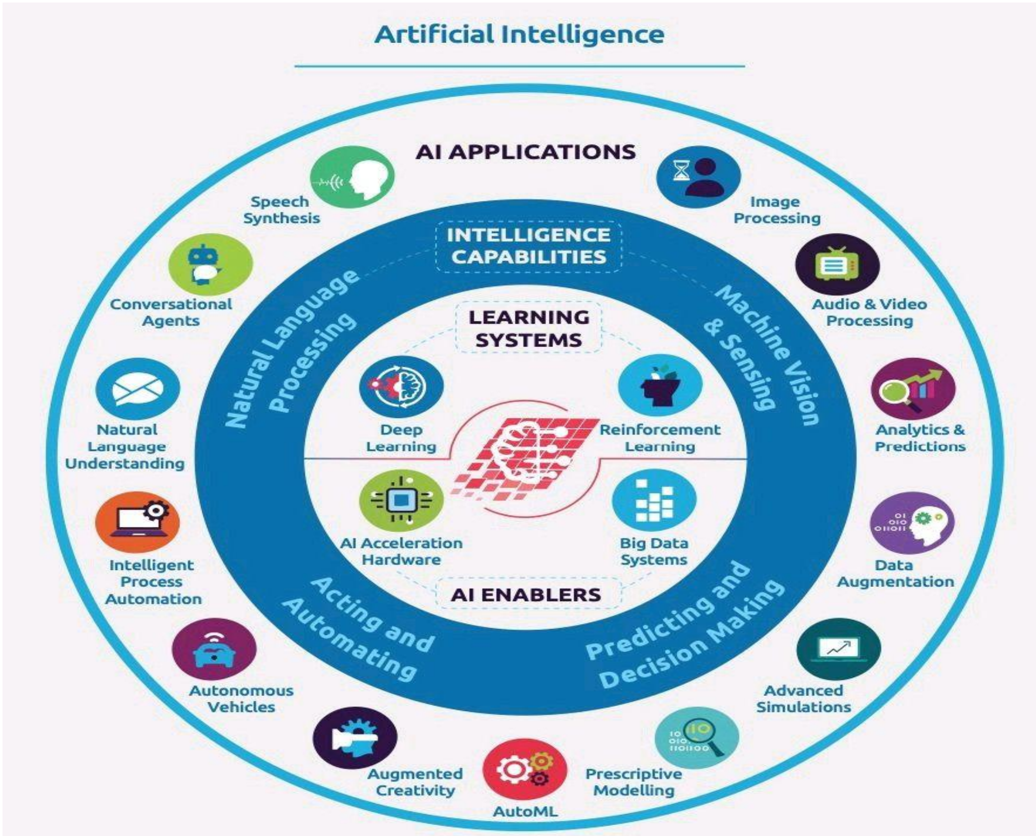


Figure 2.4 Applications of AI

2.8 The use of artificial intelligence in our project:

Our goal is to develop an integrated system that uses artificial intelligence to detect, track and jam drones. This system will use artificial intelligence technologies to identify and track in real-time unmanned aerial vehicles (UAVs), known as drones. It will also include a jamming system that uses radio frequency signals to safely and effectively disable and redirect the drone's path.

We also used the artificial intelligence detection and tracking system, which is an advanced system that uses artificial intelligence techniques to detect and track objects in real time. This system finds applications in various fields such as facility security, traffic control, autonomous robotics, aerial photography, and many other scenarios that require accurate object detection and tracking.

The system relies on artificial intelligence techniques such as machine learning and deep learning to analyze and understand images and videos. It is trained on a large set of visual data to enable it to recognize specific patterns and features. The system uses object detection and *tracking techniques to identify and classify objects in images or videos and track their movements over successive frames.*

2.9 Image Processing

2.9.1 Introduction

Generally, an image is a visual representation of such a thing. It is a picture which has been formed or copied and stored in electronic form. Also, it is a combination of two dimensional function f(x,y) where x&y the spatial domain coordinates, and at any pair of coordinates (x,y) the amplitude of (f) is known as the intensity of image at this level. We will call the image a digital image if the x,y and the amplitude values of f are finite and discrete quantities. A digital image contains a finite number of elements that is known as pixels that each of them has a special value and location. Digital image processing performs automatic processing, manipulation and interpretation of such visual information. It focuses on the methods and implementations that we use to extract meaningful information and specific characteristics from the image.

These operations help to enhance or modify the image properties in order to achieve better results after classification. It plays an increasingly important role in many areas of our lives, including a wide range of disciplines and fields in science and technology, with applications such as photography, television, robotics, remote sensing and industrial inspection. It forms core research area within engineering and computer science disciplines too.[1]

Image processing is a method to perform some operations on an image, in order to get an enhanced image or to extract some useful information from it. It is a type of signal processing in which input is an image and output may be image or characteristics/features associated with that image.

Image processing basically includes the following three steps:

- *Importing the image via image acquisition tools.*
- *Analyzing and manipulating the image*

• Output in which result can be altered image or report that is based on image analysis. Image processing was one of the fundamental areas for most of the researchers to work on. Text detection and recognition are popular sub-parts of image processing. There are several algorithms available that can do it. There are many algorithms and techniques available for various image processing techniques. Text detection and recognition are the main techniques used in this project. Because there are so many of them, manually selecting accurate algorithms to perform these techniques is extremely difficult. Developers have created a smart method for automatically selecting of appropriate algorithms called Open-Source Computer Vision (Open CV) Which contains a large number of pre-installed libraries for image processing, and it chooses the most applicable algorithms required for an operation by automatically mapping imaging and selecting your desired technique.[2]

2.10 Open CV

2.10.1 Introduction

OpenCV is a library of programming functions mainly used for image processing. It is freely available on the open source Berkely Software Distribution (BSD) license. It was started as a research project by Intel. OpenCV contains various tools to solve computer vision problems. It contains low level image processing functions and high-level algorithms for face and object detection, feature matching and tracking. It has C++, C, Python and Java interfaces and supports Windows, Linux, Mac OS, iOS, and Android.

In simple words, with machine learning, computers are able to recognize and process the objects from the video/images as a human can be able to recognize.[3]

2.10.2 Features of OpenCV:

OpenCV is equipped with a rich set of features, including:

- *Image and video processing algorithms*
- *Object detection and tracking*
- *Facial recognition*
- *Machine learning and deep learning support*

- *Camera calibration and 3D reconstruction*
- *Augmented reality*
- *Gesture recognition*
- *Robotics support*

2.10.3 Application of Open CV with Python With the help of Open CV in python

it is possible to process images, videos easily and can extract useful information out of that, as there are lots of functions available. Some of the common applications are:

A. Image Processing:

Image processing is a form of signal processing in which the input is an image such as a photograph or video frame, the output is an image or set of characteristics related to image. OpenCV is a library of programming functions mainly used for image processing. It is freely available on the open source Berkely Software Distribution license. It was started as a research project by Intel. OpenCV contains various tools to solve computer vision problems. It contains low level image processing functions and high level algorithms for face detection, feature matching and tracking.

- **Some of the main image processing techniques are given below:**

  - **Image Filtering:**

It is a technique for modifying or enhancing an image. Image filtering is of two types. The one is linear image filtering, in which, the value of an output pixel is a linear combination of the values of the pixels of the input pixel's neighborhood. The second one is the non-linear image filtering, in which, the value of output is not a linear function of its input.

  - **Image Transformation***: Image transformation generates "new" image from two or more sources which highlight particular features or properties of interest, better than the original input images. Basic image transformations apply simple arithmetic operations to the image data. Image subtraction is often used to identify changes that* *have occurred between images collected on different dates. Main image transformation methods are*

- *Radon Transform: used to reconstruct images from fan-beam and parallel-beam projection data*
- *Discrete Cosine Transform: used in image and video compression*
- *Discrete Fourier Transform: used in filtering and frequency analysis*
- *Wavelet Transform: used to perform discrete wavelet analysis, denoise, and fuse images*

B. Object Tracking:

Object tracking is the process of locating a object (or multiple objects) over a sequence of images. It is one of the most important components in a wide range of applications in computer vision, such as surveillance, human computer interaction, and medical imaging.

Feature Detection:

A feature is defined as an "interesting" part of an image and features are used as a starting point for many computer vision algorithms. Since features are used as the -starting point and main primitives for subsequent algorithms, the overall algorithm will often only be as good as its feature detector. Feature detection is a process of finding specific features of a visual stimulus, such as lines, edges or angle. It will be helpful for making local decisions about the local information contents (image structure) in the image.

The modules of openCV for image processing applications are given below CORE module contains basic data structures and basic functions used by other modules. IMGPROC module contains image processing related functions such as linear, non-linear image filtering and geometrical image transformations etc. VIDEO module contains motion estimation and object tracking algorithms. ML module contains *machine-learning interfaces. HighGUI module contains the basic I/O interfaces and multi-platform windowing capabilities.*

C. Face Detection:

where an input image is searched to find a face, then the image is processed to crop and extracts the person face. OpenCV has face detector called "Haar Cascade classifier". Given an input image, which is from the camera or live video, the face detector examines the image location and classifies it as face or not face. The classifier uses xml file (haarcascade_frontalface_default.xml) to decide how to classify each image location. In openCV 2.4.10, the xml file is in path "opencv/sources/data/haarcascades".

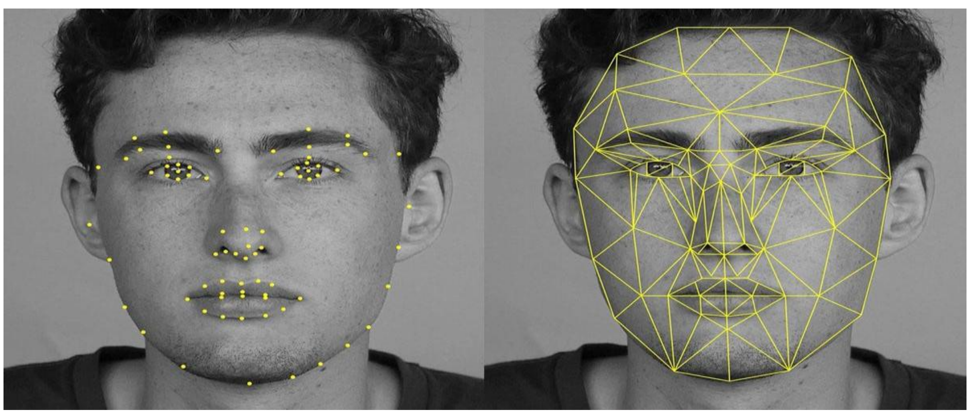


Figure 2.5: face detection

D. Face Recognition:

it is another phase, where the detected face image is compared with images in the database of faces. The openCV framework contains the inbuilt face detector that can work 90-95% on the clear images. It is slightly difficult to detect a face if a person wearing glasses or an image is blurring.

2.11 OpenCV For Object Detection

It's far easier to write code for images captured in controlled lighting conditions than in dynamic conditions with no guarantees. If you are able to control the environment and, most importantly, the lighting when you capture an image, the easier it will be to write code to process the image. With controlled lighting conditions, you're able to hardcode parameters, including:

- *Amount of blurring*
- *Edge detection bounds*
- *Thresholding limits*
- *Etc. Essentially, controlled conditions allow you to take advantage of your a priori knowledge of an environment and then write code that handles that specific environment rather than trying to handle every edge case or condition. of course, controlling your environment and lighting conditions isn't always possible*

At the beginning, to implement text detection in the paper we will use OpenCV with python. Initially image acquisition is done with the help of raspberry pi camera. First image of the paper is captured. In addition to this, the steps that we need to follow to build this project are:

1- *Rotate image to be in portrait mode then convert it to grayscale.*
2- *smooth image by using the cv2.GaussianBlur.*
3- *Find the edges in the image using canny edge detector.*
4- *Apply morphological operations to Handle object shapes such as thickening, thinning, and filling.*
5- *Use the edges to find all the contours.*
6- *Select only the contour of the ROI (region of interest) text region.*
7- *Apply warp perspective to get the top-down view of the document.*
8- *Apply tesseract OCR engine for text recognition.*

2.12 YOLO :

2.12.1 Definition :

YOLO is refreshingly simple: see Figure 1. A single convolutional network simultaneously predicts multiple bounding boxes and class probabilities for those boxes. YOLO trains on full images and directly optimizes detection performance. This unified model has several benefits over traditional methods of object detection.

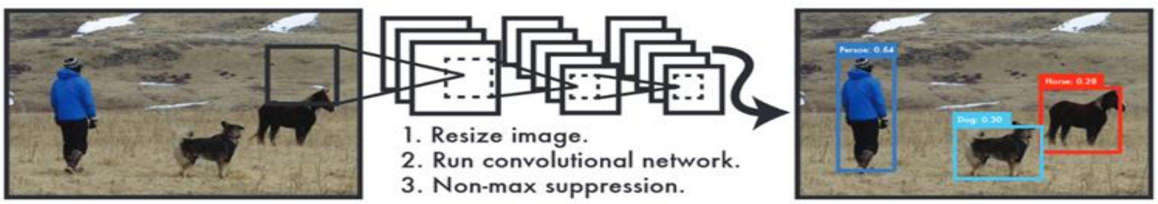


Figure 2.6: The YOLO Detection System. Processing images with YOLO is simple and straightforward. Our system (1) resizes the input image to 448 × 448, (2) runs a single convolutional network on the image, and (3) thresholds the resulting detections b

First, YOLO is extremely fast. Since we frame detection as a regression problem we don't need a complex pipeline. We simply run our neural network on a new image at test time to predict detections. Our base network runs at 45

frames per second with no batch processing on a Titan X GPU and a fast version runs at more than 150 fps. This means we can process streaming video in real-time with less than 25 milliseconds of latency. Furthermore, YOLO achieves more than twice the mean average precision of other real-time systems.

Second, YOLO reasons globally about the image when making predictions. Unlike sliding window and region proposal-based techniques, YOLO sees the entire image during training and test time so it implicitly encodes contextual information about classes as well as their appearance. Fast R-CNN, a top detection method, mistakes background patches in an image for objects because it can't see the larger context. YOLO makes less than half the number of background errors compared to Fast R-CNN.

Third, YOLO learns generalizable representations of objects. When trained on natural images and tested on artwork, YOLO outperforms top detection methods like DPM and R-CNN by a wide margin. Since YOLO is highly generalizable it is less likely to break down when applied to new domains or unexpected inputs.

2.12.2 How does YOLO work:

YOLO trains on full images and directly optimizes detection performance. With YOLO, a single CNN simultaneously predicts multiple bounding boxes and class probabilities for those boxes. It also predicts all bounding boxes across all classes for an image simultaneously. It divides the input image into an $S \times S$ grid. If the center of an object falls into a grid cell, that grid cell is responsible for detecting that object. Each grid cell predicts B bounding boxes and confidence scores for those boxes. These confidence scores reflect how confident the model is that the box contains an object and also how accurate it thinks the box it predicted is.

*Each bounding box is represented by 6 numbers (pc,bx,by,bh,bw,c),where pc is the confidence of an object being present in the bounding box;bx,by,bh,bw represents the bounding box itself;c is a vector containing the class probabilities. We also define Anchor boxes by exploring the training data to choose reasonable height/width ratios that represent the different classes. An anchor box can have multiple bounding boxes. For each anchor box (of each grid cell) we compute the element-wise product pc*c[i] and extract a probability score of the box containing a certain class. The class associated with the maximum score is assigned to the anchor box along with the score itself*

We can then get rid of boxes with low score by using a threshold of probability score. However ,we still get a lot of boxes. So we use something called Non-maxima suppression(NMS) in which we select only one box when several boxes overlap with each other and detect the same object.

2.13 YOLOv8 :

YOLO models are single stage object detectors. In a YOLO model, image frames are featurized through a backbone. These features are combined and mixed in the neck, and then they are passed along to the head of the network YOLO predicts the locations and classes of objects around which bounding boxes should be drawn. YOLOv8 is the latest iteration in the YOLO series of real-time object detectors, offering cutting-edge performance in terms of accuracy and speed. Building upon the advancements of previous YOLO versions, YOLOv8 introduces new features and optimizations that make it an ideal choice for various object detection tasks in a wide range of applications.

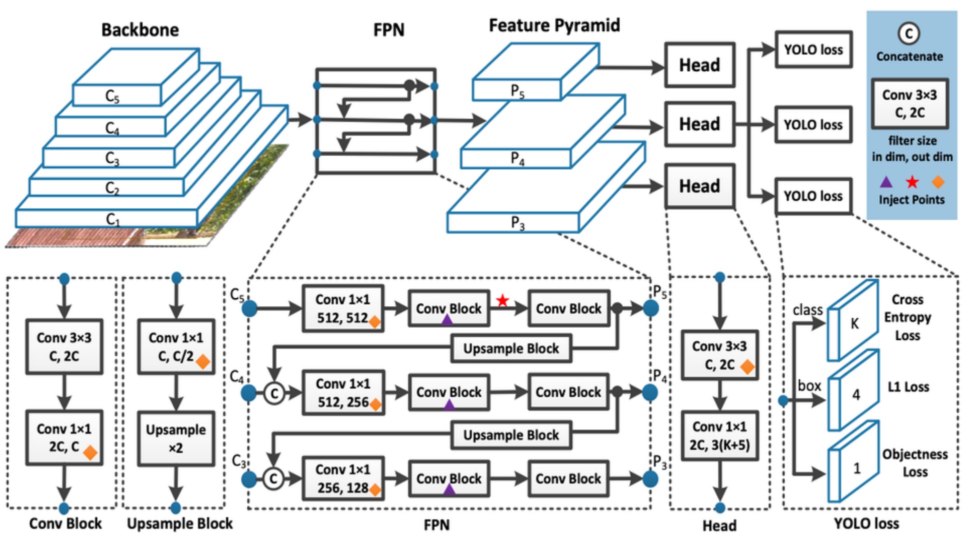


Figure 2.7: YOLO network architecture as depicted in PP-YOLO

In the beginning, YOLO models were used widely by the computer vision and machine learning communities for modeling object detection because they were small, nimble, and trainable on a single GPU. This is the opposite of the giant transformer architectures coming out of the leading labs in big tech which, while effective, are more difficult to run on consumer hardware.

Since their introduction in 2015, YOLO models have continued to proliferate in the industry. The small architecture allows new ML engineers to get up to speed quickly when learning about YOLO and the real-time inference speed allows practitioners to allocate minimal hardware compute to power their applications.

2.14 What Makes YOLOv8 Different :

YOLOv8, short for You Only Look Once version 8, is an object detection algorithm designed to detect and classify objects in images with remarkable speed and accuracy.

It builds upon the success of its predecessors, addressing their limitations and incorporating advanced techniques to enhance performance.

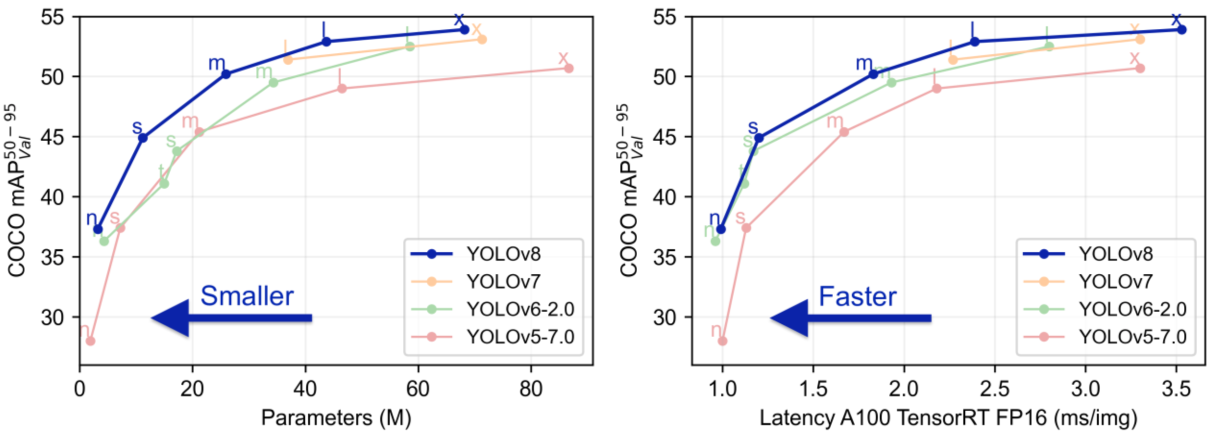


Figure 2.8: Performance of two object detection models, YOLOv3 and YOLOv8, on a specific dataset

2.15 YOLOv8 Architecture Overview

- **Backbone Network**

The backbone network is the foundation of YOLOv8, responsible for feature extraction from the input image. YOLOv8 employs CSPDarknet53, a variant of Darknet, as its backbone.

The CSPDarknet53 architecture introduces a novel Cross-Stage Partial (CSP) connection, enhancing the information flow between different stages of the network and improving gradient flow during training.

- ### Neck and Head Structures

YOLOv8 introduces a Path Aggregation Network (PANet) as the neck structure. PANet facilitates information flow across different spatial resolutions, enabling the model to capture multi-scale features effectively.

The head structure consists of multiple detection heads, each responsible for predicting bounding boxes, class probabilities, and objectness scores at different scales.

- ### Detection Head

The detection head of YOLOv8 is where the real innovation lies. It utilizes a modified version of the YOLO head, incorporating dynamic anchor assignment and a novel IoU (Intersection over Union) loss function.

These improvements contribute to more accurate bounding box predictions and better handling of overlapping objects.

2.16 YOLOv8 in our project:

Drone detection has become a crucial area of research due to the rising popularity of unmanned aerial vehicles (UAVs). In this section, we delve into the application of YOLOv8, a state-of-the-art object detection algorithm, in conjunction with PyTorch, a powerful deep learning framework. Specifically, we explore the process of creating a custom dataset, labeling it using LabelImg, and splitting it into training, validation, and testing sets.

1. ***Dataset Collection**: Collect a dataset containing images or videos of drones, annotate them with bounding boxes. Each image was meticulously annotated with bounding boxes around the drones and non-drones. This self-labeled dataset ensured the model would learn from accurate and consistent annotations.*
2. ***Preparation**: Prepare the dataset by preprocessing images and dividing them into training, validation, and test sets.*

3. ***Model Training**: Fine-tune the YOLOv8 model on your drone dataset, adjusting parameters for optimal performance.*
4. ***Model Evaluation**: Evaluate the trained YOLOv8 model to assess its performance on a separate validation set.*
5. ***Inference**: Perform inference using the trained YOLOv8 model on new drone images or videos.*
6. ***Post-processing**: Apply techniques such as non-maximum suppression and confidence thresholding to refine the detection results.*

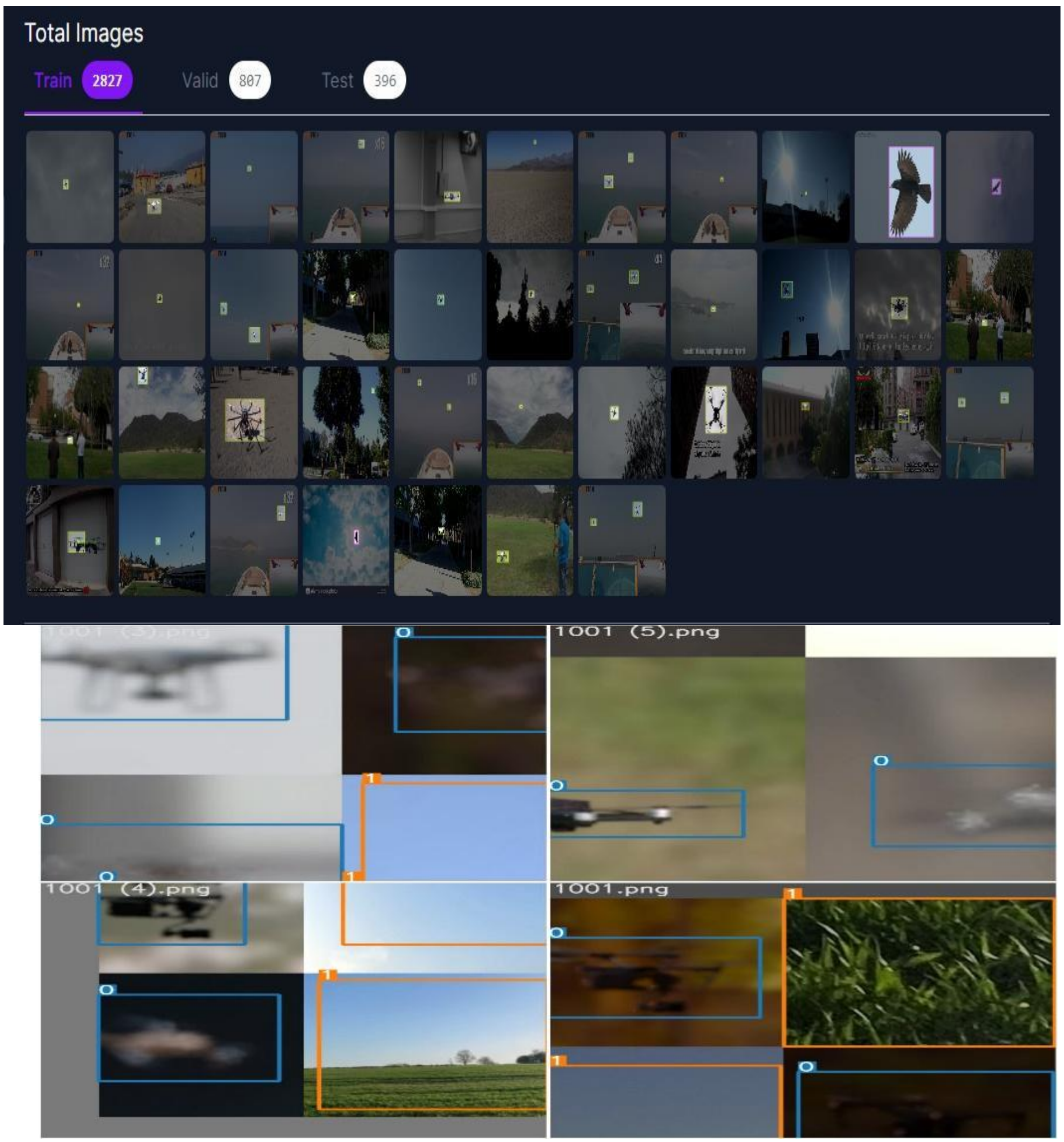


Figure 2.9: Datasets for train, valid and test image(4030)

2.16.1 Results

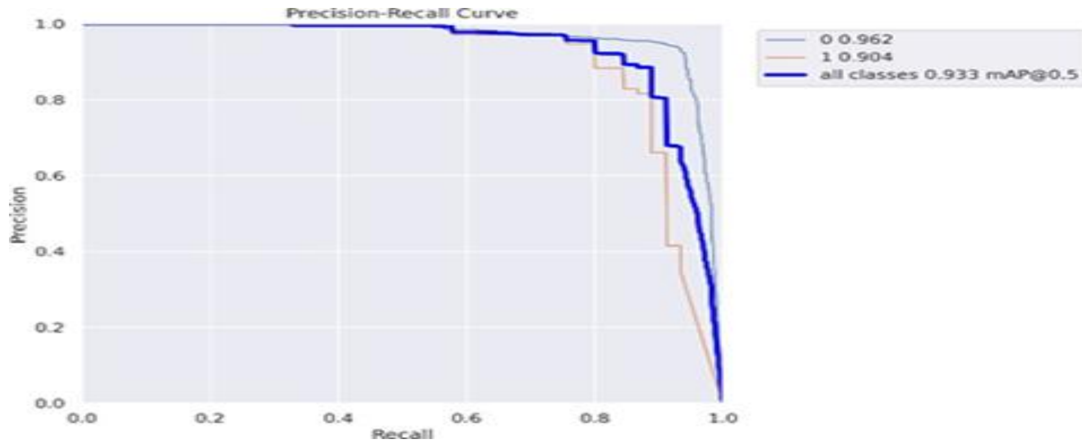


Figure 2.10 precision-recall curve

The curve is a precision-recall curve for the model. It shows the trade-off between the model's precision (the ability to correctly identify a drone) and its recall (the ability to find all the drones in an image).

The model has a high precision of 0.962 when the recall is 0.904. This means that for 90.4% of the drones in the image that the model detects, it is correct 96.2% of the time.

The mAP@0.5 value is 0.933. This stands for "mean Average Precision at an Intersection over Union (IoU) threshold of 0.5". IoU is a metric that measures how well a predicted bounding box overlaps with the actual drone in the image. An IoU of 0.5 means that the bounding box must overlap with the drone by at least 50% for it to be counted as a correct detection. The mAP@0.5 value of 0.933 means that the model has an an average precision of

0.933 when the IoU threshold is set to 0.5.

Figure 2.11 recall-confidence curve

The curve is a recall-confidence curve for the model. It shows the trade- off between the model's recall (the ability to find all the drones in an image) and its confidence (how certain the model is that a detection is actually a drone). The model has high recall (0.904) at a reasonable confidence level (0.962).

This means that the model can find a large proportion of the drones in an image (90.4%) while still being fairly certain (96.2%) that they are actually drones.

The mAP@0.5 value is 0.933. This stands for "mean Average Precision at an Intersection over Union (IoU) threshold of 0.5". IoU is a metric that measures how well a predicted bounding box overlaps with the actual drone in the image. An IoU of 0.5 means that the bounding box must overlap with the drone by at least 50% for it to be counted as a correct detection. The mAP@0.5 value of 0.933 means that the model has an average precision of 0.933 when the IoU threshold is set to 0.5.

Figure 2.12 precision-confidence curve

The curve is a precision-confidence curve. It shows the trade-off between the model's precision (the fraction of correct detections among all detections) and its confidence (how certain the model is that a detection is actually a drone).

The model has high precision (1.00) at a confidence level of 0.906. This means that when the model is very confident (confidence ≥ 0.906) in a detection, it is almost always correct (precision = 1.00).

The mAP@0.5 value is not provided in the image. However, we can see that the average precision across all confidence levels is close to 1.0, which suggests that the model is very good at making accurate detections.

the image shows a confusion matrix for the model

Confusion Matrix

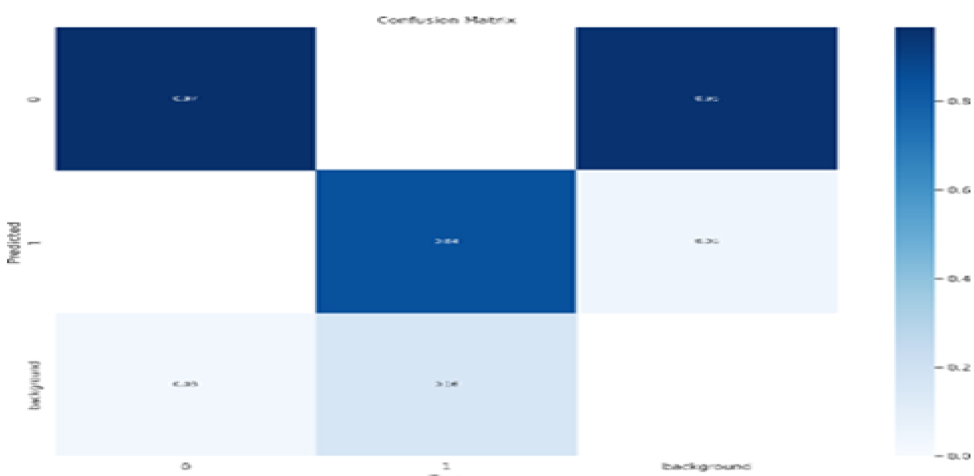


Figure 2.13 Confusion Matrix

0.97: This value represents the True Positive Rate (TPR), also known as recall, which means 97% of the actual drones in the images were correctly identified by the model.

0.03: This value represents the False Positive Rate (FPR), which means 3% of the time, the model identified something as a drone when it wasn't actually a drone.

0.95: This value represents the True Negative Rate (TNR), which means 95% of the time, the model correctly identified non-drones as non-drones.

0.05: This value represents the False Negative Rate (FNR), which means 5% of the time, the model missed a drone and didn't identify it.

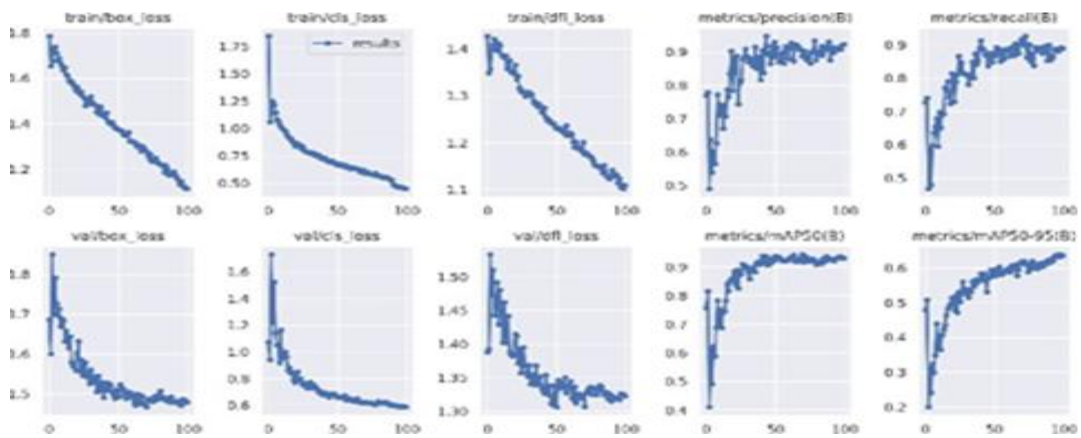


Figure 2.14 Losses and map

mAP@0.5: 0.933. This means the model has an average precision of 0.933 when the IoU threshold is set to 0.5.

Precision at recall of 0.904: 0.962.

This means that when the model recalls 90.4% of the drones (i.e., finds 90.4% of all actual drones), it has a precision of 96.2% (meaning 96.2% of its detections are correct).

mAP@0.95: 0.600. This means the model has an average precision of 0.600 when the stricter IoU threshold of 95% is applied.

Precision at recall of 0.5: 0.745. This means that when the model recalls 50% of the drones with the stricter IoU threshold, it has a precision of 74.5%.

The model seems to be performing well at detecting drones in images, with a high recall (97%) and a reasonable precision (around 0.933 at an IoU of 0.5). However, there is always room for improvement, and future work could focus on reducing the false positive rate (3%) and the false negative rate (5%).

2.17 YOLOv9

YOLOv9, an evolution of the popular You Only Look Once (YOLO) object detection framework, stands as a pinnacle in real-time object detection. Developed by Alexey Bochkovskiy, Chien-Yao Wang, and Hong-Yuan Mark Liao, YOLOv9 incorporates significant improvements in both accuracy and efficiency over its predecessors.

Utilizing a single neural network to predict bounding boxes and class probabilities simultaneously, YOLOv9 achieves remarkable speed, making it ideal for applications requiring rapid detection. Its architecture is built upon a backbone network, typically Darknet or YOLOv5's CSPDarknet, ensuring robust feature extraction.

Key features of YOLOv9 include:

1. Improved Backbone: YOLOv9 employs a more efficient backbone network, enhancing feature extraction and model performance.
2. Enhanced Training Techniques: Incorporating advanced training strategies such as mosaic data augmentation, multi-scale training, and more, YOLOv9 ensures superior generalization and robustness.
3. Modular Design: YOLOv9's modular architecture facilitates easy customization and adaptation to diverse datasets and tasks, empowering researchers and developers to tailor the model as needed.

Whether it's for surveillance systems, autonomous vehicles, or object recognition in images and videos, YOLOv9 stands as a versatile and powerful tool in the field of computer vision, offering state-of-the-art performance with unparalleled speed and accuracy.

2.17.1 YOLOv9 Architecture Overview

Backbone Network:

- **Enhanced Backbone**: YOLOv9 might utilize an improved backbone network for feature extraction, possibly based on newer architectures like EfficientNet or Transformer-based backbones. These would help in capturing more complex features while maintaining efficiency.

Neck:

- **Feature Pyramid Networks (FPN)**: An advanced FPN or a path aggregation network (PANet) to better aggregate features at different scales.
- **Spatial Pyramid Pooling (SPP)**: Enhanced SPP to help the model handle objects at varying scales and improve the receptive field.

Head:

- **Anchor-Free Design**: Incorporate an anchor-free detection head, which has become popular for reducing computational complexity and improving performance.
- **Dynamic Head**: Use dynamic convolutions in the head to better adapt to various object sizes and shapes

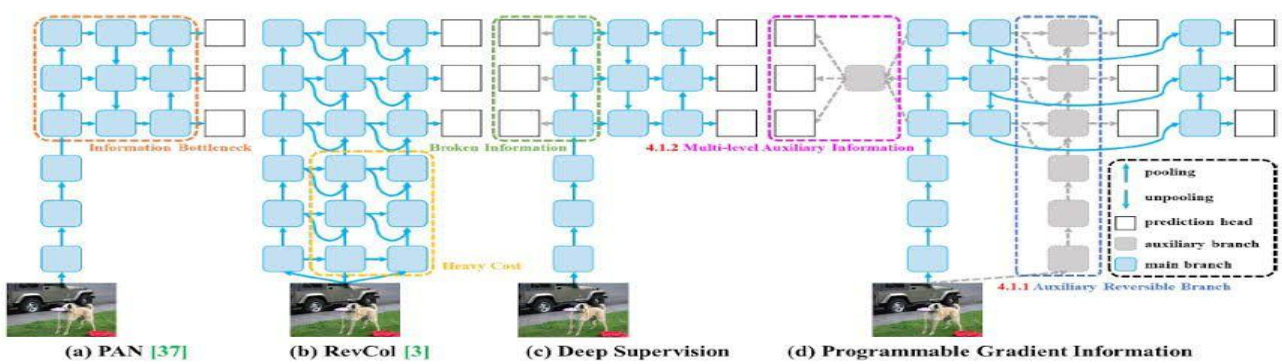


Figure 2.15 **Architecture for yolov9**

2.17.2 YOLOv9 in our project:

The proliferation of unmanned aerial vehicles (UAVs) has underscored the importance of drone detection technology. In response, researchers are turning to sophisticated object detection algorithms like YOLOv9, in conjunction with robust deep learning frameworks such as PyTorch. This report delves into the practical application of YOLOv9 and PyTorch for drone detection, focusing specifically on the steps involved in dataset creation, labeling using tools like LabelImg, and the crucial process of splitting the dataset into training, validation, and testing subsets.

1- Creating a Custom Dataset: To develop an accurate drone detection model, a custom dataset comprising 9,000 images was created. The dataset included both drone and non-drone classes. We took on the task of labeling the dataset ourselves, leveraging the LabelImg annotation tool. Each image was meticulously annotated with bounding boxes around the drones and non-drones. This self-labeled dataset ensured the model would learn from accurate and consistent annotations. 2- 2

2- Splitting the Dataset: To assess the model's performance and generalization, we divided the custom dataset into three subsets: a training set, a validation set, and a testing set. The training set, accounting for 70% of the images, was used to train the YOLOv9 model on a Windows platform. The validation set, consisting of 15% of the dataset, aided in hyperparameter tuning and preventing overfitting. Finally, the remaining 15% of images were reserved for the testing set, providing an independent evaluation of the model's performance.

3- Training the Model on a Windows Platform: To train the drone detection model, we utilized the YOLOv9 algorithm implemented with the PyTorch deep learning framework. The flexibility and easeof-use of PyTorch on a Windows platform allowed us to seamlessly integrate the training process. Leveraging the GPU capabilities of Windows, we accelerated the training process, significantly reducing the time required to complete the 300 training epochs. This expedited training enabled us to iterate and experiment with different configurations to optimize model performance.

4- Fine-tuning and Hyperparameter Optimization: Throughout the training process, we fine-tuned the YOLOv9 architecture and optimized hyperparameters to achieve the best possible performance. We adjusted Page 43 of 115 parameters such as learning rate, batch size, and optimization algorithms to strike a balance between accuracy and training speed. By monitoring the training and validation loss, we ensured that the model was learning effectively without overfitting or underfitting. Through meticulous experimentation and analysis, we attained a well-trained drone detection model.

Figure 2.16 dataset for Yolov9

2.17.3 Results

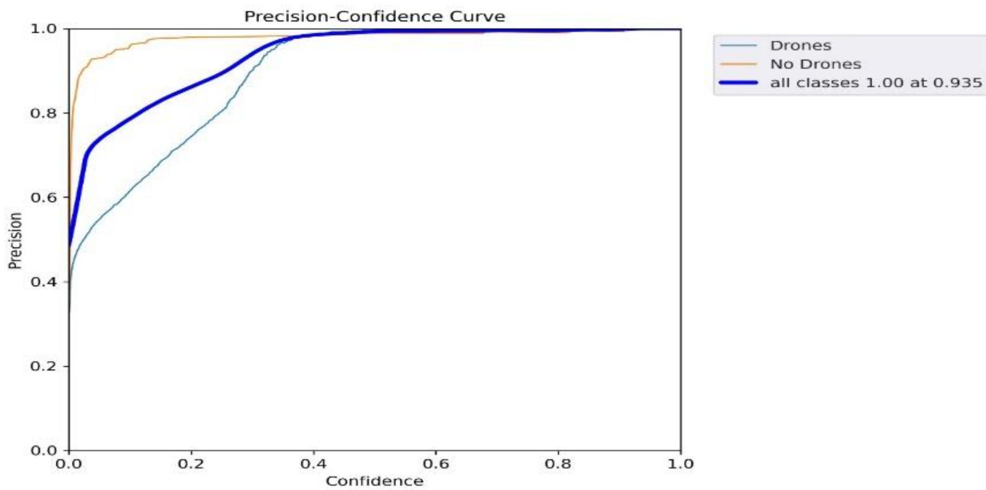


Figure 2.17 Precision-Confidence Curve

The curve in the image also includes a line for "no drones". This line shows the precision of the model for identifying images that do not contain any drones. In this case, the precision is always 1.0, regardless of the confidence threshold. This is because the model is always correct when it says that an image does not contain a drone.

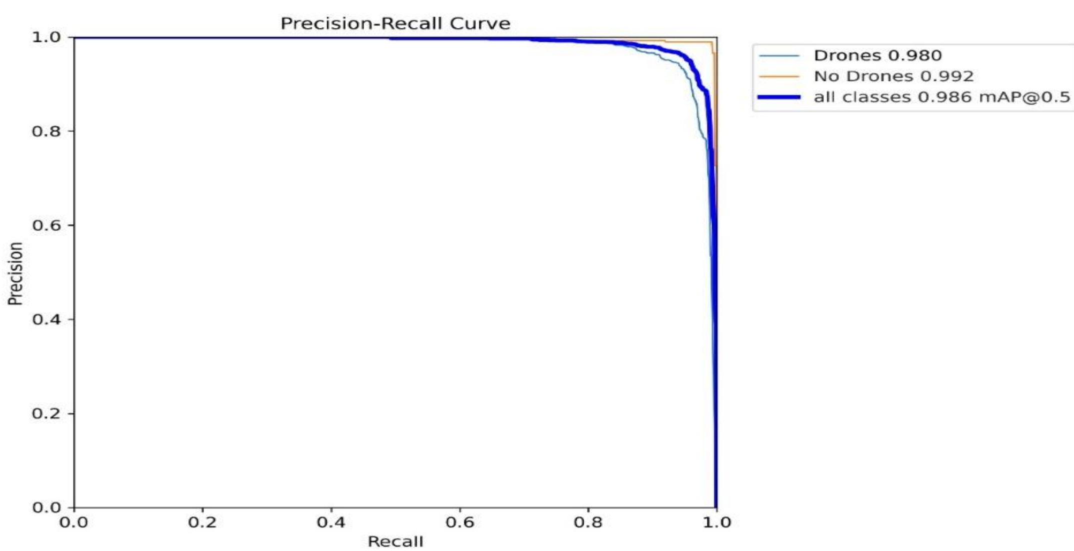


Figure 2.18 precision-recall curve

The precision-recall curve indicates the model performs well in both precision and recall, and the mAP@0.5 further strengthens this by showing good average performance across various detection scenarios.

- "Drones 0.980" - This is likely the model's average precision for correctly identifying images containing drones.
- "No Drones 0.992" - This represents the model's average precision for correctly classifying images that don't have any drones (higher because it's easier to identify their absence).
- "all classes 0.986 mAP@0.5" - This refers to the mean Average Precision (mAP) across all classes at an Intersection over Union (IoU) threshold of 0.5. IoU is a metric that measures how well the bounding box the model draws around a detected drone overlaps with the actual drone in the image. A threshold of 0.5 means the bounding box needs to overlap with at least half of the drone to be considered a correct detection. The mAP@0.5 of 0.986 suggests that on average, the model has a high precision of 0.986 when the IoU threshold is set to 0.5.

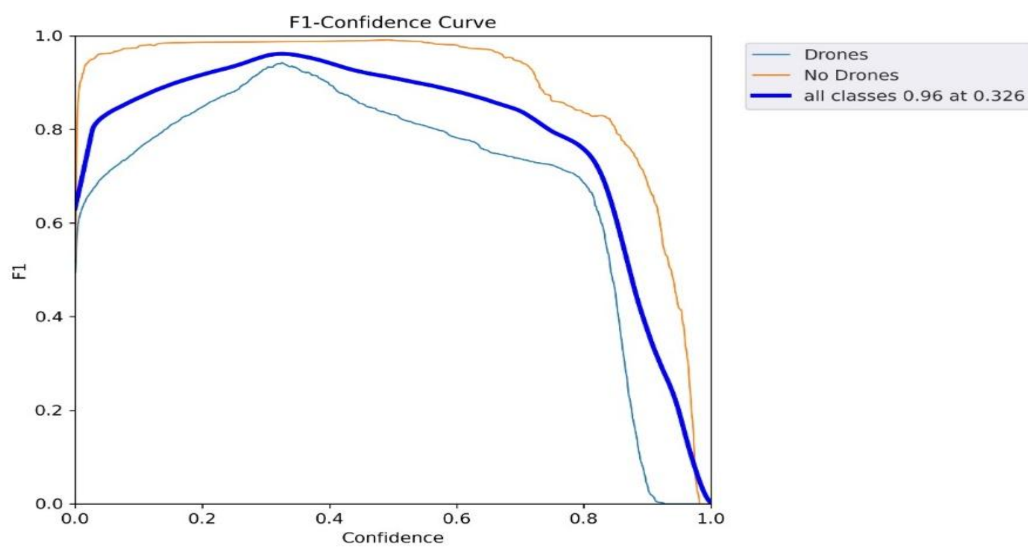


Figure 2.19 F1-confidence curve

the F1-confidence curve shows that the model performs well when it's highly confident in its classifications (drone vs. no drone). The performance weakens some for less confident predictions, but it's important to consider the specific application to determine if this an acceptable trade-off.

- "1.0 F1-Confidence Curve" at the top: This indicates a perfect scenario where the model achieves an F1 score of 1.0 for all confidence levels.

- "Drones" and "No Drones" on the right: These correspond to the different classes the model is trying to classify. It's likely trying to identify whether an image contains a drone or not.
- "all classes 0.96 at 0.326": This line refers to the overall F1 score (0.96) achieved by the model at a specific confidence level (0.326). This confidence level is marked by a vertical line on the curve.

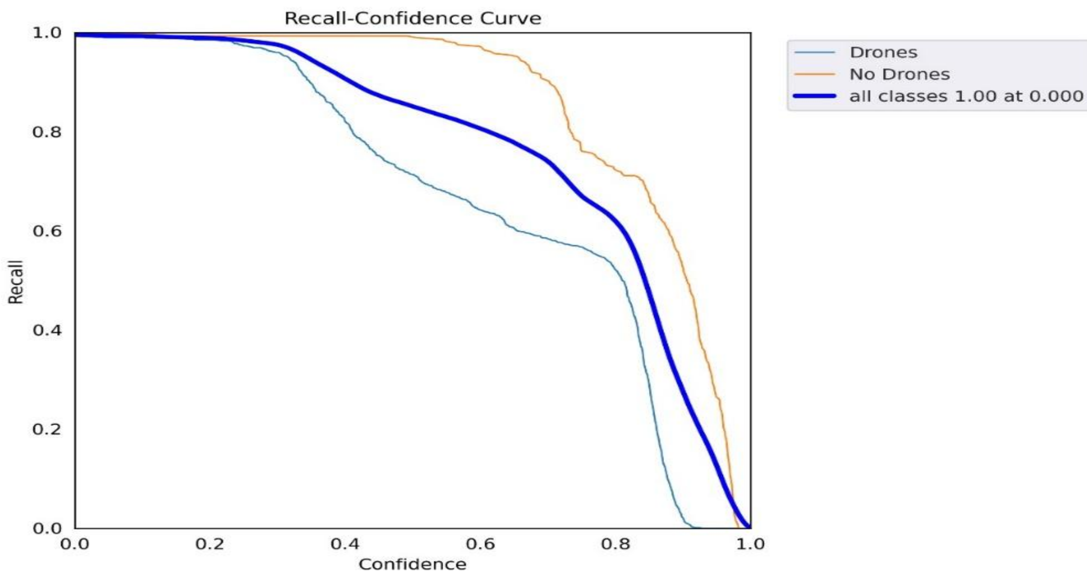


Figure 2.20 the -recall- confidence curve

- "Drones 0.962" - This is likely the model's average precision for correctly identifying images containing drones.
- "No Drones 1.00 at 0.000" - This represents the model's perfect precision (1.00) for classifying images that don't have any drones (easier to identify their absence).
- "all classes 0.933 mAP@0.5" - This refers to the mean Average Precision (mAP) across all classes at an Intersection over Union (IoU) threshold of 0.5. IoU is a metric that measures how well the bounding box the model draws around a detected drone overlaps with the actual drone in the image. A threshold of 0.5 means the bounding box needs to overlap with at least half of the drone to be considered a correct detection. The mAP@0.5 of 0.933 suggests that on average, the model has a high precision of 0.933 when the IoU threshold is set to 0.5.

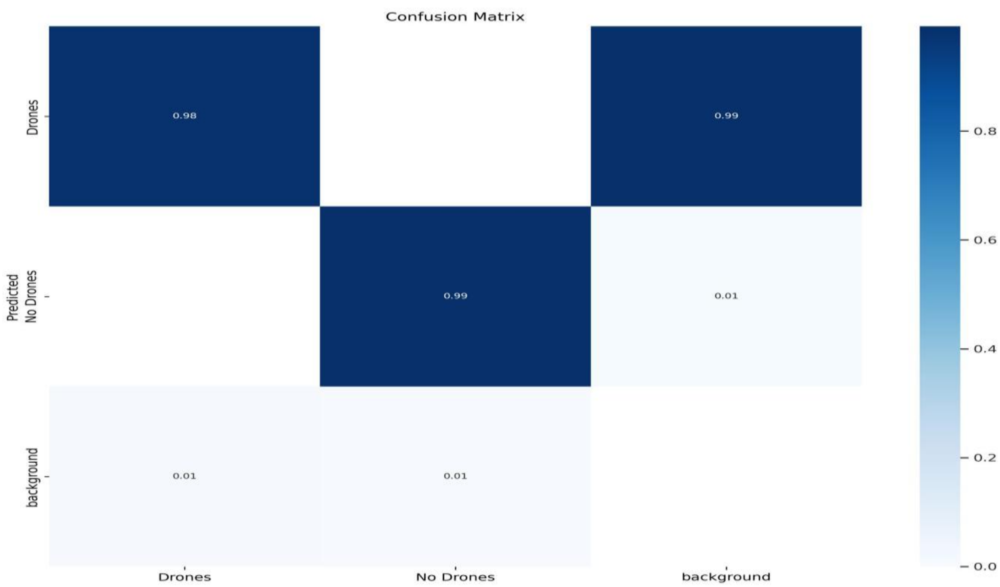


Figure 2.21 confusion matrix

The model is trying to classify images that contain drones and images that do not contain drones. There are four possible outcomes that the model can predict:

- **True Positive (TP):** The model correctly predicts that an image contains a drone. The value in this cell of the confusion matrix is 0.98.
- **False Positive (FP):** The model incorrectly predicts that an image contains a drone, when it actually does not contain a drone. The value in this cell of the confusion matrix is 0.01.
- **True Negative (TN):** The model correctly predicts that an image does not contain a drone. The value in this cell of the confusion matrix is 0.99
- **False Negative (FN):** The model incorrectly predicts that an image does not contain a drone, when it actually does contain a drone. The value in this cell of the confusion matrix is 0.02

- **Losses and mAP**

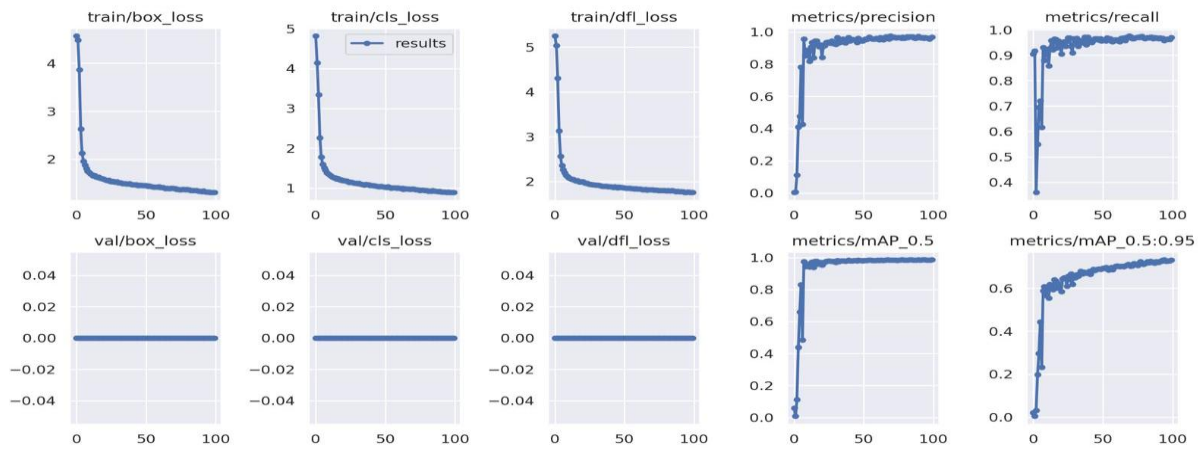


Figure 2.22 Losses and map for yolov9

A set of 10 graphs. Each graph plots the value of a metric (such as loss or precision) on the vertical axis, versus the number of training iterations on the horizontal axis. There are two sets of graphs, with one set labeled "train" and the other labeled "val." The "train" set likely refers to the training data that the model was trained on, and the "val" set likely refers to the validation data that the model's performance was measured on.

2.18 Conclusions:

The use of YOLOv8 and YOLOv9 for drone detection demonstrates significant advancements in real-time object detection capabilities. Both versions build upon the foundational principles of YOLO, leveraging a single convolutional neural network to predict bounding boxes and class probabilities directly from full images. Here are the key takeaways from applying these algorithms to drone detection:

1. ***Speed and Efficiency**: YOLO models are exceptionally fast, capable of processing images and videos in real-time. YOLOv8 and YOLOv9 continue this tradition, with improvements that enable higher frame rates and lower latencies, making them ideal for applications like live surveillance and real-time monitoring of UAVs.*

2. ***Accuracy and Precision:***
   - **YOLOv8**: Utilizes the CSPDarknet53 backbone and PANet for multi-scale feature aggregation, along with dynamic anchor assignment and an enhanced IoU loss function. These features contribute to its superior performance in detecting drones with high accuracy and reduced false positives.
   - **YOLOv9**: Further refines detection capabilities with an improved backbone network, advanced training techniques like mosaic data augmentation, and an anchor-free detection head. This results in higher precision and recall, as evidenced by the confusion matrices and PR curves, indicating a robust ability to correctly identify drones while minimizing false detections.
3. ***Generalization and Robustness****: Both YOLOv8 and YOLOv9 show strong generalization capabilities. When trained on diverse datasets, including images of drones in various environments and conditions, these models effectively handle new, unseen data, maintaining high detection performance across different contexts.*
4. ***Evaluation Metrics:***
   - **Confusion Matrix**: Both models demonstrate a high number of true positives and a relatively low number of false negatives, indicating reliable detection of drones. However, the balance between true negatives and false positives suggests areas for further optimization to enhance the models' discrimination between drone and non-drone images.
   - **PR Curve**: The precision-recall curves illustrate the trade-off between precision and recall at various thresholds. Higher areas under these curves for both YOLOv8 and YOLOv9 indicate robust performance, with YOLOv9 showing particularly impressive results with near-perfect AUC scores.
5. ***Losses and mAP****: The training and validation loss curves, along with the mean Average Precision (mAP) scores, provide insights into the models' learning efficiency and effectiveness. YOLOv9, in particular, shows a more stable and lower loss curve, along with higher mAP values, reflecting its enhanced architecture and training methodologies.*

Chapter 3 The Hardware Components Overview

<u>Presented by/</u>

F. PASSANT NAGI MOURICE GHATTAS 91255
G. RAWAN MAHMOUD ABDELBADIE 91630
H. MAHMOUD TALAAT FARAG 91621
I. MOHAMED ABDALRADY EBRAHIM 91636
J. ADEL MAHMOUD MOHAMED 91620

3.1 Introduction

This chapter discusses the requirements for each part in the exact order of design and implementation.

Since this is ***STAND ALONE JAMMER SYSTEM AGAINST UAVs USING***

HELICAL ANTENNAs*, there must be a group of interconnected devices managed by software programs to achieve the desired results autonomously. Raspberry Pi is a small single board computer. By connecting peripherals like Keyboard, mouse, display to the Raspberry Pi, it will act as a mini personal computer.*

Raspberry Pi is popularly used for real time Image/Video Processing, IoT based applications and Robotics applications. Raspberry Pi is slower than laptop or desktop but is still a computer which can provide all the expected features or abilities, at a low power consumption.

Raspberry Pi Foundation officially provides Debian based Raspbian OS. Also, they provide OS for Raspberry Pi. We can install several Third-Party versions of OS like Ubuntu, RISC OS, Windows 10 IOT Core, etc.

Raspbian OS is official Operating System available for free to use. This OS is efficiently optimized to use with Raspberry Pi. Raspbian have GUI which includes tools for Browsing, Python programming, office, games, etc. We should use SD card (64 GB) to store the OS (operating System)

Raspberry Pi is more than computer as it provides access to the on-chip hardware i.e., GPIOs for developing an application. By accessing GPIO, we can connect devices like camera , LED, motors, sensors, etc. and can control them too.

3.2 Hardware requirements

To design a project that meets the required standards for a sufficient Embedded system, some requirements such as cost, timesaving, security, mobility, and space must be taken into consideration. Therefore, we narrowed down our choice of hardware devices into the following:

Raspberry Pi:

The Raspberry Pi is a single-board computer developed in the UK by the Raspberry Pi. The Raspberry Pi is a credit-card sized computer that plugs into your TV and a keyboard. It's a capable little PC which can be used for many of the things that your desktop PC does, like spreadsheets, word processing and games.

It's have a lot of features:

• Budget-Friendly

• Space-Saver

• Easy usage/maintenance

• Compatible with several devices

• Low risk and fast time to market

• High performance in low-cost designs

• Physically addressed caches for multi-tasking performance

• Broad OS support, multiple Linux distributions, amazing ARM ecosystem

• Full Internet experience

• Low Power Leadership

3.2.1 Comparison between different versions of Raspberry pi:

	Raspberry Pi Zero	Raspberry Pi 3 B+	Raspberry Pi 4 B
			
SOC Type	Broadcom BCM2835	Broadcom BCM2837B0	Broadcom BCM2711
Core Type	ARM1176JZF-S	Cortex-A53 64-bit	Cortex-A72 (ARM v8) 64-bit
No. Of Cores	1	4	4
GPU	Video Core IV	Video Core IV	Video Core VI
CPU Clock	1 GHz	1.4 GHz	1.5 GHz
RAM	512 MB	1 GB DDR2	1 GB , 2 GB, 4 GB, 8GB LPDDR4
USB	**Yes** 1x micro OTG	**Yes** 4x USB2.0	**Yes** 2x USB3.0 + 2x USB2.0 + USB-C OTG
Ethernet	**No**	**Yes** Gigabit – Over USB 2.0	**Yes** Gigabit
HDMI port	**Yes** mini HDMI	**Yes** full HDMI	**Yes** 2x micro HDMI
Analog Video Out	- via unpopulated pin	**Yes** shared with audio jack	**Yes** shared with audio jack
Analog Audio Out	- HDMI audio	**Yes** 3.5mm jack	**Yes** 3.5mm jack
LCD Panel	**No**	**Yes**	**Yes**
Wi-Fi	**Yes** 802.11n	**Yes** 2.4GHz and 5GHz 802.11 b/g/n/ac	**Yes** 2.4GHz and 5GHz 802.11 b/g/n/ac
Bluetooth®	**Yes** 4.1 BLE	**Yes** 4.2, BLE	**Yes** 5.0
Power ratings	180 mA	1.13 A @5V	1.25 A @5V
Power sources	microUSB or GPIO	microUSB, GPIO	USB-C
Power Over Ethernet	**No**	- with PoE Hat	- with PoE Hat

3.2.2 Raspberry Pi 4model B technical specifications

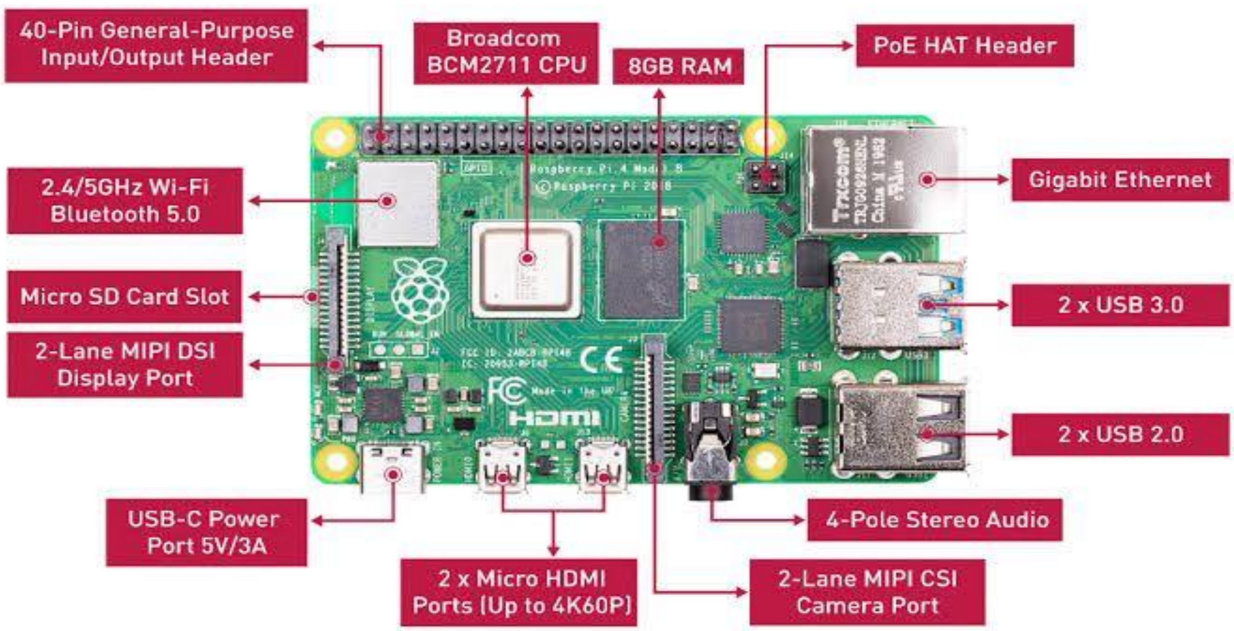


Figure 3.2.2 Raspberry Technical Specifications

In terms of end use, it is important to note that the performance of the new Raspberry Pi 4 Model B is equivalent to that of an entry-level x86 computer. Among the main features of this latest Raspberry Pi computer, we can note:

• A high-performance 64-bit quad-core processor

• Dual display support with resolutions up to 4K via a pair of micro-HDMI ports

• Hardware video decoding up to 4Kp60

•8 GB of RAM

• A connection to the dual-band wireless local area network 2.4/5.0 GHz

• Bluetooth 5.0 / Gigabit Ethernet / USB 3.0 / PoE features (via a separate HAT PoE add-on module)

• SoC Broadcom BCM2711, quad-core Cortex-A72 (ARM v8) 64-bit at 1.5GHz

• SDRAM 4 GB LPDDR4-2400

• Wireless LAN 2.4 GHz and 5.0 GHz IEEE 802.11b/g/n/ac, Bluetooth 5.0, BLE

• True Gigabit Ethernet

• 2 USB 3.0 ports, 2 USB 2.0 ports

• Fully backward compatible 40-pin GPIO connector

• 2 HDMI micro ports supporting video resolution up to 4K 60Hz

• 2-way MIPI DSI DSI/CSI ports for camera and display

• Stereo audio output and composite video port, 4-pole

• Slot for Micro SD card, for operating system and data storage

• Requires 5.1V, 3A power supply via USB-C or GPIO

• PoE (Power over Ethernet) enabled (requires PoE HAT)

3.2.3 Raspberry Pi 4 Pins (GPIO):

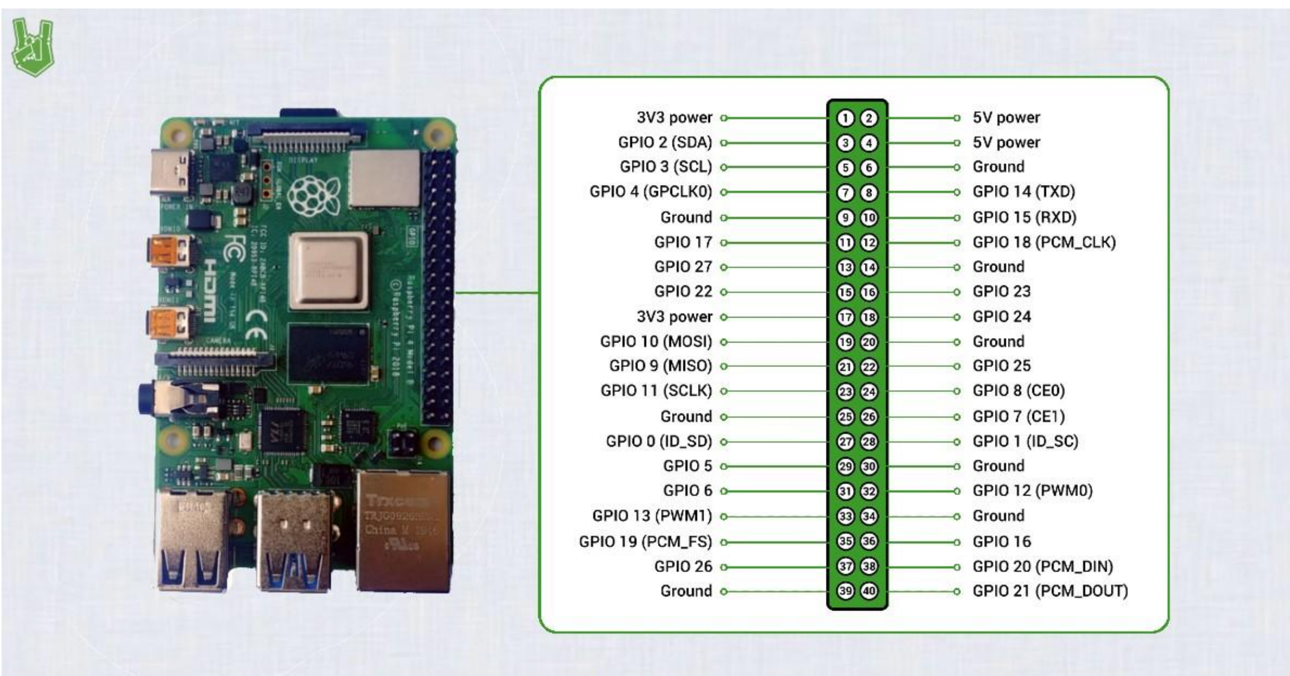


Figure 3.3.3 Raspberry Pi 4 Pins (GPIO)

3.2.4 Professional Camera:

Camera Is used to detect drones within the dataset used in AI model.

4MP Fixed Dome Network Camera

- *High quality imaging with 4 MP resolution Efficient H.265+ compression technology*

Figure 3.2.4 Hikvision IP Camera

- *Clear imaging even with strong back lighting due to 120 dB WDR*
- *Water and dust resistant (IP67) and vandal resistant (IK10)*
- *EXIR 2.0: advanced infrared technology with long IR range*
- *Light Range up to 30 meters*
- *The field of view is presented in three measurements: horizontal, vertical, and diagonal: horizontal viewing angle in degrees, approximately 98.0° , vertical viewing angle, approximately 53.1° and viewing angle across the diagonal, approximately 114.7°*

Camera Features:

• High quality imaging with 4 MP resolution

• Efficient H.265+ compression technology

• Clear imaging even with strong back lighting due to 120 dB WDR

Camera Specifications:

Max. Resolution	2560 × 1440
Min. Illumination	Color: 0.01 Lux @(F2.0, AGC ON), B/W: 0 Lux with IR
Shutter Time	1/3 s to 1/100,000 s
Day & Night	IR cut filter
Angle Adjustment	Pan: 0° to 355°, tilt: 0° to 75°
Supplement Light Range	Up to 30 m
Supplement Light Type	IR
Power	12 VDC ± 25%, 0.4 A, max. 5 W, Ø 5.5 mm coaxial power plug PoE: IEEE 802.3af, Class 3, 36 V to 57 V, 0.2 A to 0.15 A, max. 6.5 W
Ethernet Interface	1 RJ45 10 M/100 M self-adaptive Ethernet port

3.2.5 Arduino uno

1- Features

*Arduino UNO is a microcontroller board based on the **ATmega328P**. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.*

2- Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts. The power pins are as follows:

- *VIN. The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.*

- *5V.This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.*

- *3V3. A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.*

• *GND. Ground pins.*

3.2.6 Memory:

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the (EEPROM library).

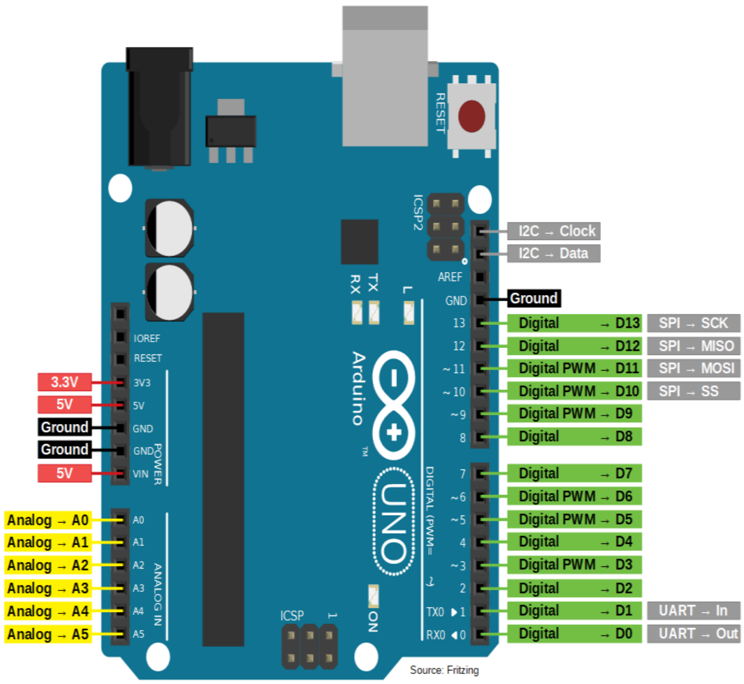


Figure3.2.6: Arduino uno

3.2.7 Motors

In our project we are using a Brushless Stepper Motor (200 steps/Revolution, 8-mm diameter Shaft) which has the ability to deliver high power to the antenna and camera parts.

1. Brushed motors:

An armature rotates inside a brushed DC motor, which has permanent magnets inside its exterior body. The permanent magnets are immovable and are called the 'stator'. The term "rotor" refers to the rotating armature that has an electromagnet inside of it.

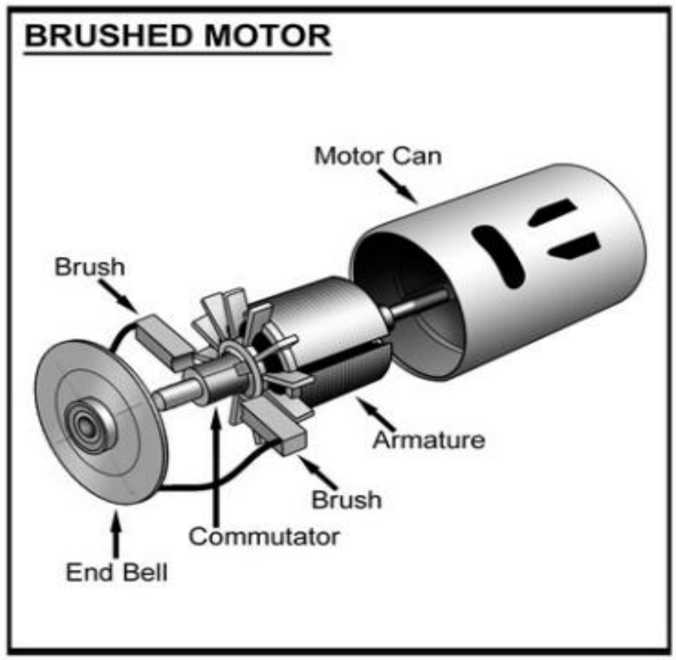


Figure 3.2.7(a): Brushed motors

When the armature of a brushed DC motor receives an electric current, the rotor rotates 180 degrees. To go past the first 180 degrees, the electromagnet's poles have to reverse. When the rotor spins, carbon brushes make contact with the stator, which flips the magnetic field and allows the rotor to spin 360 degrees.

These coils need power to function, which is supplied to them. In brushed motors, the commutator, which is positioned near the top of the shaft, transfers power to the center shaft via brushes. As may be seen on the right, a standard motor has two brushes. To charge the coils and maintain motor operation, these brushes need to be in contact with the commutator at all times. As you may expect, there is a great deal of heat and friction generated by the brushes and commutator. A well-performing motor depends on this component being kept clean.

2. Brushless motors:

The coils of brushless motors also require an electrical supply, but they are located inside the motor can rather than on the shaft. This enables a wire connection that is direct. There is no need for brushes because the magnets are fixed to the rotor, or central shaft.

Because there is no friction or current loss from brushes rubbing against a commutator, brushless motors have a longer running length than brushed motors.

Longer run times and greater power result from this. Despite their efficiency, brushless motors nevertheless produce heat, and any electric motor that overheats can fail.

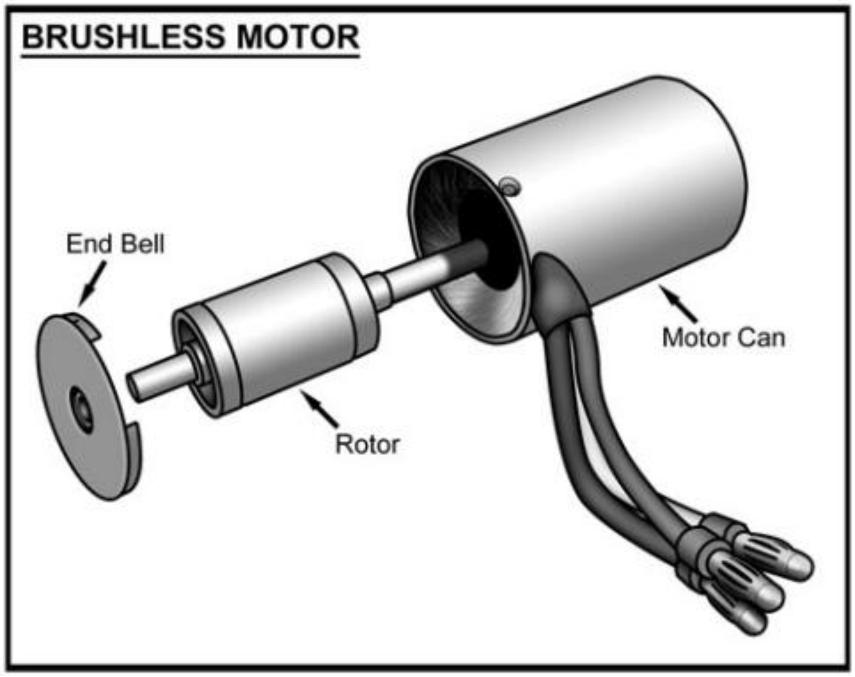


Figure 3.2.7(b): Brushless motors.

3. Stepper motors:

A stepper motor is a unique type of DC motor that rotates in fixed steps of a certain number of degrees. Step size can range from 0.9 to 90°. It consists of a rotor and stator. In this case, the rotor is a permanent magnet, and the stator is made up of electromagnets (field poles). The rotor will move (or step) to align itself with an energized field magnet. If the field magnets are energized one after the other around the circle, the motor can be made to move in a complete circle.

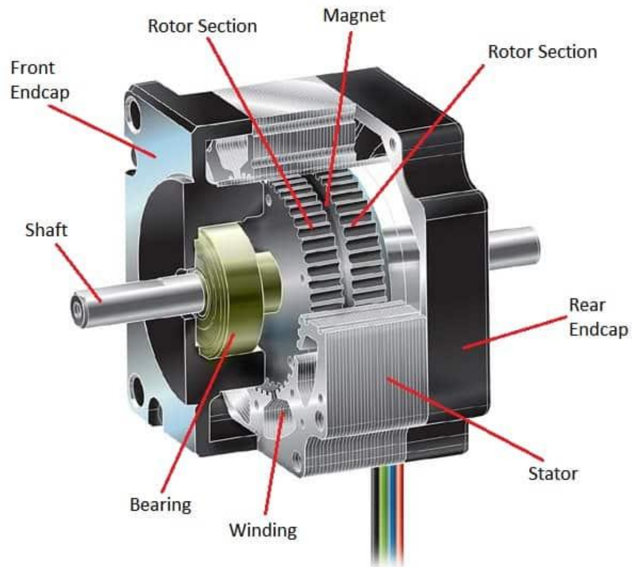


Figure3.2.7(c) Stepper Motor

In a two-phase bipolar stepping motor, when coils are excited in order one phase at a time, the motor rotates.

If excitation occurs in the opposite order, motor rotation in the opposite direction is possible.

Stepper motor features:

NEMA 24 35 Kg-cm

- Step angle accuracy: + - 5%(full step,not load)
- Resistance accuracy: + - 10%
- Inductance accuracy: + - 20%
- Ambient temperature -----------—20deg ~+50deg
- Insulation resistance:100MΩ Min,500VDC
- Insultion Strength--------500VAC for one minute
- Step Angle: 1.8 degrees
- Steps per Revolution: 200
- 2-Phase
- Bipolar
- Voltage (V): 4.8
- Current (A): 3
- Phase Resistance: 1.6Ω
- Phase Inductance: 8.4mH
- Holding Torque: 35.0 kg.cm
- Weight: 1.3kg

Stepper motor implementation:

1) Black-Brown wire connects to pin A+
2) Green-Orange wire connects to pin A-
3) Red-Yellow wire connects to pin B+
4) Blue-Blue wire connects to pin B-

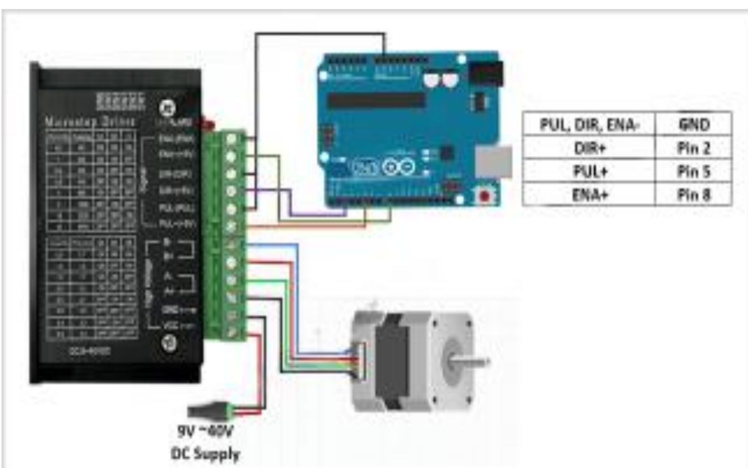


Figure 3.2.7(d)Stepper motor connection

3.3 Motor driver module:

The components' job is to react to the step command pulses coming from the machine controller and convert them into the proper on-off pattern required to drive the stepper motor. This electronic device will transform our movement instructions from a controller into a sequence where the winding in the stepper motor will be turned on or off while still providing enough power to it.

We used in our project motor driver DM556.This is a professional two-phase stepper motor driver. It supports speed and direction control. You can set its micro step and output current with 8 DIP switch. There are 16 kinds of micro steps and 8 kinds of current control (1.4A, 2.1A, 2.7A, 3.2A, 3.6A, 4.3A, 4.9A, 5.6A) in all.

Figure 3.3 Microstep Driver

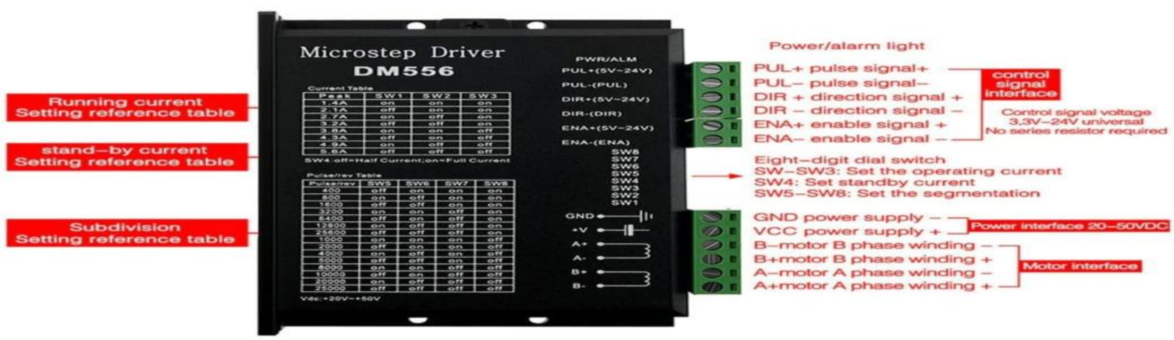
Driver features:

- Anti-Resonance, provides optimum torque and nulls mid-range instabilities
- Supply voltage up to +50 VDC (recommended not to exceed 45 V because of "back EMF")
- Output current programmable, from 0.5 A to 5.6A
- Automatic idle-current reduction (in standstill mode) to reduce motor heating; function switchable (reduction rate can be software configured)
- Motor self-test and parameter auto-setup technology, offers optimum responses with different motors
- Pulse input frequency up to 200 kHz
- TTL compatible and optically isolated input
- Multi-Stepping allows a low resolution step input to produce a higher microstep output for smooth system performance
- Microstep resolutions programmable, from full-step to 102,400 steps/rev
- Suitable for 2-phase and 4-phase motors
- Support PUL/DIR and CW/CCW modes
- Over-voltage, over-current, phase-error protections.

3.3.1 Electrical Specification:

Instruction	DM556N-L			
	Minimum	Typical	Maximum	Unit
Output Current	1.4	-	5.6 (Peak)	Amps
Input Voltage	20	36	50 (contain the ripple)	VDC
	15	24	40(contain the ripple)	VAC
Control Signal Voltage	3	3.3	5.5	VDC
Control Signal Current	7	10	16	mA
Signal Pulse Frequency	0	-	200	KHz
Insulation Resistance	500			MΩ

3.3.2 Driver implementation:



Signal Input:

- **PUL+** Pulse+
- **PUL-** Pulse-

- **DIR+** Direction+
- **DIR-** Direction-
- **EN+** Off-line Control Enable+
- **EN-** Off-line Control Enable-

Motor Machine Winding:

- **A+** Stepper motor A+
- Stepper motor A-
- **B+** Stepper motor B+
- Stepper motor B-

Power Supply:

- **VCC** VCC(DC20-50V)
- **GND** GND

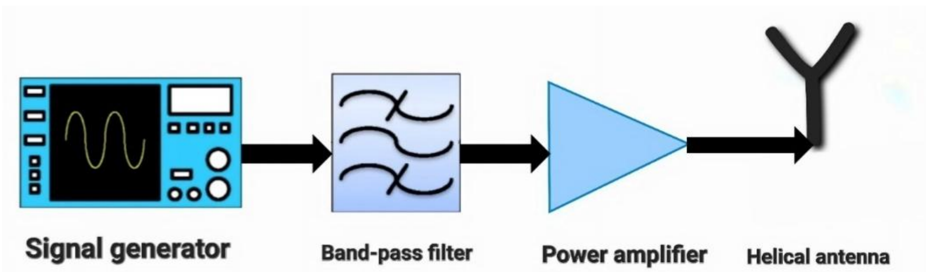
Connection:

- **VCC** - **Positive** terminal of the battery to be connected.
- **GND** - **Ground** terminal of the battery to be connected.
- **PUL-,DIR-,ENA-** Connected To Ground Terminal of Arduino
- **DIR+** Connected to Pin 2 in Arduino
- **PUL+** Connected to Pin 5 in Arduino

3.4 The Antenna System

The System of Antenna is Consists of :

- *Signal generator*
- *Power Amplifier*
- *Band Pass Filter*
- *Helical Antenna*



3.4.1 Signal generator:

A signal generator is an electronic instrument that produces electrical signals with specific properties, such as:

*• **Amplitude**: The strength or intensity of the signal.*

*• **Frequency**: The number of cycles of the signal per second, measured in Hertz (Hz).*

*• **Waveform**: The shape of the signal, such as sine, square, triangle, or sawtooth.*

Signal generators are used in a wide variety of applications, including:

*• **Electronics testing:** Signal generators are used to test the performance of electronic circuits and devices. For example, a signal generator can be used to test the frequency response of an amplifier or the sensitivity of a radio receiver.*

*• **Telecommunications:** Signal generators are used to generate the signals that are used for communication, such as radio waves, microwaves, and optical signals.*

*• **Medical imaging:** Signal generators are used to generate the signals that are used for medical imaging, such as ultrasound and MRI.*

• ***Scientific research:*** *Signal generators are used in a wide variety of scientific research applications, such as spectroscopy and materials science.*

There are two main types of signal generators:

• ***Analog signal generators:*** *Analog signal generators produce continuous analog signals.*
• ***Digital signal generators:*** *Digital signal generators produce discrete digital signals.*

Signal generators can also be classified by the type of signal they produce:

• ***Arbitrary waveform generators:*** *Arbitrary waveform generators can produce any type of waveform, including complex waveforms that are not easily generated by other types of signal generators.*

• ***Function generators:*** *Function generators can produce a limited number of waveforms, such as sine, square, triangle, and sawtooth.*

• ***Pulse generators:*** *Pulse generators can produce pulses of various shapes and durations.*

• ***RF signal generators:*** *RF signal generators produce radio frequency signals.*
More general-purpose signal generators allow control of all the characteristics of a signal. Modern general-purpose signal generators will have a microprocessor control and may also permit control from a personal computer.

3.4.2 Band pass filter:

A band-pass filter or band pass filter (BPF) is a device that passes frequencies within a certain range and rejects (attenuates) frequencies outside that range. It is commonly used in electronics, signal processing, and optics.

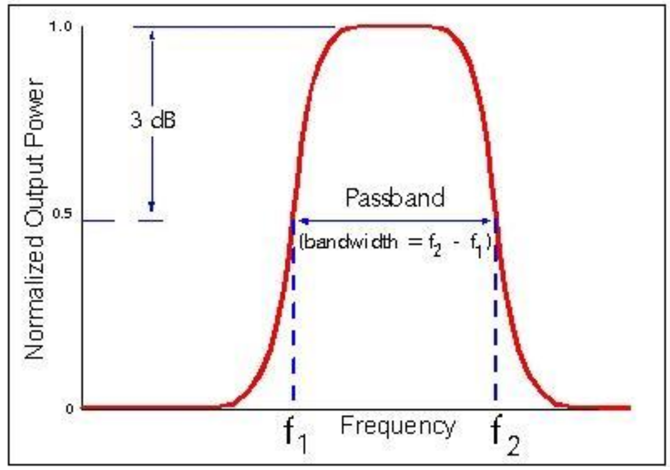


Figure 3.6.1(a): Band pass filter chr

3.4.3 Power amplifier:

A power amplifier is an electronic amplifier designed to increase the magnitude of power of a given input signal. The power of the input signal is increased to a level high enough to drive loads of output devices like speakers, headphones, RF transmitters etc.

Types of Power Amplifiers:

Depending on the type of output device that is connected, power amplifiers are divided into the following three types:

- ***RF Power Amplifiers**: Wireless transmissions require modulated waves to be sent over long distances through air. The signals are transmitted using antennas and the range of transmission depends on the magnitude of power of signals fed to the antenna. For wireless transmissions, like FM broadcasting, antennas require input signals at thousands of kilowatts of power. Here, Radio Frequency Power amplifiers are employed to increase the magnitude of power of modulated waves to a level high enough for reaching the required transmission distance. The output of an audio power amplifier ranges from a few milliwatts (like in headphone amplifiers) to thousands of watts (like power amplifiers in Hi-Fi/Home theatre systems).*
- ***DC Power Amplifiers**: DC power amplifiers are used to amplify the power of a PWM (Pulse Width Modulated) signals. They are used in electronic control systems which need high power signals to drive motors or actuators. They take input from microcontroller systems, increase its power and feed the amplified signal to DC motors or Actuators.*

Power amplifiers are classified into different classes *based on their efficiency and operating characteristics. Class A amplifiers are the most linear and accurate, but they are also the least efficient. Class B amplifiers are more efficient, but they can introduce distortion into the signal. Class AB amplifiers are a compromise between Class A and Class B, offering good efficiency and sound quality. Class D amplifiers are a type of switching amplifier that is very efficient, but they can generate more distortion than other classes.*

When choosing a power amplifier, it is important to consider the following factors:

- ***The power output you need:*** *This will depend on the application and the size of the speakers or other devices you are driving.*
- ***The type of signal you are amplifying:*** *Audio amplifiers are designed for audio signals, while RF amplifiers are designed for radio frequency signals.*
- ***The efficiency you need:*** *If efficiency is important, then a Class AB or Class D amplifier may be a good choice.*
- ***The sound quality you need:*** *If sound quality is important, then a Class A amplifier may be the best choice.*

Applications:

Below are the applications of power amplifiers across different sectors:

- ***Consumer Electronics****: Audio power amplifiers are used in almost all consumer electronic devices ranging from microwave ovens, headphone drivers, televisions, mobile phones and Home theatre systems to theatrical and concert reinforcement systems.*

- ***Industrial****: Switching type power amplifiers are used for controlling most of the industrial actuator systems like servos and DC motors.*

- ***Wireless Communication****: High power amplifiers are important in transmission of cellular or FM broadcasting signals to users. Higher power levels made possible because of power amplifiers increases data transfer rates and usability. They are also used in satellite communication equipment.*

3.4.4 Helical Antenna:

helical antenna *is one of the types of broadband antenna which is also called helix antenna. This is one of the most primary, realistic & straightforward antennas which are designed with conducting wire-wound in a helical structure form.*

What is Helical Antenna?

Definition of helical antenna: *The simplest antennas which are used widely in ultra-high frequencies are known as helical antennas, so this antenna works in VHF & UHF ranges. These antennas are designed with conducting wire in a helix shape. This antenna has some unique characteristics like wide bandwidth, high gain & circular polarization.*

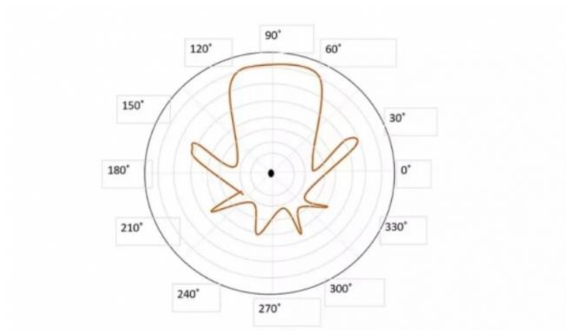
The frequency range of this antenna ranges from 30MHz0-3GHz. This antenna is used in space communication such as satellite relays and also in radio astronomy, wireless networking & satellite communications.

It's The most popular helical antenna (helix) is a travelling wave antenna in the shape of a corkscrew that produces radiation along the axis of the helix antenna. These helix antennas are referred to as axial-mode helical antennas. The benefits of this helix antenna is it has a wide bandwidth, is easily constructed, has a real input impedance, and can produce circularly polarized fields

Modes in Helical Antenna

1- Normal mode ($C = \pi D << \lambda$)

In the normal mode of radiation, the radiation field is normal to the helix axis and the radiated waves are circularly polarized waves. This mode of radiation is obtained if the dimensions of a helix are small compared to the wavelength. The radiation pattern of this helical antenna is a combination of short dipole and loop antenna.



The shown figure is the radiation pattern for the normal mode of radiation in a helical antenna.

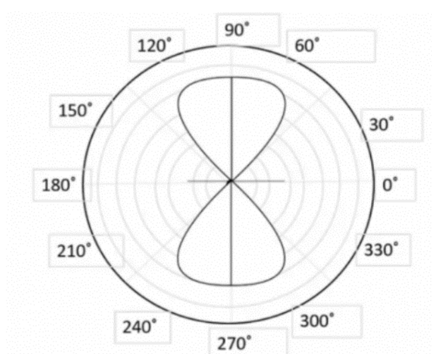
It depends upon the values of the diameter of helix D and it turns spacing S. Main problem with this mode of operation is that the radiation efficiency is low and the bandwidth is narrow. Hence it is practically limited and hardly used

2- Axial mode ($C \approx \lambda$)

In the axial mode of radiation, the radiation is in the end-fire direction along the helical axis and the waves are circular or nearly circular polarized waves. This mode of operation is obtained by raising the circumference to the order of one wavelength (C/λ) and a spacing of approximately $\lambda/4$. The radiation pattern is broad and directional along the axial beam producing minor lobes at oblique angles

The shown figure is the radiation pattern for an axial mode of radiation in the helical antenna.

This antenna, when used for reception, if it is designed for right-handed circularly polarized waves, it will not receive left-handed circularly polarized waves and vice versa. This mode of operation is generated with great ease and is more practically used.



Features

*The **salient features of a helical antenna** include the following.*

1- *This is a simple antenna used for circular polarization.*

2- *It is utilized in different bands like VHF &UHF.*

3- *It is most commonly used in axial mode.*

4- *It is not chosen in normal mode where efficiency and beamwidth are small in this mode.*

5- *Its design is very simple & has maximum directivity.*

6- *In axial mode, it is a wideband antenna.*

7- *If the axial ratio is zero then, linear horizontal polarization occurs.*

8- *If the axial ratio is infinite then linear vertical polarization occurs.*

9- *If the axial ratio is one, then circular polarization occurs.*

Design of Helical Antenna

The construction of the helical antenna is shown below. This antenna can be designed with a conducting wire-like thick copper wire wounded in helical form & it is connected to the ground plate through a feeder line. This antenna is very simple to design and it provides waves that are polarized circularly, so it is used in different communication-based applications where satellite relays are involved

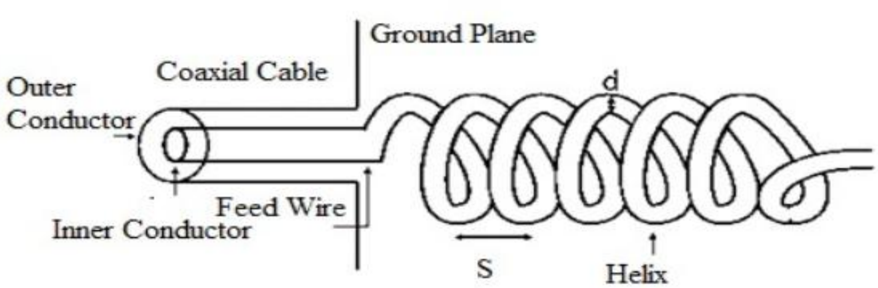
The previous diagram depicts a helical antenna system that needs wider outdoor space. Here, one helix end is connected to the middle conductor of the cable whereas the external conductor is simply connected to the ground plate which is made with the conductor. This antenna is fed by a coaxial cable which can be functioned in axial & normal modes.
We know that the helical antenna operates in two modes where the deciding factor of these modes is the diameter of the helix & spacing between two consecutive spins.

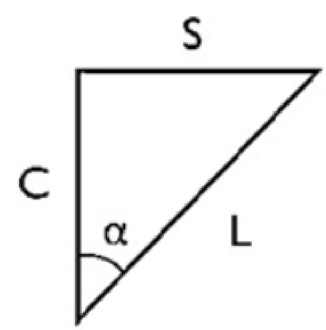
Suppose, the length of a single turn of the helical antenna is 'L', the spacing between consecutive turns is 'S', then the whole antenna's length will be NS. The helix circumference is denoted with C that is given as 'πD'. Here, 'D' is the helical spring diameter.

When we consider the one unrolling turn of the helix antenna, then the different parameters which are related to it can be defined through the following triangle. The helical antenna's radiation mainly depends on the turn spacing, diameter & pitch angle. So, the pitch angle is the existing angle in between a line tangent to the helix wire & plane normal to the helix axis

- *So,* $\tan \alpha = S/C = S/\pi D \Rightarrow$
- *Pitch angle in a Helical Antenna* $\alpha = \tan^{-1}(S/\pi D)$
- *D' is the helix diameter.*
- *'S' is the turn spacing*
- *'α' is the pitch angle.*

Therefore, finally, we can conclude that the antenna radiation characteristics are modified by changing the above parameters based on the wavelength.





Formulas

The following formulas are used for calculating helical antenna gain, diameter, space between coils, wire length, half-power beamwidth, beamwidth first nulls, and appearance.

1- $Helical\ Antenna\ Gain\ (G) = \ 10.8 + 10 * Log(NS)$
2- $Diameter\ (D) = \frac{\lambda}{3.14}$
3- $Space\ between\ coils\ (S) = \ Space\ between\ coils\ x\ wavelength = s * \lambda$
4- $Length\ of\ wire\ (L) = N\sqrt{\lambda^2 + S^2}$
5- $Half\ Power\ Beam\,Width\ of\ antenna\ = \frac{52}{\sqrt{NS}}$
6- $Beam\,Width\ First\ Nulls\ of\ antenna\ = \frac{115}{\sqrt{NS}}$
7- $Aperture\ = \frac{10*\frac{G}{10}*\lambda^2}{4*3.14}$

Advantages

*The **advantages of a helical antenna** include the following.*

1- *Design is simple.*
2- *Directivity is high.*
3- *Wide bandwidth.*
4- *Circular polarization can be obtained.*
5- *It can be used at VHF and HF bands.*
6- *Robust construction.*
7- *When it uses a circularly polarized pattern then it is acceptable through both vertical & horizontal polarized antenna types.*
8- *High gain*

Disadvantages

1- *The **disadvantages of a helical antenna** include the following.*

2- *Its size is larger so occupies more space.*

3- *The efficiency mainly depends on the number of turns so, because of the number of turns, the efficiency will be decreased.*

4- *High cost.*

Applications

*The **applications of helical antennae** include the following.*

1- *These antennas are applicable in satellite & space probe communications because of their circular polarization of the transmitted electromagnetic waves & maximum directivity.*

2- *A single or array of helical antennas are used for transmitting & receiving VHF signals.*

3- *Used for satellites at Earth stations.*

4- *Used for telemetry links through ballistic missiles.*

5- *Communication can be established between the moon & the earth.*

6- *Helical antennas are used in many satellites like data relay and weather.*

7- *This antenna is used for transmitting & receiving VHF waves, especially for ionospheric propagation.*

8- *It is used for different communications like radio astronomy, space telemetry, satellite, and space.*

9- *It is used in jamming depend on it's high gain*

3.5 *Solar panel*

- *A **solar panel** is a device that converts sunlight into electricity by using photovoltaic (PV) cells. PV cells are made of materials that produce excited electrons when exposed to light. The electrons flow through a circuit and produce direct current (DC) electricity, which can be used to power various devices or be stored in batteries. Solar panels are also known as **solar cell panels**, **solar electric panels**, or **PV modules**.*

  *Solar panels are usually arranged in groups called **arrays** or **systems**. A photovoltaic system consists of one or more solar panels, an inverter that converts DC electricity to alternating current (AC) electricity, and sometimes other components such as controllers, meters, and trackers.*

3.5.1 Uses of Solar panel

A photovoltaic system can be used to provide electricity for off-grid applications, such as remote homes or cabins, or to feed electricity into the grid and earn credits or payments from the utility company. This is called a grid-connected photovoltaic system.

3.5.2 advantages and disadvantage of solar panels

***Some advantages** of solar panels are that they use a renewable and clean source of energy, reduce greenhouse gas emissions, and lower electricity bills.*

***Some disadvantages** are that they depend on the availability and intensity of sunlight, require cleaning, and have high initial costs. Solar panels are widely used for residential, commercial, and industrial purposes, as well as for space and transportation applications.*

3.5.3 Theory and constructions

Photovoltaic modules consist of a large number of solar cells and use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. Most modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module can be either the top layer or the back layer. Cells must be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones based on thin-film cells are also available. The cells are usually connected electrically in series, one to another to the desired voltage, and then in parallel to increase *current. The power (in watts) of the module is the voltage (in volts) multiplied by the current (in amperes), and depends both on the amount of light and on the electrical load connected to the module. The manufacturing specifications on solar panels are obtained under standard conditions, which are usually not the true operating conditions the solar panels are exposed to on the installation site*

A PV junction box is attached to the back of the solar panel and functions as its output interface. External connections for most photovoltaic modules use MC4 connectors to facilitate easy weatherproof connections to the rest of the system. A USB power interface can also be used.[11] Solar panels also use metal frames consisting of racking components, brackets, reflector shapes, and troughs to better support the panel structure

3.5.4 Cell connection techniques

In solar modules, the cells themselves need to be connected to form the module, with front electrodes blocking the solar cell front optical surface area slightly. To maximize frontal surface area available for sunlight and improve solar cell efficiency, ***manufacturers use varying rear electrode solar cell connection techniques:***

- *Passivated emitter rear contact (PERC) adds a polymer film to capture light*
- *Tunnel oxide passivated contact (TOPCon) adds an oxidation layer to the PERC film to capture more light[12]*
- *Interdigitated back contact (IBC)*

Light capture:

The amount of light absorbed by a solar cell depends on the angle of incidence of whatever direct sunlight hits it. This is partly because the amount falling on the panel is proportional to the cosine of the angle of incidence, and partly because at high angle of incidence more light is reflected. To maximize total energy output, modules are often oriented to face south (in the Northern Hemisphere) or north (in the Southern Hemisphere) and tilted to allow for the latitude. Solar tracking can be used to keep the angle of incidence small.

Solar panels are often coated with an anti-reflective coating, which is one or more thin layers of substances with refractive indices intermediate between that of silicon and that of air. This *causes destructive interference in the reflected light, diminishing the amount. Photovoltaic manufacturers have been working to decrease reflectance with improved anti-reflective coatings or with textured glass.*

Power curve

In general with individual solar panels, if not enough current is taken, then power isn't maximized. If too much current is taken, then the voltage collapses. The optimum current draw is roughly proportional to the amount of sunlight striking the panel. Solar panel capacity is specified by the MPP (maximum power point) value of solar panels in full sunlight.

Inverters

Solar inverters convert the DC power provided by panels to AC power.

MPP (Maximum power point) of the solar panel consists of MPP voltage (V_{mpp}) and MPP current (I_{mpp}). Performing maximum power point tracking (MPPT), a solar inverter samples the output (I-V curve) from the solar cell and applies the proper electrical load to obtain maximum power.

Connectors

Outdoor solar panels usually include MC4 connectors. Automotive solar panels may also include an auxiliary power outlet and/or USB adapter. Indoor panels (including solar pv glasses, thin films and windows) can integrate a microinverter (AC Solar panels).

3.5.5 Efficiency

Each module is rated by its DC output power under standard test conditions (STC) and hence the on field output power might vary. Power typically ranges from 100 to 365 Watts (W). The efficiency of a module determines the area of a module given the same rated output – an 8% efficient 230 W module will have twice the area of a 16% efficient 230 W module. Some commercially available solar modules exceed 24% efficiency. Currently the best achieved sunlight conversion rate (solar module efficiency) is around 21.5% in new commercial products typically lower than the efficiencies of their cells in isolation. The most efficient mass-produced solar modules have power density values of up to 175 W/m^2 (16.22 W/ft^2)

3.5.6 Performance and degradation

Module performance is generally rated under standard test conditions (STC): irradiance of 1,000 W/m^2, solar spectrum of AM 1.5 and module temperature at 25 °C.[40] *The actual voltage and current output of the module changes as lighting, temperature and load conditions change, so there is never one specific voltage at which the module operates. Performance varies depending on geographic location, time of day, the day of the year, amount of solar irradiance, direction and tilt of modules, cloud cover, shading, soiling, state of charge, and temperature. Performance of a module or panel can be measured at different time intervals with a DC clamp meter or shunt and logged, graphed, or charted with a chart recorder or data logger.*

For optimum performance, a solar panel needs to be made of similar modules oriented in the same direction perpendicular to direct sunlight. Bypass diodes are used to circumvent broken or shaded panels and optimize output. These bypass diodes are usually placed along groups of solar cells to create a continuous flow.

electrical characteristics include nominal power (P_{MAX}, measured in W), open-circuit voltage (V_{OC}), short-circuit current (I_{SC}, measured in amperes), maximum power voltage (V_{MPP}), maximum power current (I_{MPP}), peak power, (watt-peak, W_p), and module efficiency (%).

Open-circuit voltage or V_{OC} is the maximum voltage the module can produce when not connected to an electrical circuit or system. V_{OC} can be measured with a voltmeter directly on an illuminated module's terminals or on its disconnected cable.

The peak power rating, W_p, is the maximum output under standard test conditions (not the maximum possible output).

Production

The production of PV systems has followed a classic learning curve effect, with significant cost reduction occurring alongside large rises in efficiency and production output.

With over 100% year-on-year growth in PV system installation, PV module makers dramatically increased their shipments of solar modules in 2019. They actively expanded their capacity and turned themselves into gigawatt GW players. According to Pulse Solar, five of the top ten PV module companies in 2019 have experienced a rise in solar panel production by at least 25% compared to 2019

he basis of producing solar panels revolves around the use of silicon cells These silicon cells are typically 10–20% efficient at converting sunlight into electricity, with newer production models now exceeding 22%

3.5.7 Applications

There are many practical applications for the use of solar panels or photovoltaics. It can first be used in agriculture as a power source for irrigation. In health care solar panels can be used to refrigerate medical supplies. It can also be used for infrastructure. PV modules are used in photovoltaic systems and include a large variety of electric devices:

- *Solar canals*
- *Photovoltaic power stations*
- *Rooftop solar PV systems*
- *Standalone PV systems*
- *Solar hybrid power systems*

Product Features

- *accessible junction box with 4-1/2" knockout for easy installation*
- *24 volt 30 watt*
- *Rigid anodized aluminum frame and low iron-tempered glass*
- *(EVA) with TPT cushions the solar cells within the laminate and ensures the operating characteristics of the solar cells under virtually any clymatic condition*
- *Easily accessible grounding points on all four corners for fast installation*
- *Proven junction box technology*
- *Class 1 Division 2 (C1D2) Group A, B, C and D*

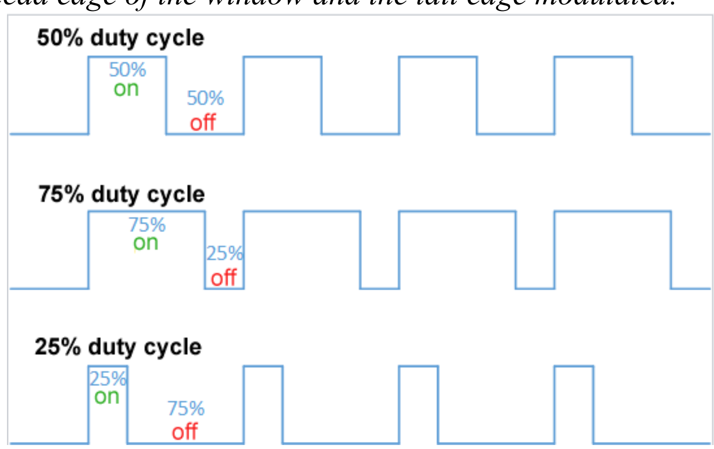
Duty cycle

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on. When a digital signal is on half of the time and off the other half of the time, the digital signal has a duty cycle of 50% and resembles a "square" wave. When a digital signal spends more time in the on state than the off state, it has a duty cycle of >50%. When a digital signal spends more time in the off state than the on state, it has a duty cycle of <50%. Here is a pictorial that illustrates these three scenarios:

Types

Three types of pulse-width modulation are possible:

1. *The pulse center may be fixed in the center of the time window and both edges of the pulse moved to compress or expand the width.*
2. *The lead edge can be held at the lead edge of the window and the tail edge modulated.*
3. *The tail edge can be fixed and the lead edge modulated.*



WM is also used in efficient voltage regulators. By switching voltage to the load with the appropriate duty cycle, the output will approximate a voltage at the desired level. The switching noise is usually filtered with an inductor and a capacitor.

One method measures the output voltage. When it is lower than the desired voltage, it turns on the switch. When the output voltage is above the desired voltage, it turns off the switch.

3.5.8 The solar panel used in our project

SOLAR CHARGER CONTROLLER 5A

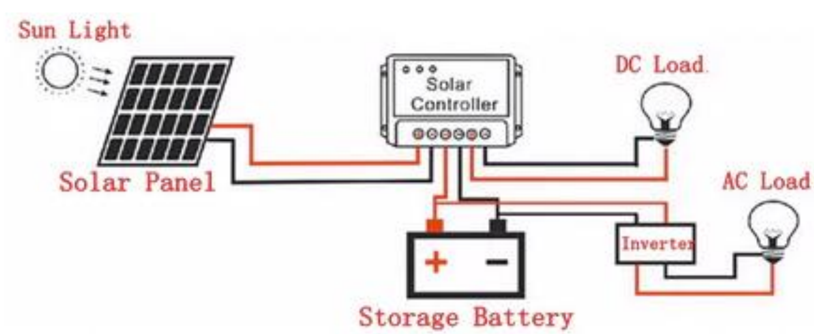
Features

- *Built-in industrial microcontroller*
- *Built-in short circuit protection*
- *built-in open circuit protection*
- *reverse protection, over-load protection*
- *one-key setting*
- *auto memory function*
- *digital display*
- *Fully 4stage PWM charge management*
- *dual MOSFET reverse current protection*

Specification

- ***Rated charge current:*** *5A*
- ***Rated load current:*** *5A*
- ***Work voltage:*** *12/24 V Auto*
- ***Over load ,short circuit protection:*** *1.25 rated load current 60 sec., 1.5 rated load current 5 sec. , over load protection action. ≥3 Rated load current short circuit protection action*
- ***No load current:*** *≤6mA*
- ***Charging circuit voltage drop:*** *≤0.26V*
- ***Load circuit voltage drop:*** *≤0.15V*
- ***Over voltage Protection:*** *14.8V*
- ***Work temperature:*** *industry stage -35C to +35C*
- ***Boost charge voltage:*** *14.6V (keep 10min.)*
- ***Direct charge voltage:*** *14.4V (keep 10min.)*
- ***Float charge voltage:*** *13.6V*
- ***Charge return voltage:*** *13.2V*
- ***Lower voltage indicate:*** *12V*
- ***Over discharge voltage:*** *11.1v (no load)*
- ***Over discharge return voltage:*** *12.6V*
- ***Control mode:*** *PWM charge mode; modified discharge voltage by the discharge rate*

Connections



Chapter 4 System Design & Implementation

<u>Presented by/</u>

K. ANAS MOHAMED IBRAHIM MOUSTAFA 80747

L. ADEL MAHMOUD MOHAMED 91620

M. MOHAMED ABDALRADY EBRAHIM 91636

N. RANA ADEL MOHAMED 91300

O. PASSANT NAGI MOURICE 91255

P. RAWAN MAHMOUD IBRAHIM 91630

4.1 Antenna Design

The system is consists of four helical antennas which cover the frequency range of Global Navigation Satellite Systems (GNSS).

4.1.1 *GNSS Signal Characteristics:-*

Constellation	Signal	Frequency [GHz]	Modulation	Multiplexing
GPS	L1 C/A	1575.42	BPSK	CDMA
	L1 C	1575.42	TMBOC	CDMA
	L5	1176.45	BPSK	CDMA
Galileo	E1	1575.42	CBOC	CDMA
	E5a	1176.45	AltBOC	CDMA
	E5b	1207.14	AltBOC	CDMA
Compass	B1	1561.098	QPSK	CDMA
	B2	1207.14	BPSK	CDMA
Glonass	L1OF	1602 + n×0.5625	BPSK	FDMA
	L1OC	1575.42	BOC	CDMA

And we applied the average of all frequencies of GNSS to recover the whole frequencies.

We apply the Ascending Order and then apply the average between the whole frequencies

The Ascending Order in (MHZ): -

- *1176.42*
- *1202.025*
- *1207.13*

1195.192MHZ

- *1227.6*
- *1242*
- *1249*
- *1278.75*

1249.3375MHZ

- *1455*
- *1455.2*

1455.1MHZ

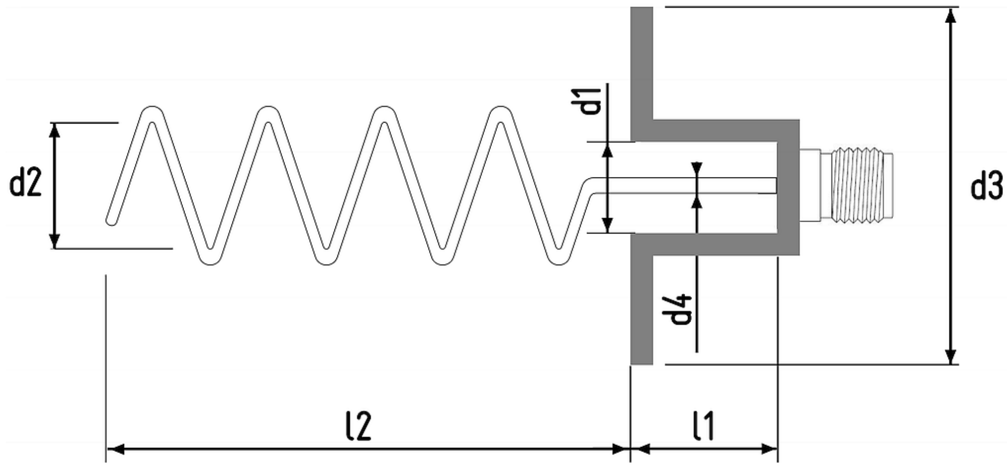
- *1575.42*
- *1598*
- *1606*

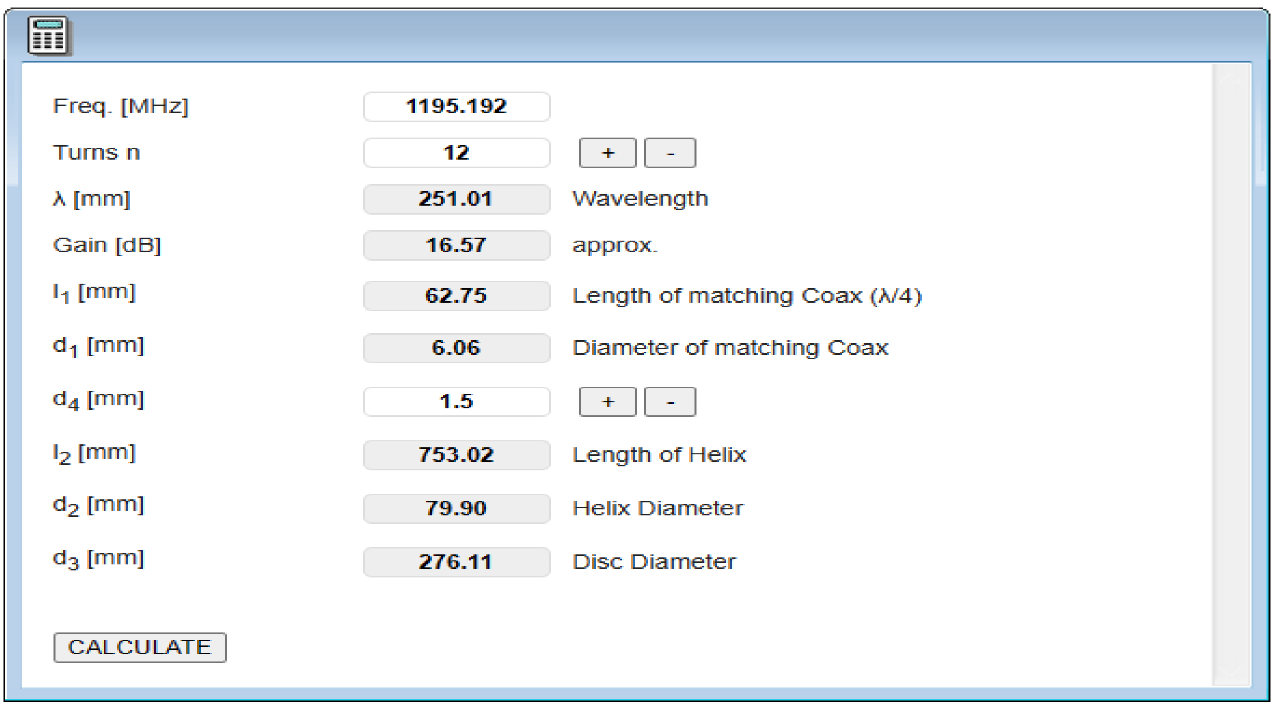
1575.42MHZ

The Components of The Helix

- *Radiating elements (copper wire)*
- *Ground plane (Reflector (conducting surface))*
- *Support structure*
- *Matching unite.*
- *Radom (optional)*
- *Feed point (connector)*

4.1.2 A Design Of 1195.192MHZ Helical Antenna

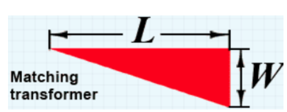




Freq. [MHz]	1195.192	
Turns n	12	+ -
λ [mm]	251.01	Wavelength
Gain [dB]	16.57	approx.
l_1 [mm]	62.75	Length of matching Coax (λ/4)
d_1 [mm]	6.06	Diameter of matching Coax
d_4 [mm]	1.5	+ -
l_2 [mm]	753.02	Length of Helix
d_2 [mm]	79.90	Helix Diameter
d_3 [mm]	276.11	Disc Diameter

CALCULATE

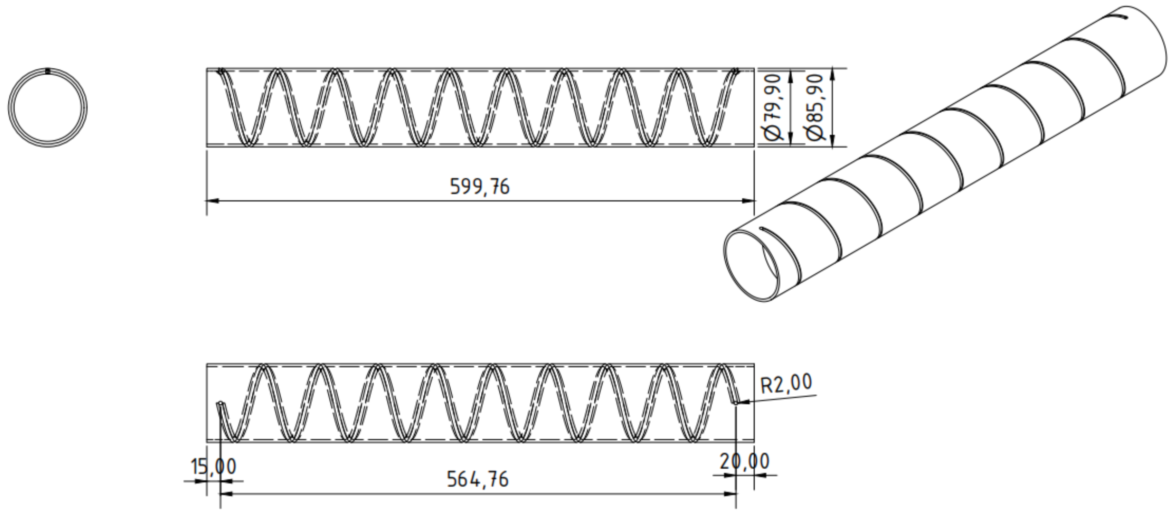
Parameters of the matching transformer 140/50 Ω:



Triangle length L: 176 mm

Triangle Height W: 52.7 mm

The 3D'S Design & the dimensions of The Helix



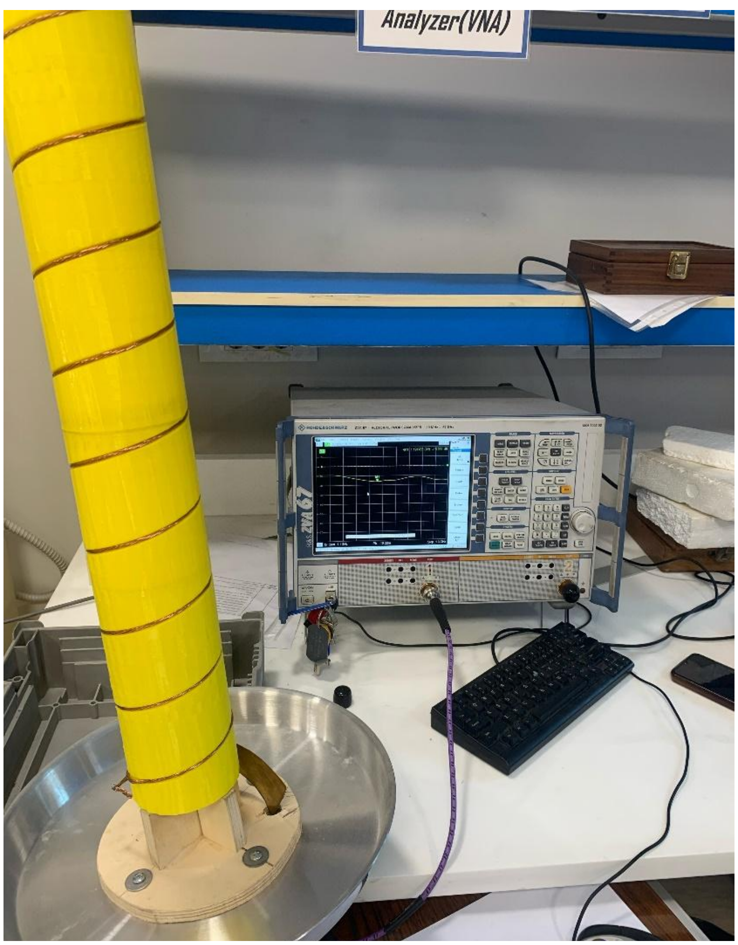
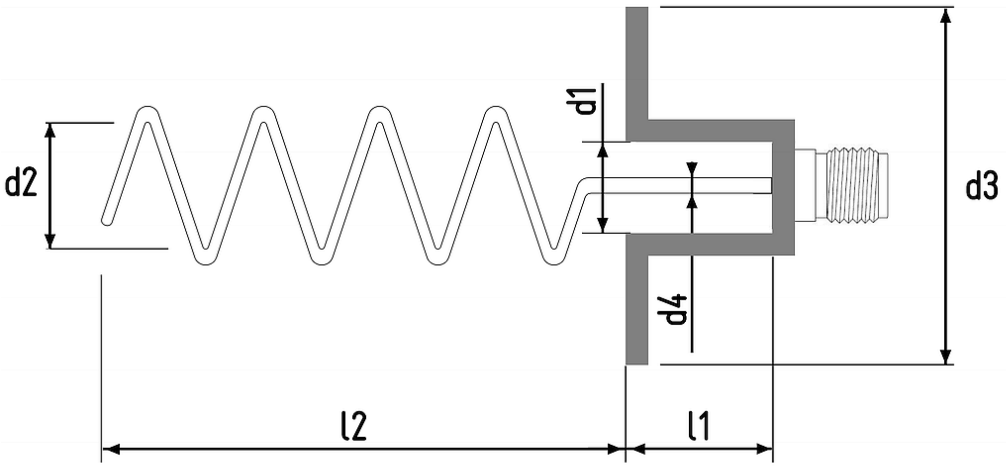
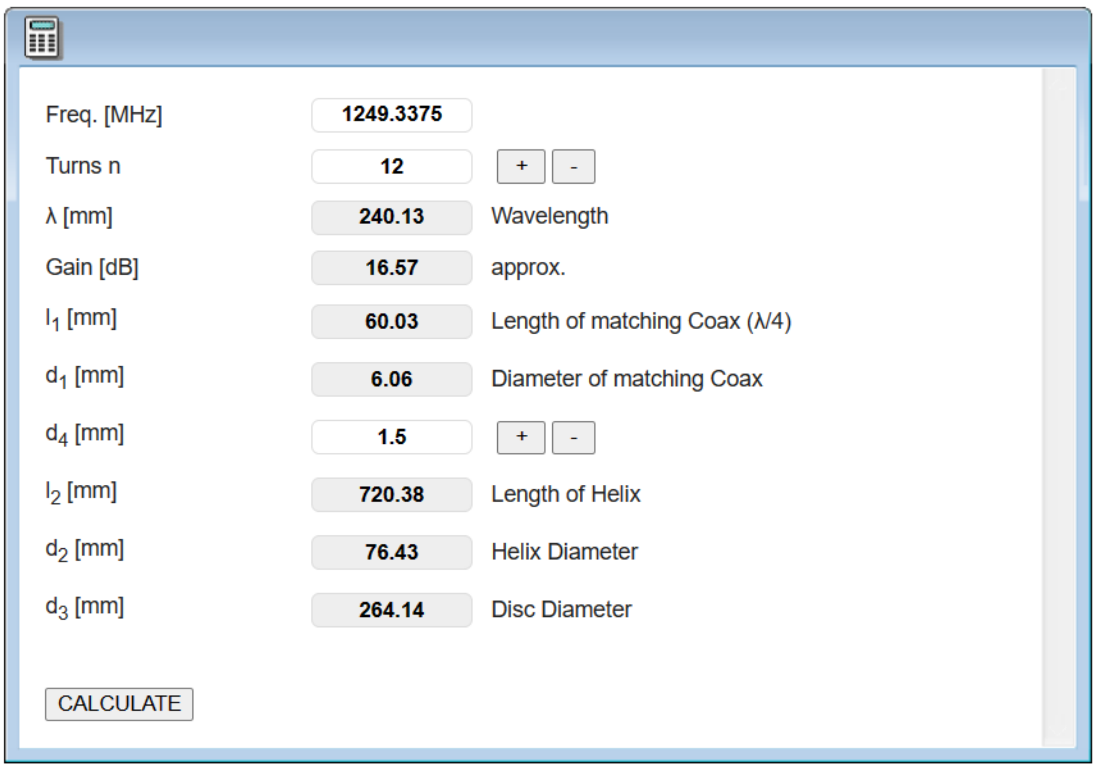


Figure 4.1.2 :1195.192 MHZ.

4.1.3 A Design Of 1249.3375MHZ Helical Antenna





Freq. [MHz]	1249.3375	
Turns n	12	+ -
λ [mm]	240.13	Wavelength
Gain [dB]	16.57	approx.
l_1 [mm]	60.03	Length of matching Coax (λ/4)
d_1 [mm]	6.06	Diameter of matching Coax
d_4 [mm]	1.5	+ -
l_2 [mm]	720.38	Length of Helix
d_2 [mm]	76.43	Helix Diameter
d_3 [mm]	264.14	Disc Diameter

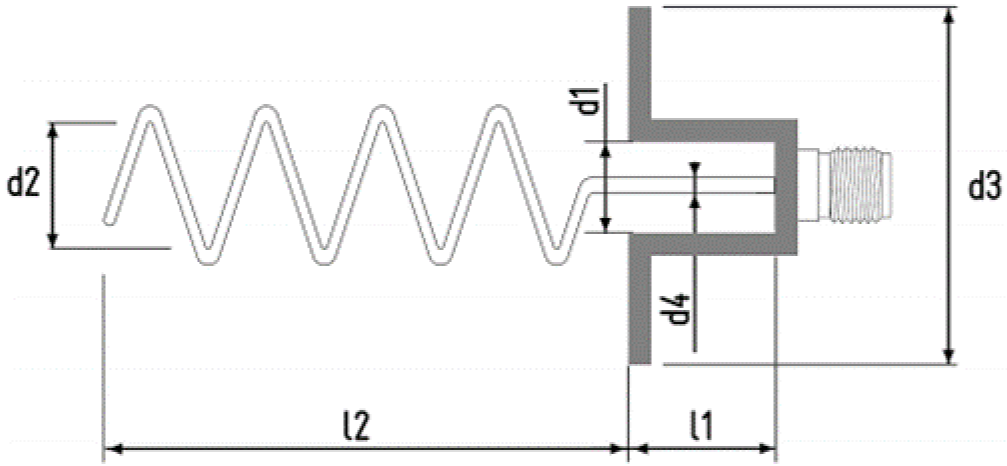
CALCULATE

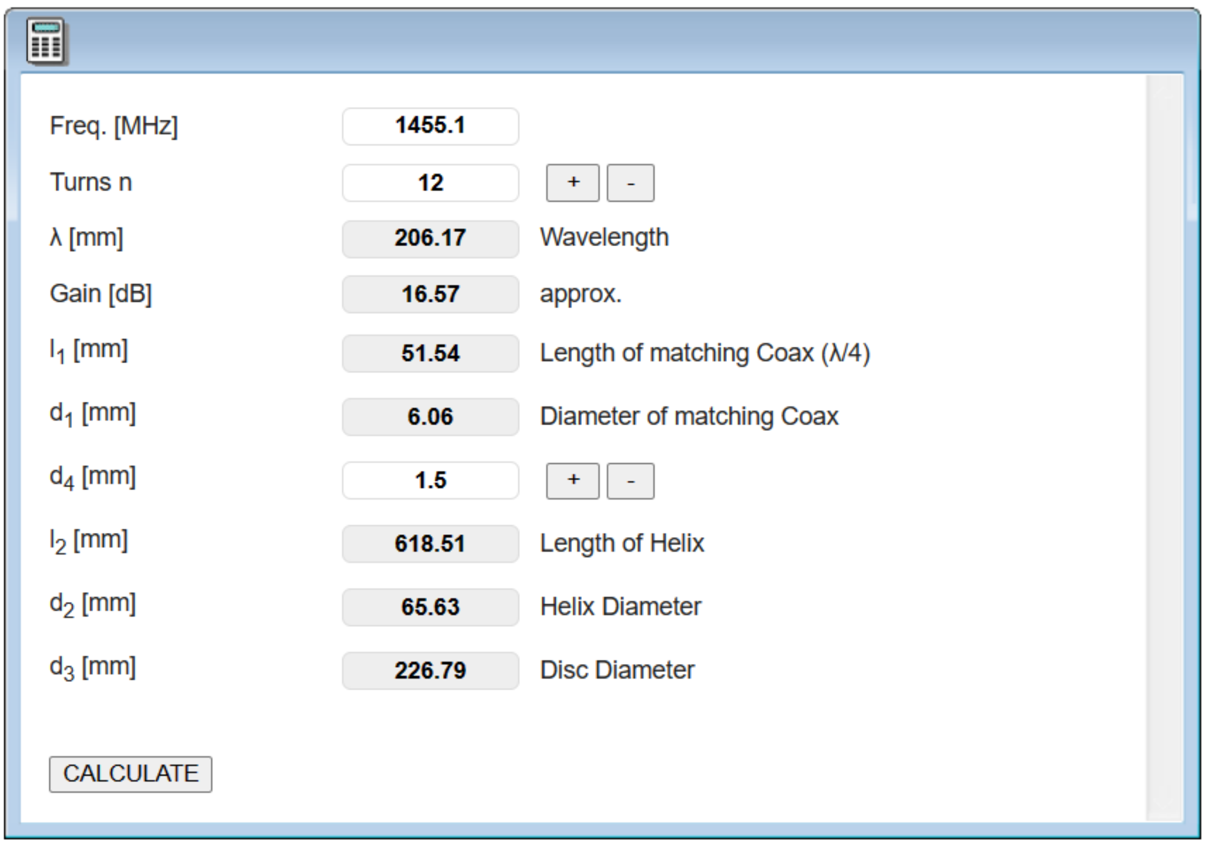
Parameters of the matching transformer 140/50 Ω:

Triangle length L: 168 mm

Triangle Height W: 50.4 mm

4.1.4 A Design Of 1455.1MHZ Helical Antenna





Freq. [MHz]	1455.1	
Turns n	12	+ -
λ [mm]	206.17	Wavelength
Gain [dB]	16.57	approx.
l_1 [mm]	51.54	Length of matching Coax (λ/4)
d_1 [mm]	6.06	Diameter of matching Coax
d_4 [mm]	1.5	+ -
l_2 [mm]	618.51	Length of Helix
d_2 [mm]	65.63	Helix Diameter
d_3 [mm]	226.79	Disc Diameter

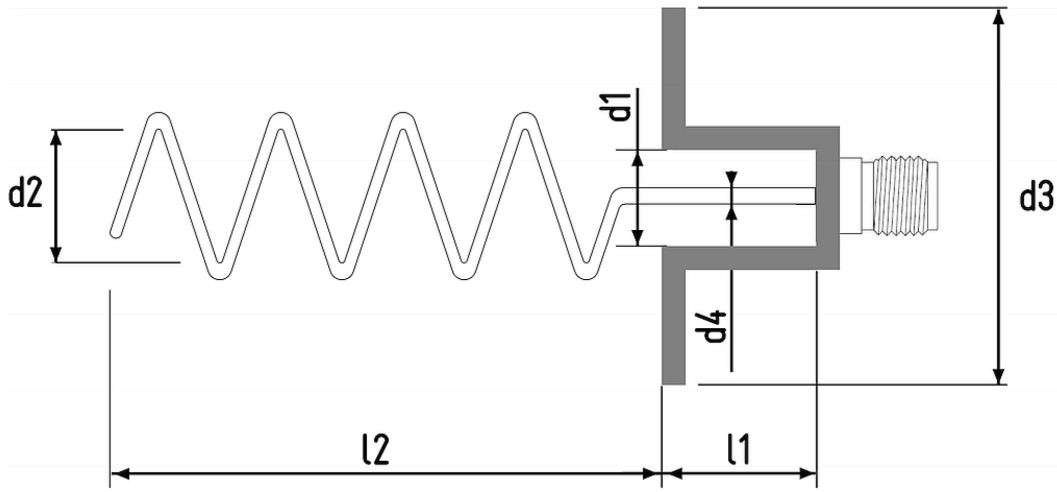
CALCULATE

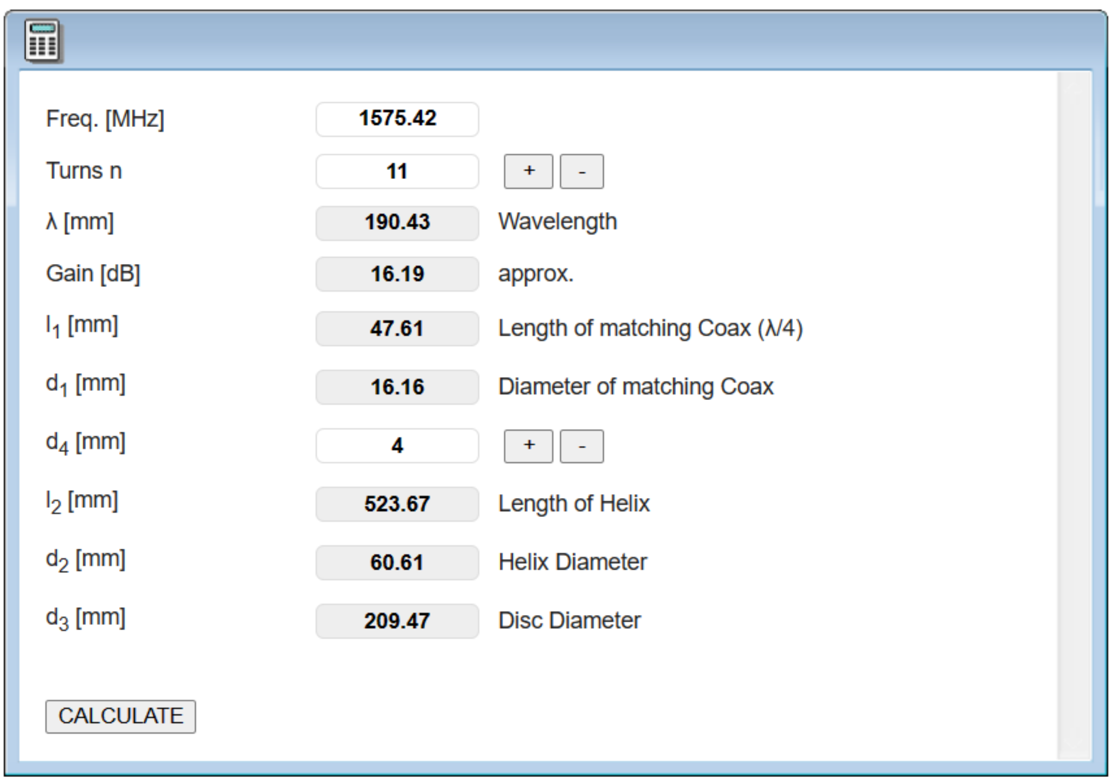
Parameters of the matching transformer 140/50 Ω:

Triangle length L: 144 mm

Triangle Height W: 43.3 mm

4.1.5 A Design Of 1575.42MHZ Helical Antenna

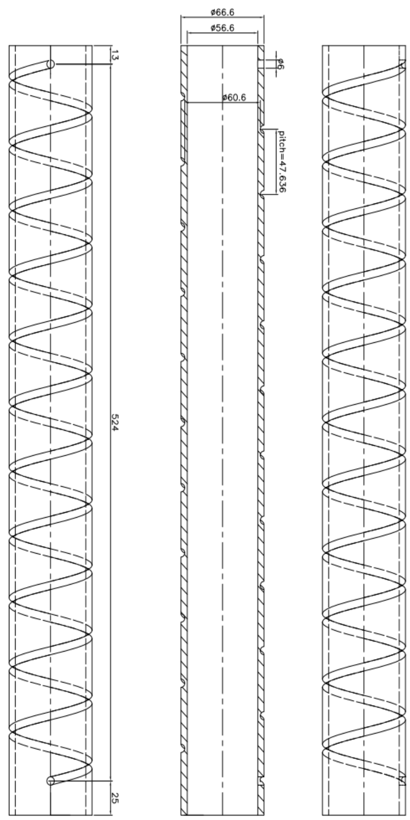


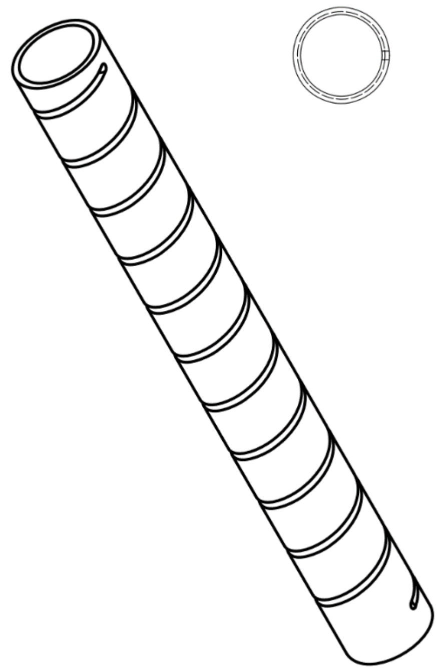


Parameters of the matching transformer 140/50 Ω

- *Triangle length **L: 133 mm***
- *Triangle Height **W: 40 mm***

The 3D’S Design of The Helix





The Output Shape of The Helix

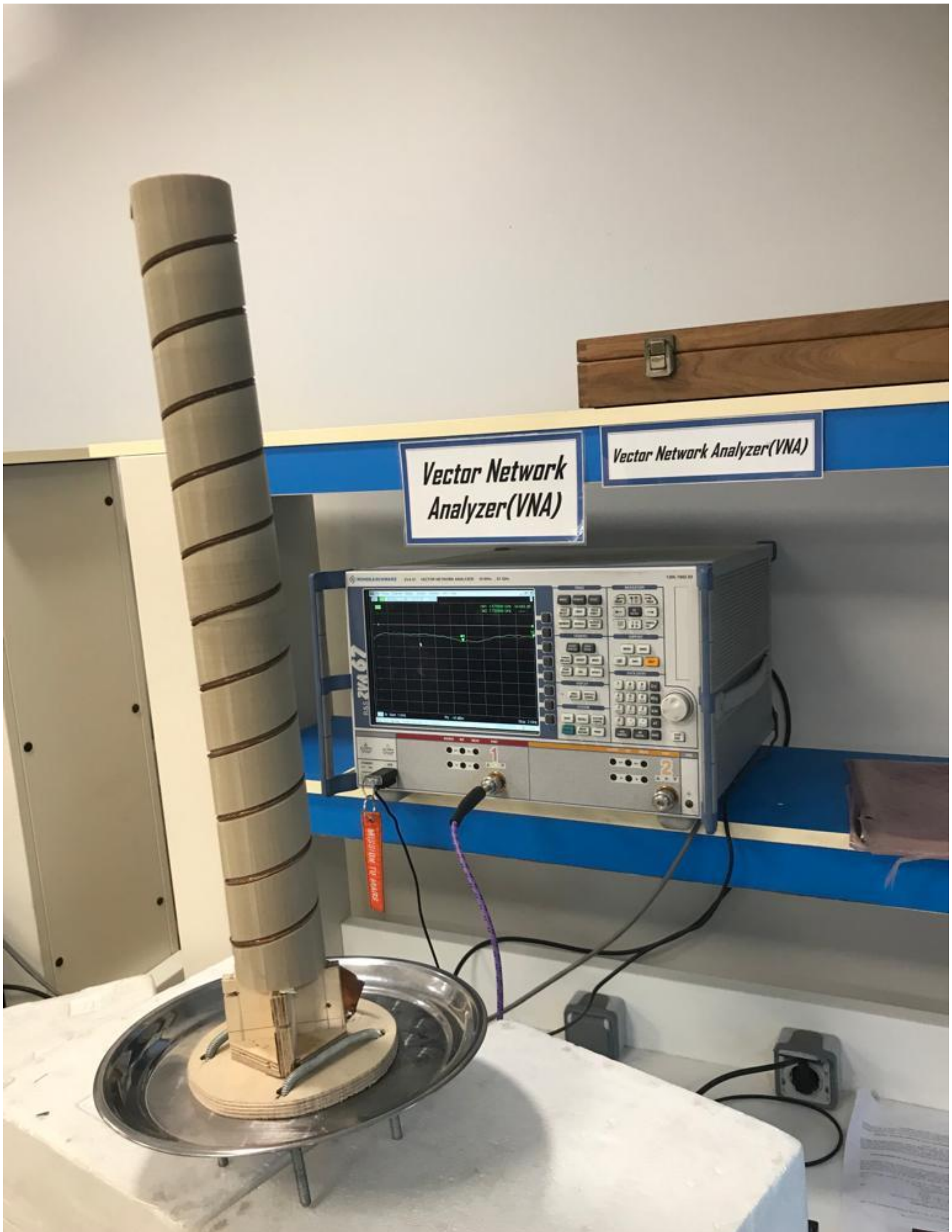


Figure 4.1.5: Design Of 1575.42MHZ Helical Antenna

4.2 The Hardware Implementation

4.2.1 Stepper motor implementation:

1) Black-Brown wire connects to pin A+
2) Green-Orange wire connects to pin A-
3) Red-Yellow wire connects to pin B+
4) Blue-Blue wire connects to pin B-

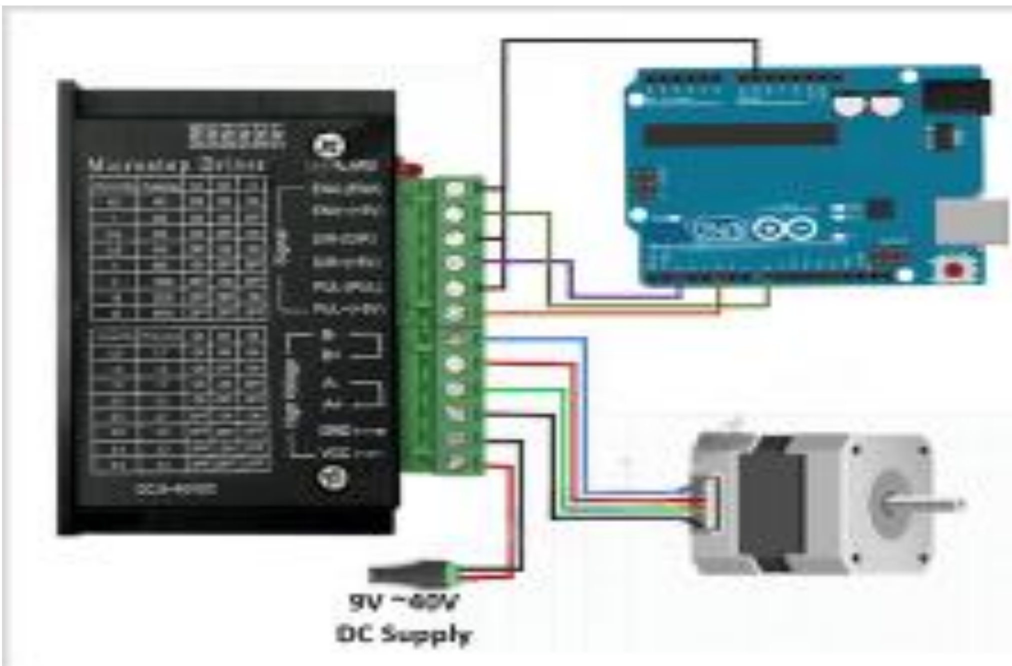


Figure 4.2.1 Stepper motor implementation

4.2.2 Motor driver module:

The components' job is to react to the step command pulses coming from the machine controller and convert them into the proper on-off pattern required todrive the stepper motor. This electronic device will transform our movement instructions from a controller into a sequence where the wind in the stepper motor will be turned on or off while still providing enough power to it.

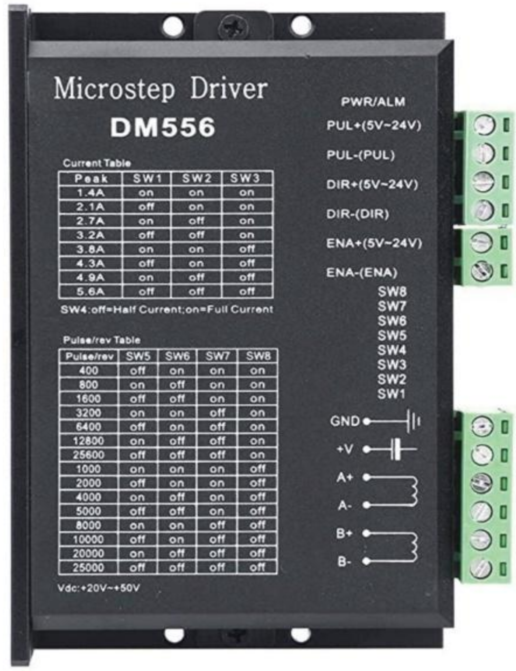


Figure 4.2.2 DM556 Motor Driver

We used in our project motor driver DM556.This is a professional two-phase stepper motor driver. It supports speed and direction control. You can set its micro step and output current with 8 DIP switch.

There are 16 kinds of micro steps and 8 kinds of current control (1.4A, 2.1A, 2.7A, 3.2A, 3.6A, 4.3A, 4.9A, 5.6A) in all.

4.2.3 Driver implementation:

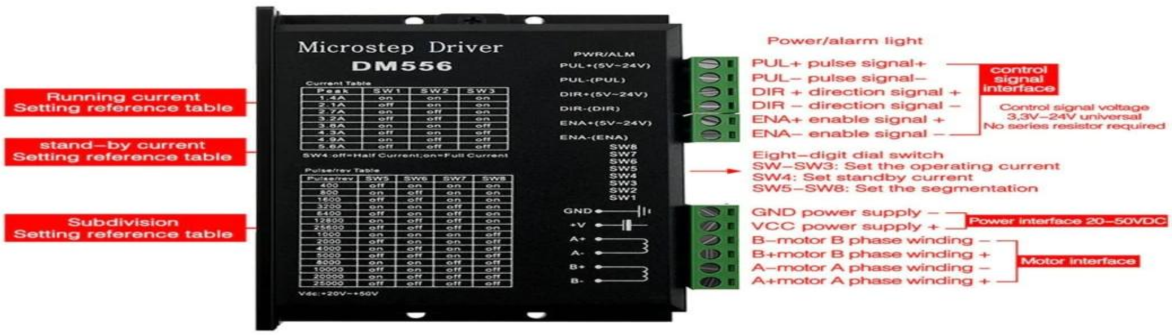


Figure Driver's Pins

Signal Input:

- **PUL+** Pulse+
- **PUL-** Pulse-
- **DIR+** Direction+
- **DIR-** Direction-
- **EN+** Off-line Control Enable+
- **EN-** Off-line Control Enable-

Motor Machine Winding:

- **A+** Stepper motor A+
  - Stepper motor A-
- **B+** Stepper motor B+
  - Stepper motor B-

Power Supply:

- **VCC** VCC(DC20-50V)
- **GND** GND

Connection:

- **VCC - Positive** terminal of the battery to be connected.
- **GND - Ground** terminal of the battery to be connected.
- **PUL-,DIR-,ENA-** Connected To Ground Terminal of Arduino
- **DIR+** Connected to Pin 2 in Arduino
- **PUL+** Connected to Pin 5 in Arduino

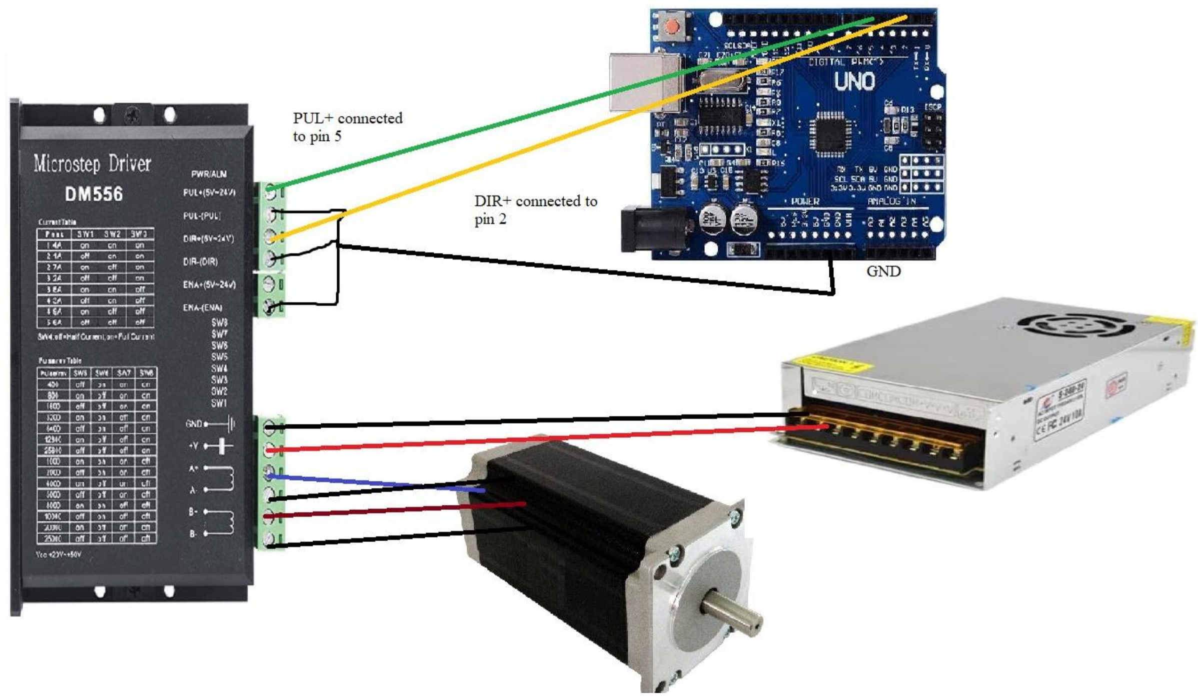


Figure 4.2.3 Driver Implementation

4.3 Software & AI Implementation

4.3.1 The detection and tracking system code

It Consists of the following components:

1. *Raspberry Pi 4*
2. *Arduino Uno*
3. *Camera*
4. *USB*
5. *Jumper Wires*
6. *Motor Driver DM556 (20-50v,1.4-5.6A)*
7. *Stepper Motor NEMA 24 (35 kg.com holding torque)*
8. *Power Supply 24V-10A*
9. *Solar Panel System*

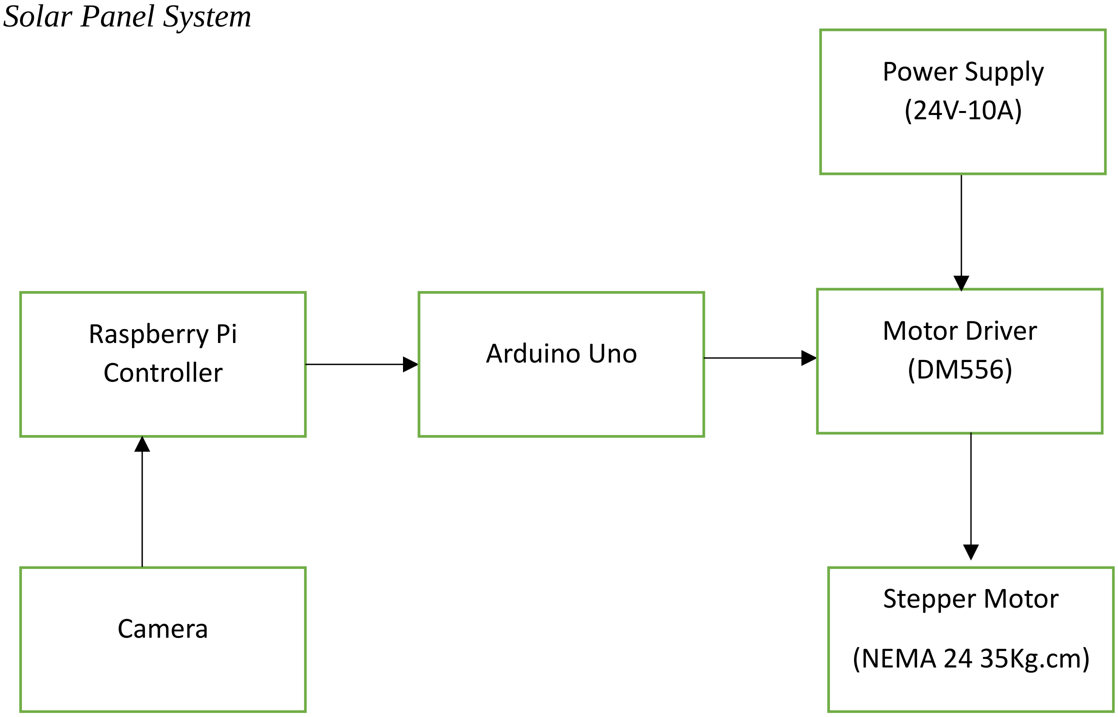


Figure Block Diagram Of Tracking System

Tracking Circuit:

- *Raspberry Pi 4 is Connected to Arduino uno and Camera via USB.*
- *Arduino Uno is Connected to Motor Driver (DM556) Which is responsible of controlling stepper motor.*
- *Motor Driver is Connected To Power Supply of 24V and 10A.*

- *Stepper Motor (Nema 24), Which has a holding torque of 15 kg.cm, is Also Connected To the Driver To ensure the accuracy and functionality of the motor.*
- *There is Solar Panel System which is responsible on Feeding the tracking system circuit in case of failure of power supply.*

Here's How the Tracking Process happens:

- *First of all, YOLO Model is installed in raspberry pi controller to let the camera identify drones.*
- *After Identification of drones, raspberry pi sends commands to Arduino uno.*
- *The Commands tells the Arduino uno to move the stepper motor by specific angle.*
- *Motor Driver is the main connection between stepper motor and Arduino uno and it controls the stepper motor.*
- *Stepper motor is informed to meet the angle by the help of motor driver.*
- *Tracking happens as the stepper motor moves in synchronization with the drone.*
- *Solar Panel System is an alternate for Power supply*

To operate Detection and tracking we operate this code using python:

```python
from ultralytics import YOLO
from time import sleep
from serial.tools import list_ports
from serial import Serial
import cvzone
import cv2
import os
class ArduinoSerial:
    def __init__(self):
        ports = [str(port) for port in list_ports.comports()]
        arduino_port = next(filter(lambda p: 'Arduino' in p, ports)).split(' ')[0].strip()

        self.serial_object = Serial(arduino_port)
        self.serial_object.baudrate = 9600

        sleep(3)

    def send_message(self, message):
        self.serial_object.write(f'{message}\n'.encode('utf-8'))
        sleep(0.1)
def map(x, a, b, c, d):
    y = (x - a) / (b - a) * (d - c) + c
    return y
cap = cv2.VideoCapture(0, cv2.CAP_DSHOW)
os.chdir(r'C:\Users\flower\Downloads\DATA')
```

```python
drone_model = YOLO('yolov8m-drone.pt')
arduino_serial = ArduinoSerial()
while cap.isOpened():
    rt, frame = cap.read()
    frame = cv2.resize(frame, (1020, 720))

    result = drone_model.predict(frame)
    for detection in result:
        for box in detection.boxes:
            x, y, w, h = box.xywh[0]
            rect = int(x - w / 2), int(y - h / 2), int(w), int(h)
            yaw = int(map(x, 0, frame.shape[1], 0, 810)) # Left and Right
            arduino_serial.send_message(yaw)

            cvzone.cornerRect(frame, rect, l=5, rt=3)
    cv2.imshow('frame', frame)
    cv2.waitKey(1)

cap.release()
cv2.destroyAllWindows()
```

4.4 The mechanical Design Implementation

4.4.1 Operating conditions

Force:1

Load type	*Force*
Magnitude	*30.000 N*
Vector X	*-15.662 N*
Vector Y	*-25.581 N*
Vector Z	*0.561 N*

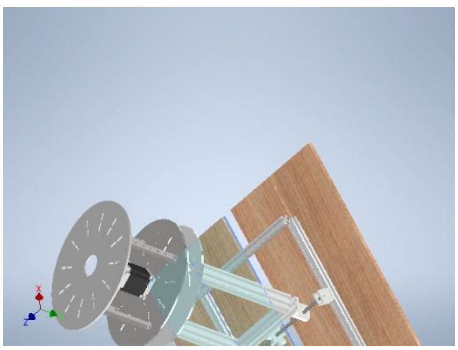


Figure 4.4.1: force 1(a)

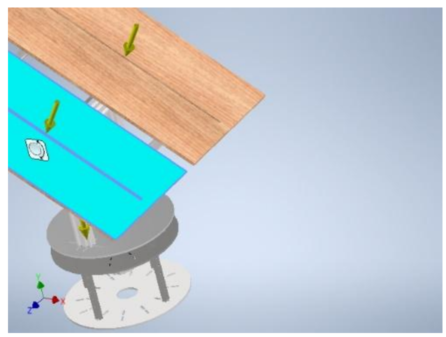


Figure 4.4.1: force 1(a)

Force2:

Load type	*Force*
Magnitude	*30.000 N*
Vector X	*-15.662 N*
Vector Y	*-25.581 N*
Vector Z	*0.561 N*

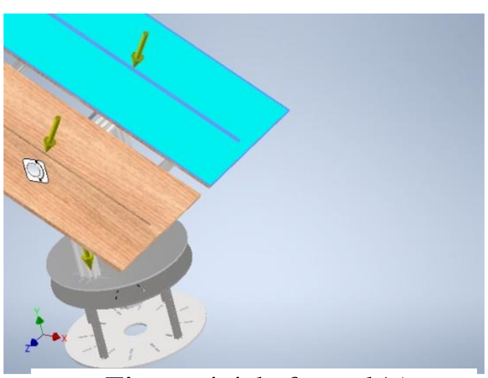


Figure 4.4.1: force 1(c)

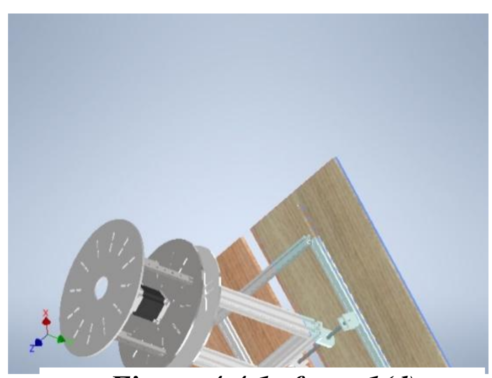
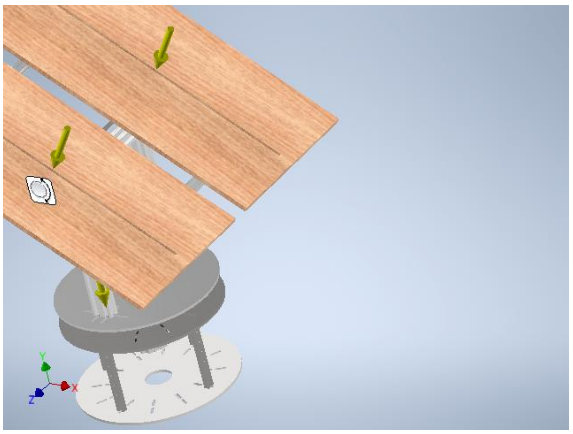


Figure 4.4.1: force 1(d)

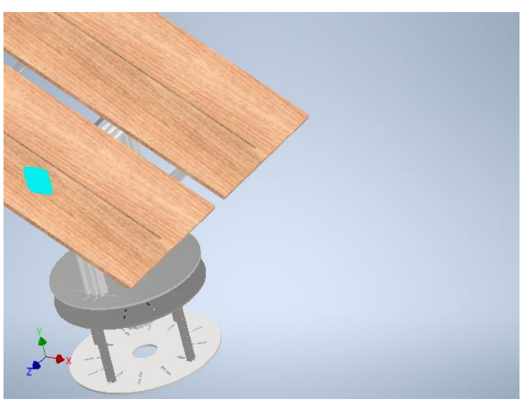
Gravity

Load type	*Force*
Magnitude	**9810.000 mm/s^2**
Vector X	***00.000*** **mm/s^2**
Vector Y	**- 9810.000 mm/s^2**
Vector Z	***00.000*** **mm/s^2**




Pin constraint:

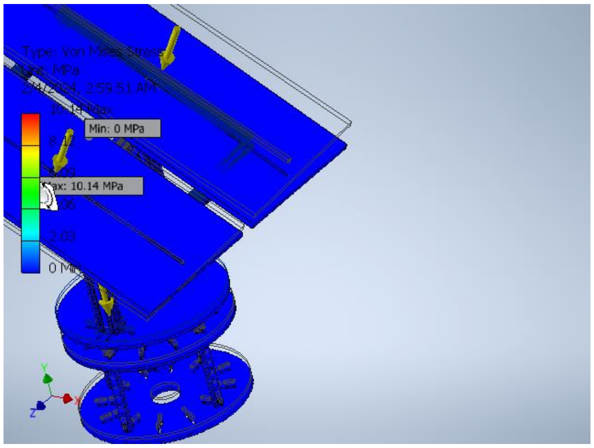
Constraint type	***Pin constraint***
Fix Radial Direction	***YES***
Fix Axial Direction	***YES***
Fix Tangential Direction	***NO***

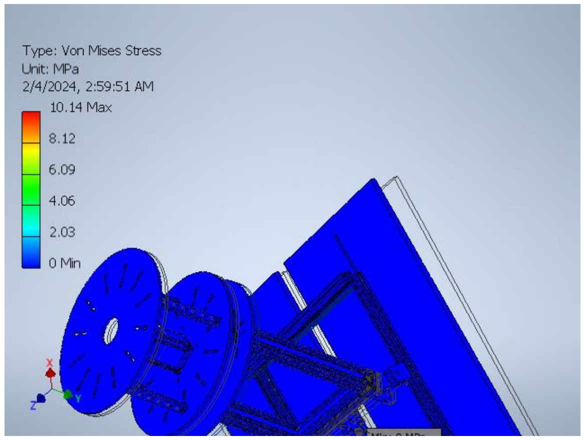


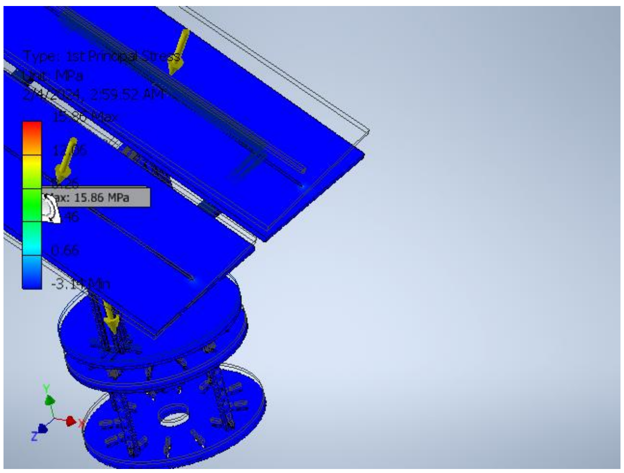

Results

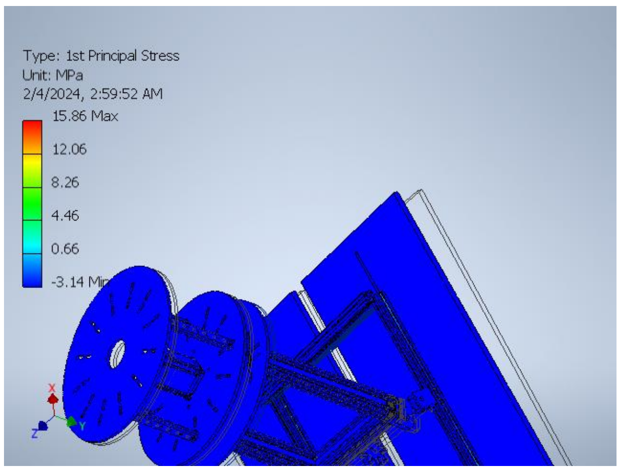
Reaction Force and Moment on Constraints

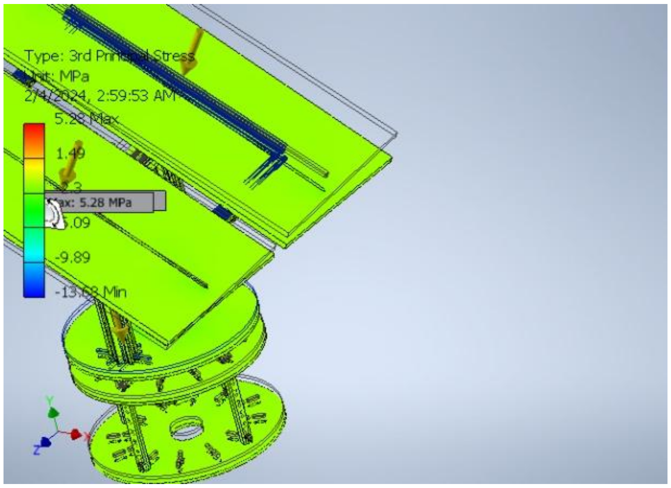
Constraint Name	Reaction Force		Reaction Moment	
	Magnitude	Component (X,Y,Z)	Magnitude	Component (X, Y,Z)
Pin Constraint:1	38.5729 N	12.9499 N	0.763139 N m	0.703566 N m
		36.1404 N		-0.294491 N m
		-3.74751 N		-0.0254992 N m

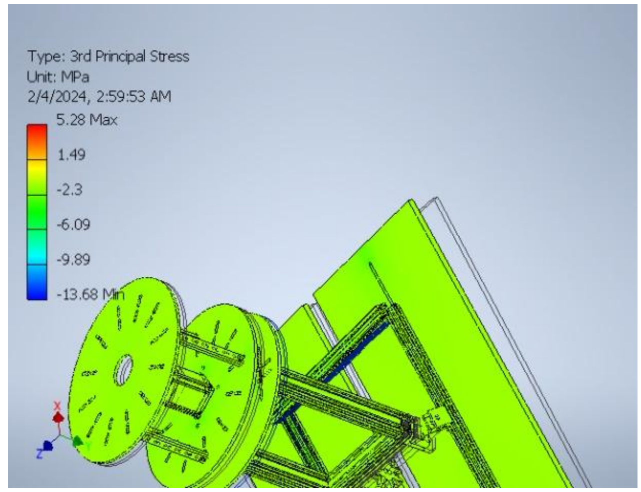


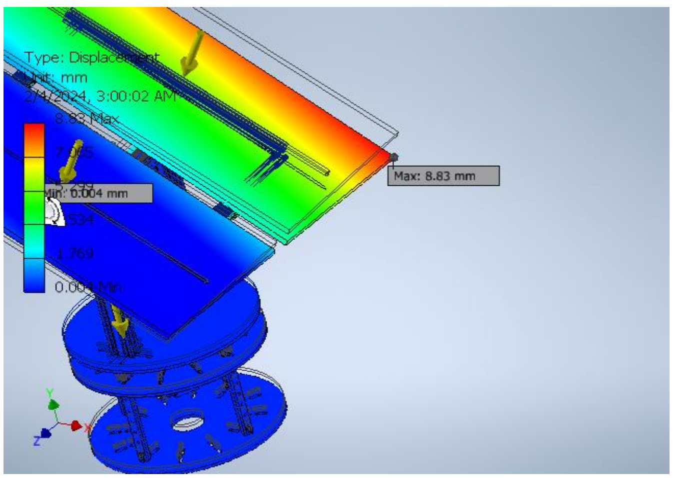


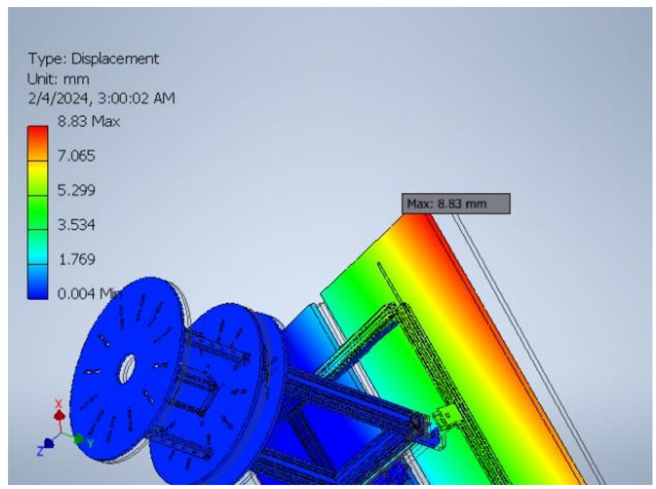


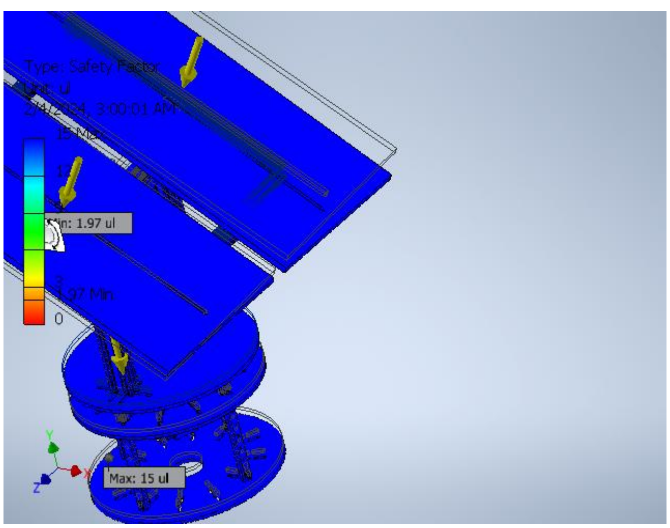


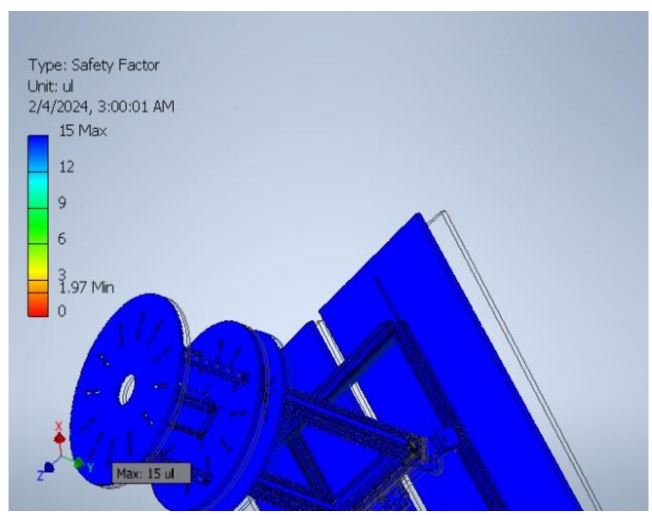

1.49
-9.89

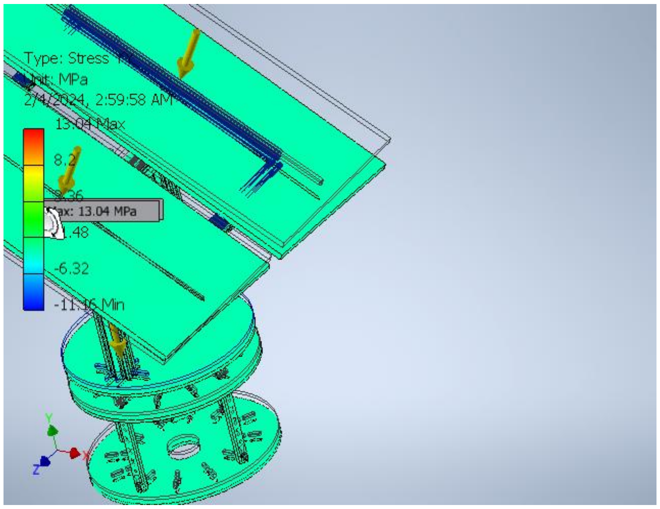

Type: 3rd Principal Stress
Unit: MPa
2/4/2024, 2:59:53 AM
5.28 Max
1.49
-2.3
-6.09
-9.89
-13.68 Min

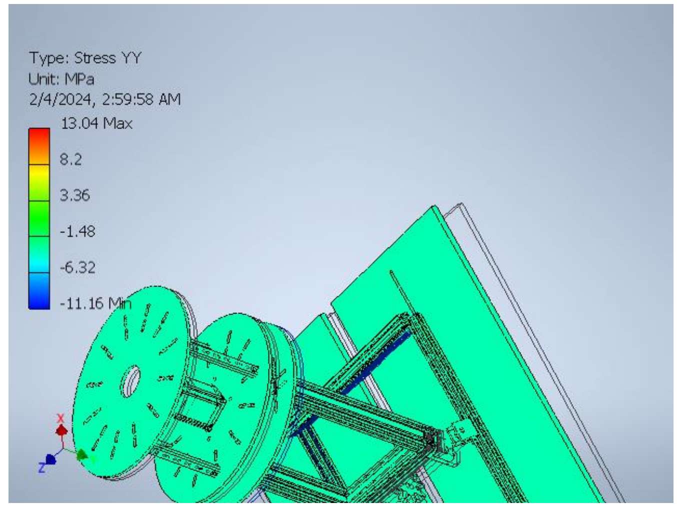

Max: 8.83 mm

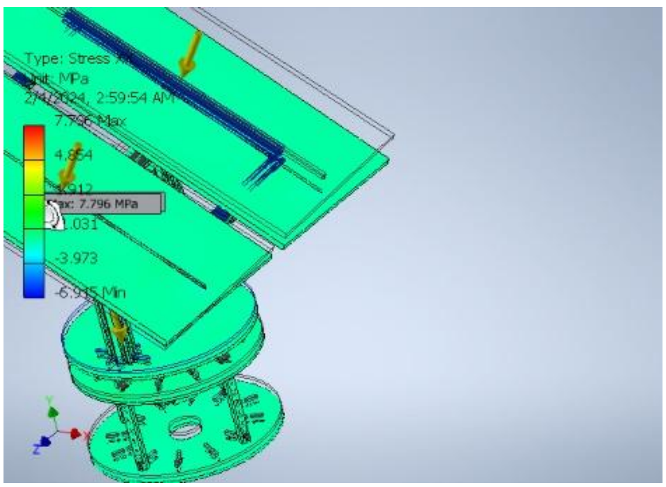

Type: Displacement
Unit: mm
2/4/2024, 3:00:02 AM
8.83 Max
7.065
5.299
3.534
1.769
0.004 Min
Max: 8.83 mm

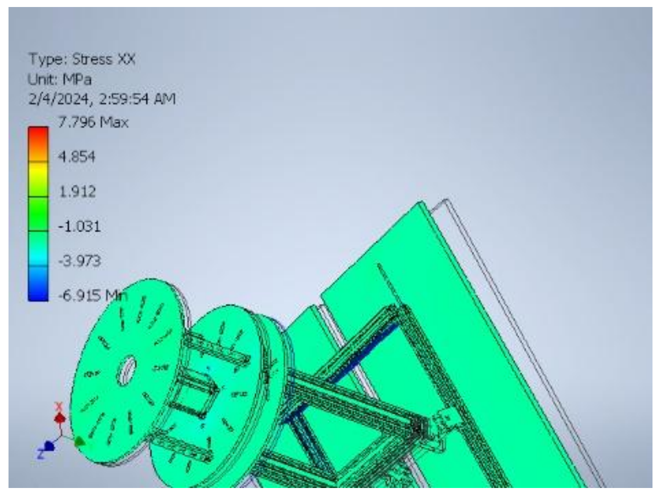

Max: 15 ul

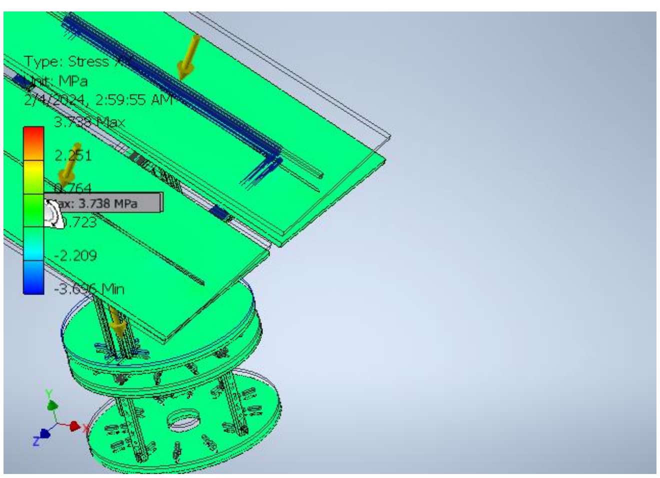

Type: Safety Factor
Unit: ul
2/4/2024, 3:00:01 AM
15 Max
12
9
6
3
1.97 Min
0
Max: 15 ul

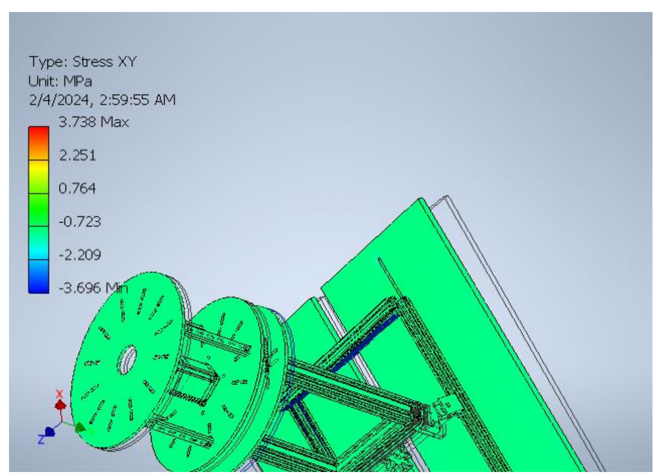

Type: Stress
-6.32

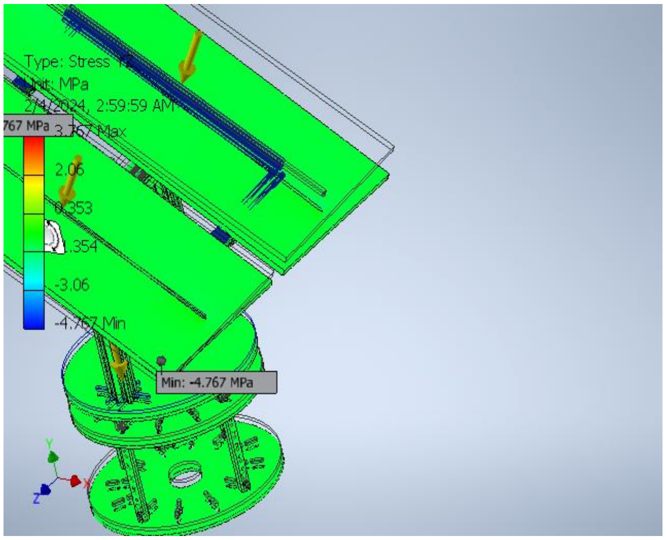

Type: Stress YY
Unit: MPa
2/4/2024, 2:59:58 AM
13.04 Max
8.2
3.36
-1.48
-6.32
-11.16 Min


-3.973

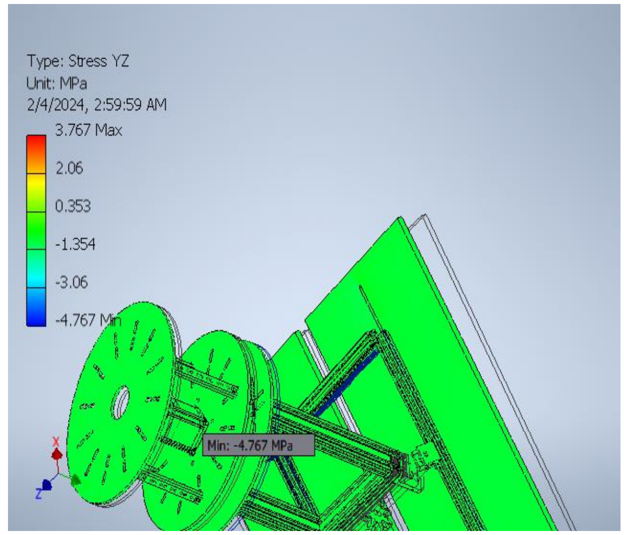

Type: Stress XX
Unit: MPa
2/4/2024, 2:59:54 AM
7.796 Max
4.854
1.912
-1.031
-3.973
-6.915 Min


ax: 3.738 MPa
-2.209

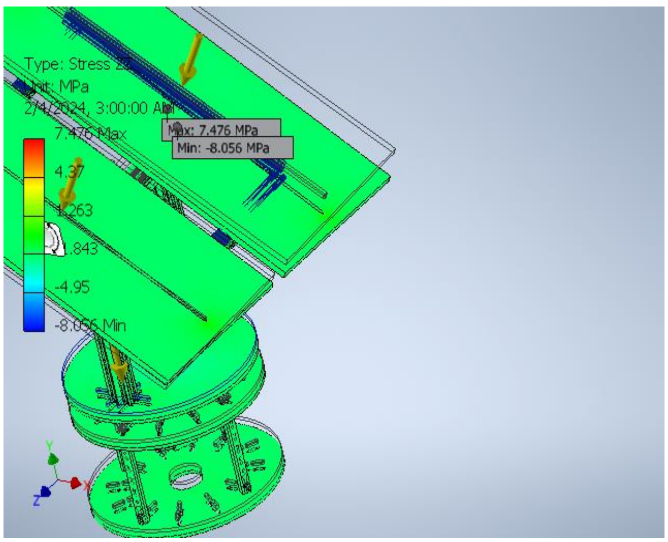

Type: Stress XY
Unit: MPa
2/4/2024, 2:59:55 AM
3.738 Max
2.251
0.764
-0.723
-2.209
-3.696 Min



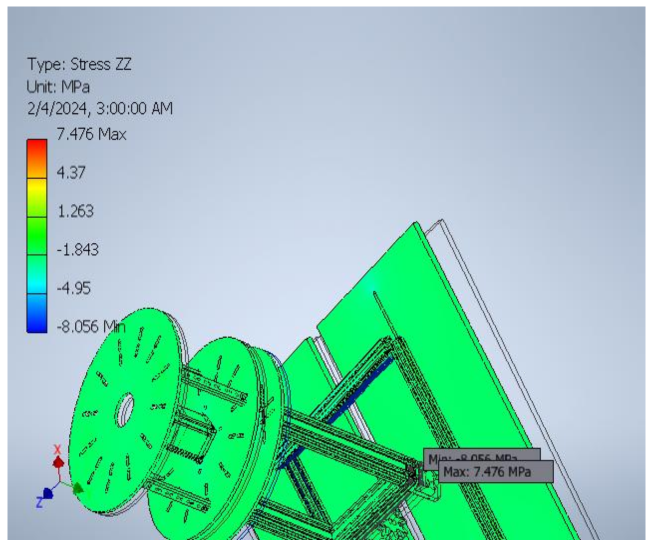
Min: -4.767 MPa



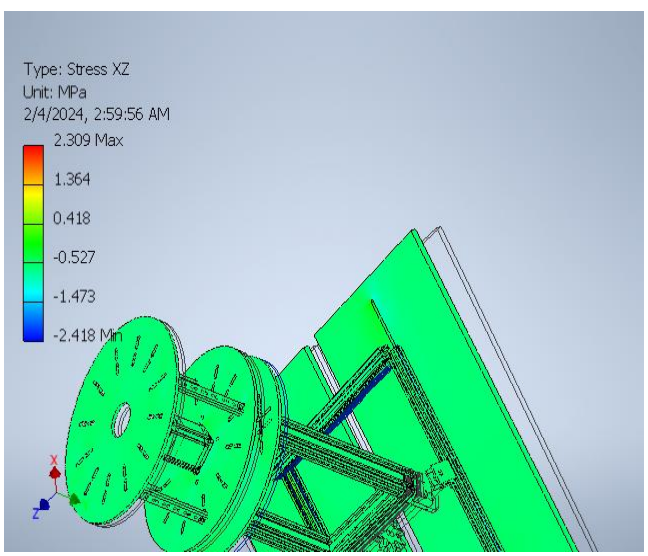
Type: Stress YZ
Unit: MPa
2/4/2024, 2:59:59 AM
3.767 Max
2.06
0.353
-1.354
-3.06
-4.767 Min
Min: -4.767 MPa



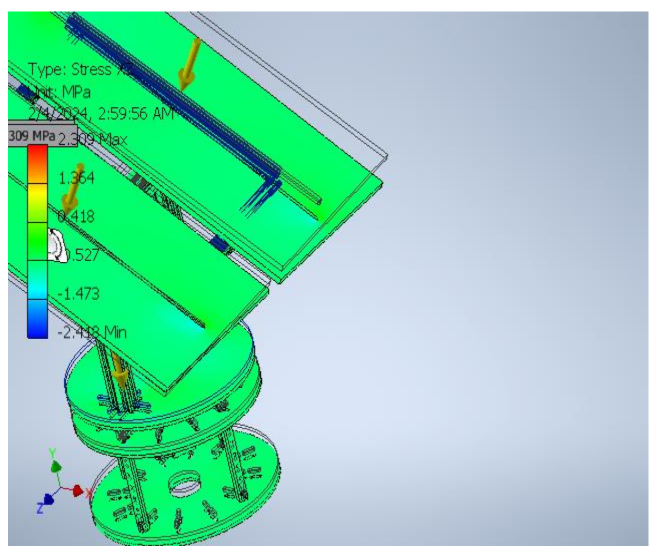
Max: 7.476 MPa
Min: -8.056 MPa



Type: Stress ZZ
Unit: MPa
2/4/2024, 3:00:00 AM
7.476 Max
4.37
1.263
-1.843
-4.95
-8.056 Min
Max: 7.476 MPa



Type: Stress XZ
Unit: MPa
2/4/2024, 2:59:56 AM
2.309 Max
1.364
0.418
-0.527
-1.473
-2.418 Min



4.5 The solar panel Results.

4.5.1 Charge controller circuit

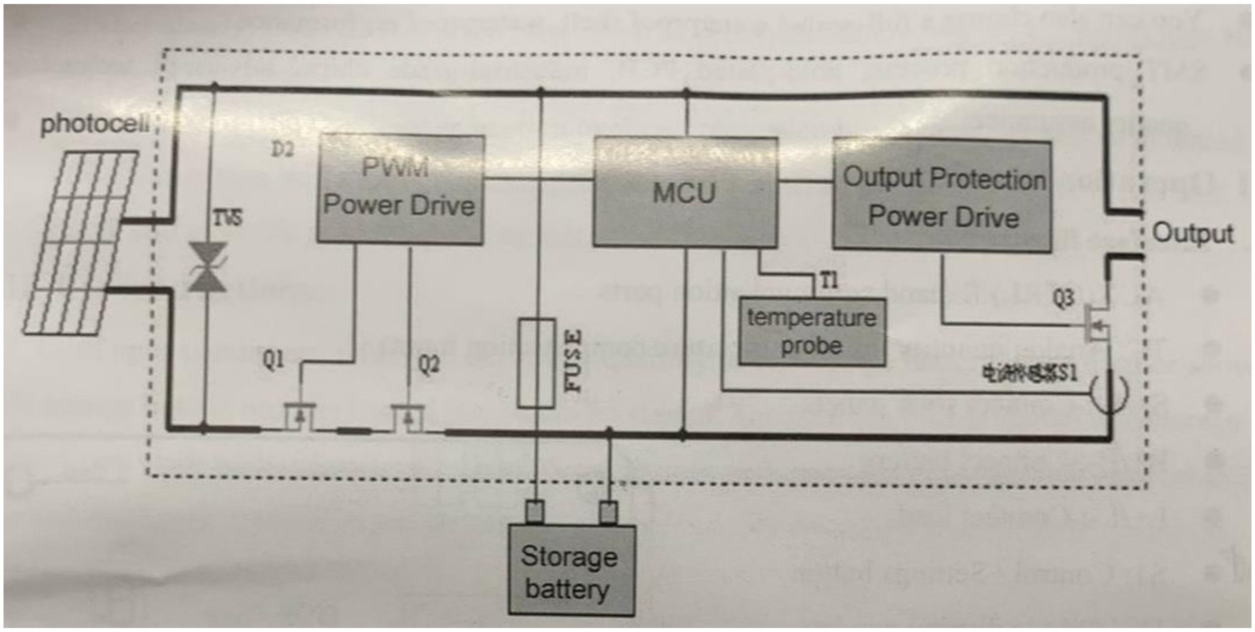


Figure4.5.1: The block diagram of the solar panel system

4.5.2 LDR CIRCUIT:

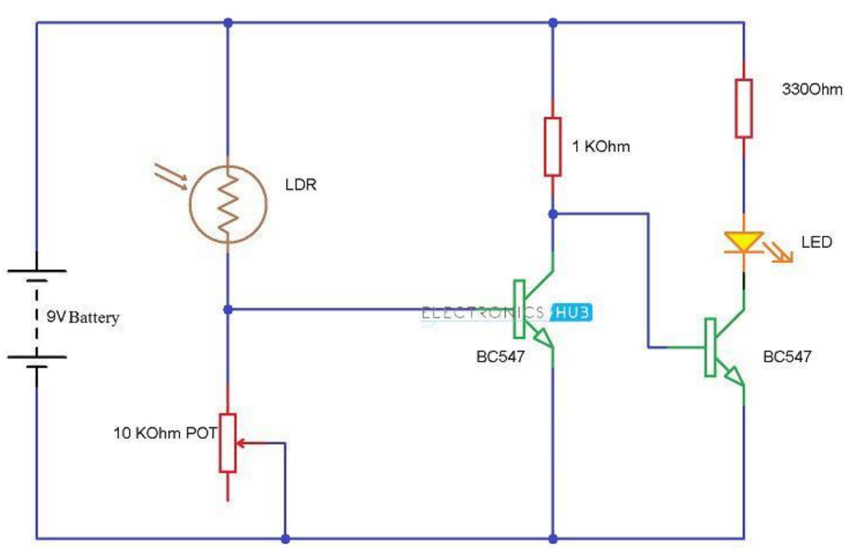
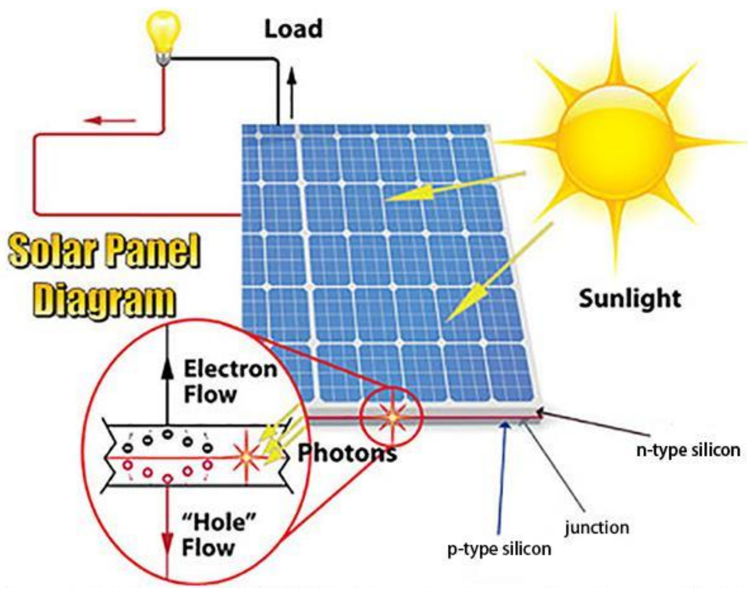


Figure4.5.2: The LDR circuit Diagram

4.5.3 Component of the circuit

Solar panel (18 V, 20 watt):

*Solar cell absorbs solar energy during the day, then it converts the solar energy into electrical energy (the light causes excitation of an electron to a higher energy state so it leaves an empty place "**hole**" and then another electron moves and so on); which is stored in the battery.*



Battery(12V):

Instead of sending solar electricity to the grid we collect it in the battery to use it later, and when the battery is fully charged the system will send the electricity back. to the grid.

Battery types:

• *Flooded Lead Acid*
• *Valve Regulated Lead Acid (**VRLA**)*

We used a Valve Regulated Lead Acid (VRLA) type, it's properties:

• Maintenance free
• Easier handling

Charge controller:

- Regulate battery charging.
- voltage and current from PV
- modules. It also can provide.
- suitable voltage set point according to the battery type. It also can be used as a protection device (such as the reverse current).

Charge controller types:

• *PWM Charge controller (Pulse Width Modulation)*

• MPPT Charge controller (Maximum Power Point Tracking).

We used a PWM Charge controller (Pulse Width Modulation) type, it's properties:

• It sends current to battery in a form of pulses

• Pulse width is defined according to battery state of charge

• it's used in small systems and when PV modules voltage is slightly higher than battery system voltage.

• Price is low .

MPPT Charge controller (Maximum Power Point Tracking) , it's properties :

• It tracks maximum power point of PV modules all the time

• It adjusts voltage of PV modules to be same as battery voltage

• It can convert all PV modules power for better charging efficiency

• Price is high

LDR (light dependent resistor) or photoresistor:

LDR is an electrical resistance whose value changes according to the amount of light falling on it , the relation between the intensity of light falling on it and the amount of resistance is completely inverse, it connected in series with another carbon resistance to protect it from passage of a high electric current through it, which may lead to complete damage, it also used as a circuit divider voltage,

The LDR circuit contains:

• ***Transistor:*** *connected at the output terminal of the Vout to act as a switch. for the circuit.*

• **LED:** (light emitting diode) is commonly used as an On/Off indicator lamp on electrical equipment's. Also, it has low power consumption.

• **Resistors** (R=330Ω, R=1 KΩ)

• **Potentiometer** (10 KΩ)

4.5.4 How does this circuit work? (for 24-volt input)

First thing the sun fall on the solar panel, so the solar panel convert this light.
energy into electrical energy, then it enters the charge controller which do the
following; it enters to a diode to let the current pass in only one direction, LM.
317 voltage regulators to be 16 V so the battery can be charged, the variable
resistance is here to control the output, current also pass through D2 and D3
and when the voltage exceeds 16 volt the Zener starts to work and make the
charging 15 V, charging current depend on R1 and R3, the current will be. about 200 to 300 mA and will charge, when the battery is fully charged which. is about 13 V Zener and darling pair is forward biased and then the charging
stops until the battery is reduced below 12 V then the Zener turns off and it starts to charge again.

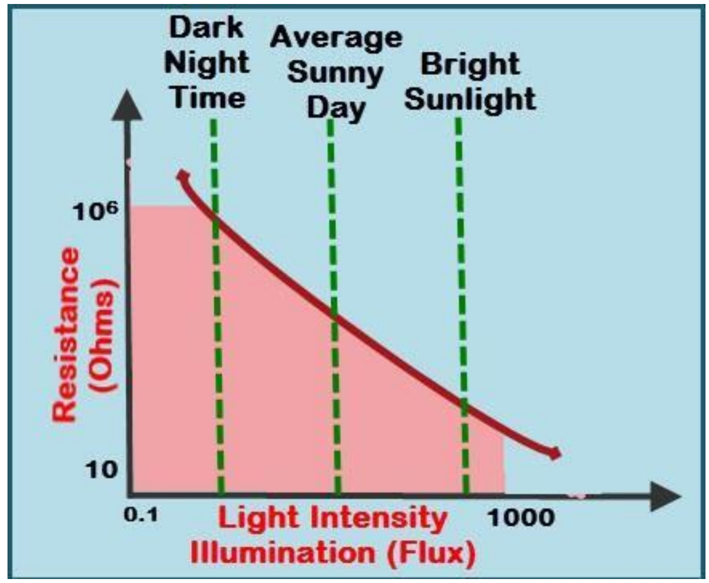
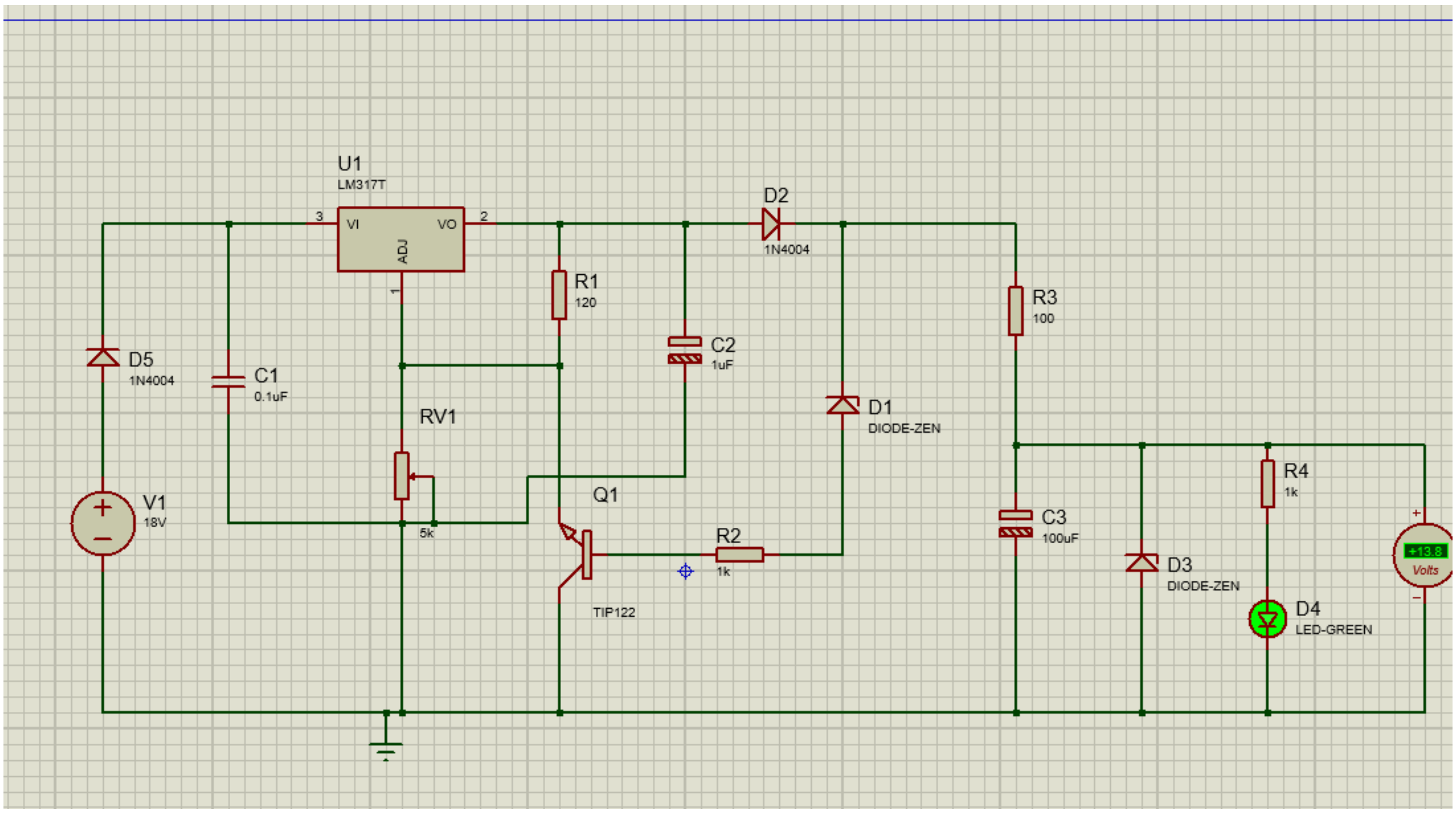


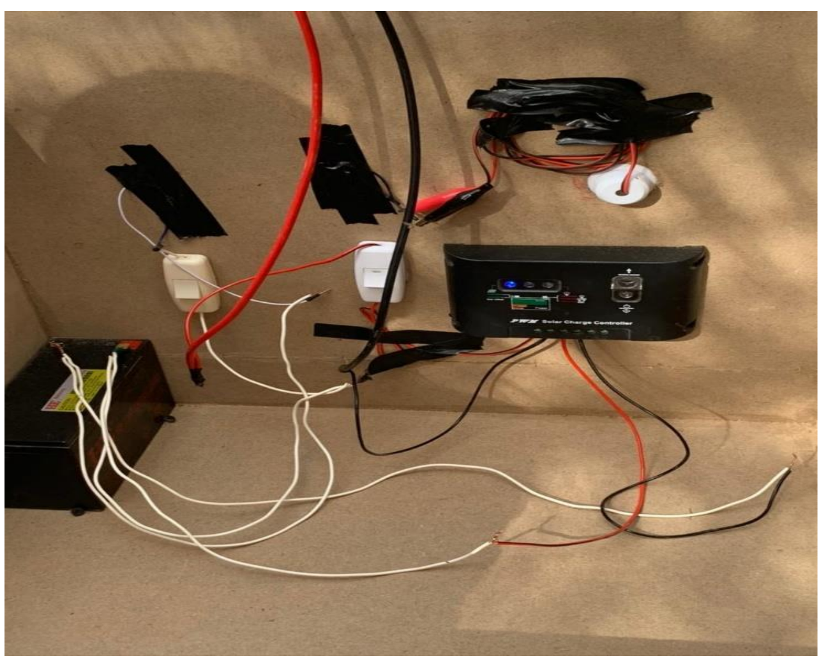
Figure 4.5.4: Light sensor circuit diagram with operation process.

***At dark**, The LDR circuit as the resistance decrease the light intensity increase. so at dark it has high resistance this make the transistor work and current can pass and LED turns on , but in **At bright** the resistance is low so the transistor can't work so no current pass and the led is turned off. LDR is a Light Detector Resistance, it is sensitive to light, its resistance decreases as light intensity increases.*

4.5.5 Simulation



4.5.6 The layout of the solar panel



Chapter 5 The System Results

5.1 *The Antenna Results*

5.1.1 The Results of the 1575.42 MHZ Helix

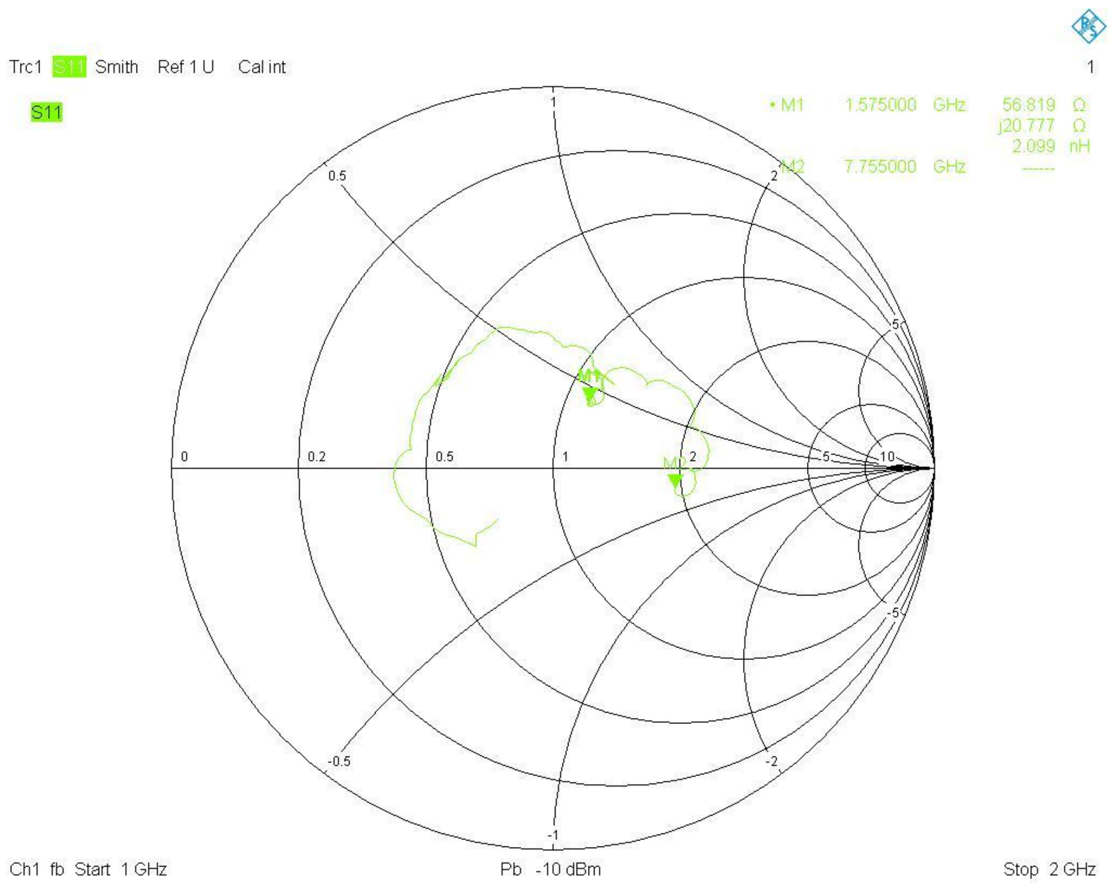


Figure 5.1.1: The smith fig of 1575.42 MHZ Antenna

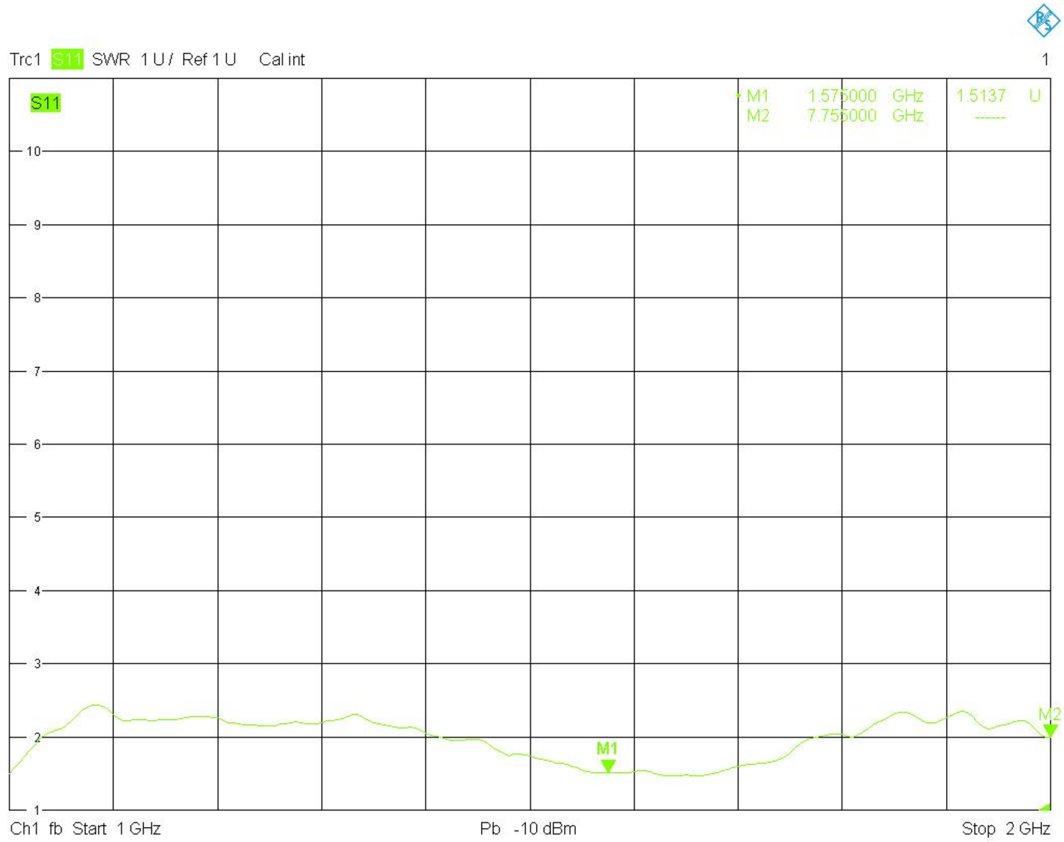


Figure 5.1.1(b): The SWR result of 1575.42 MHz Antenna.

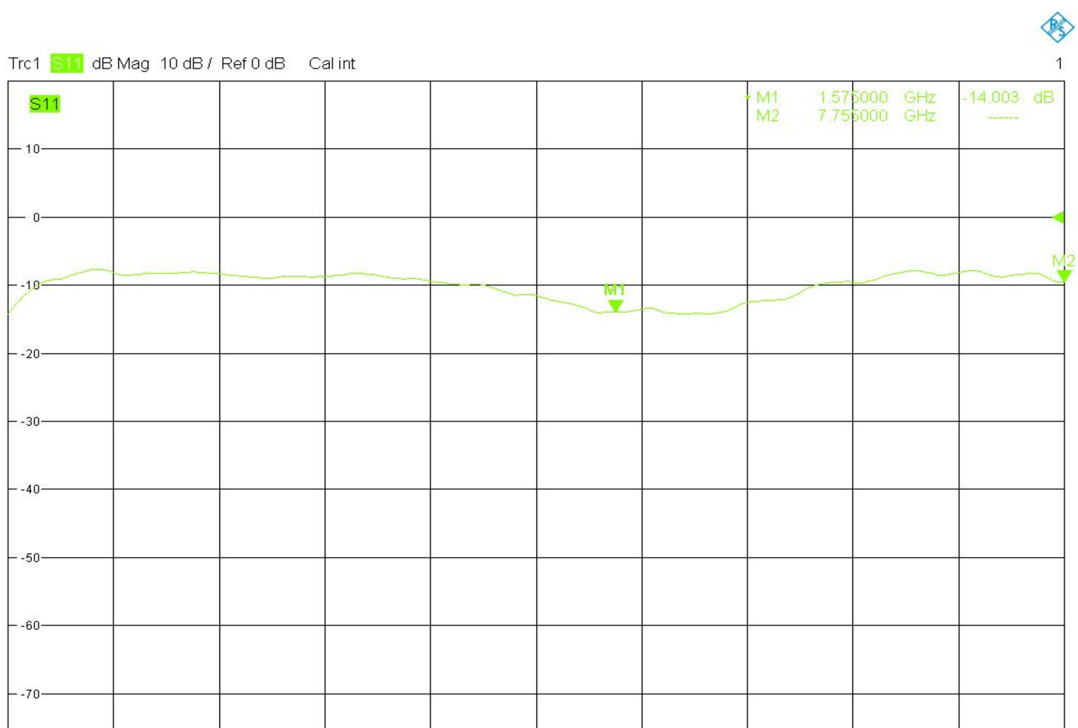


Figure 5.1.1(c): The S11 result of 1575.42 MHZ Antenna

5.1.2 The Results of the *1195.192MHZ* Helix

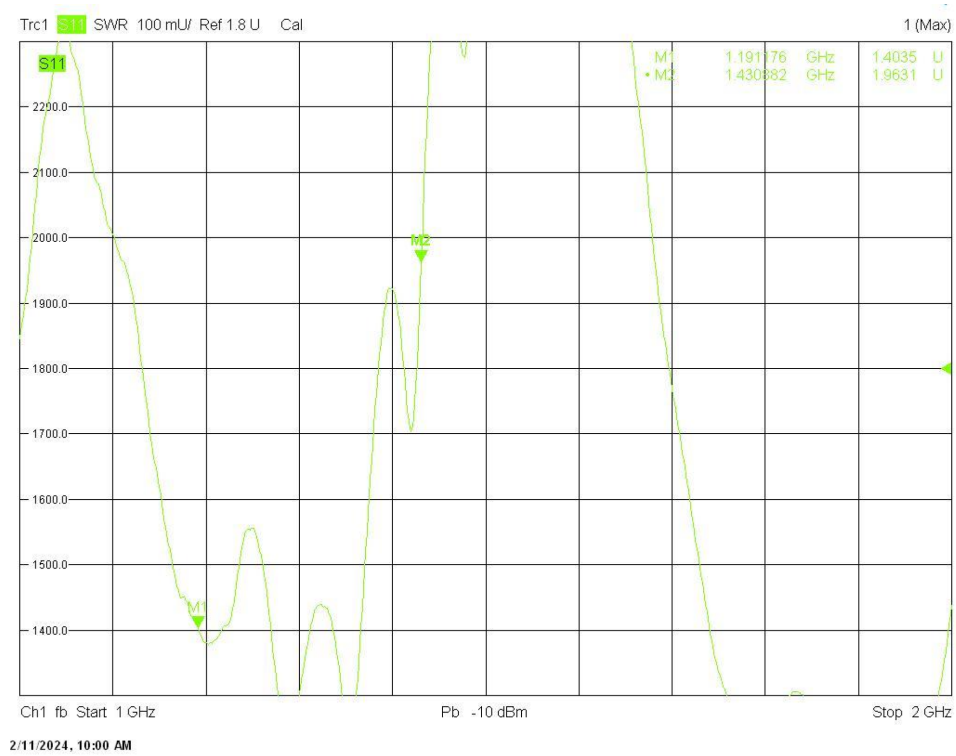


Figure 5.1.2(a): The SWR result 1195.192MHZ Antenna.

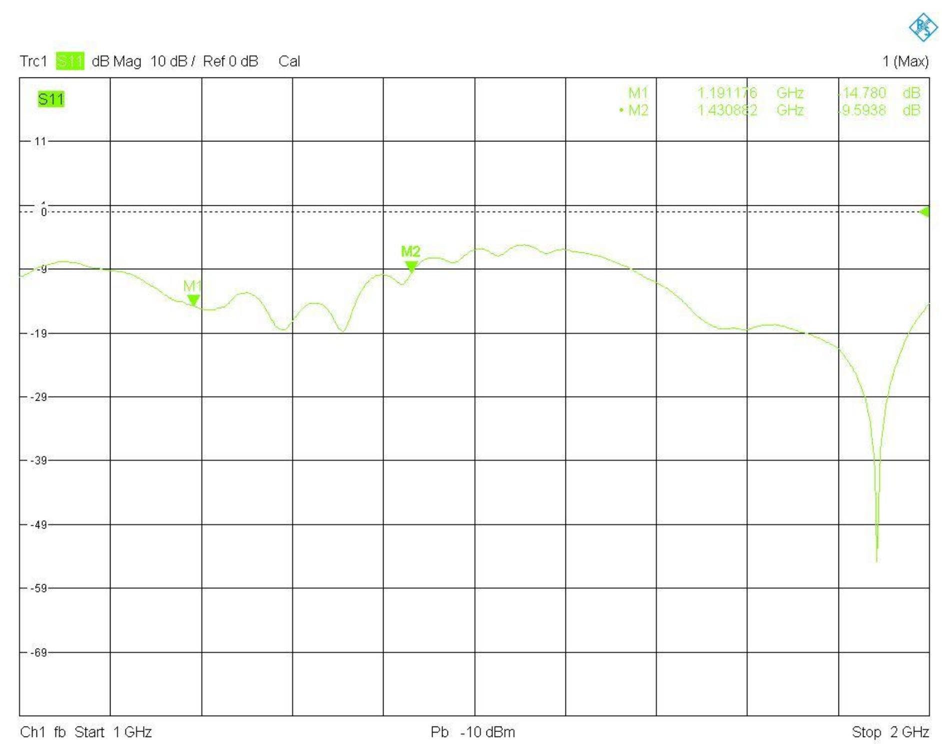


Figure 5.1.2(b): The S11 result 1195.192MHZ Antenna.

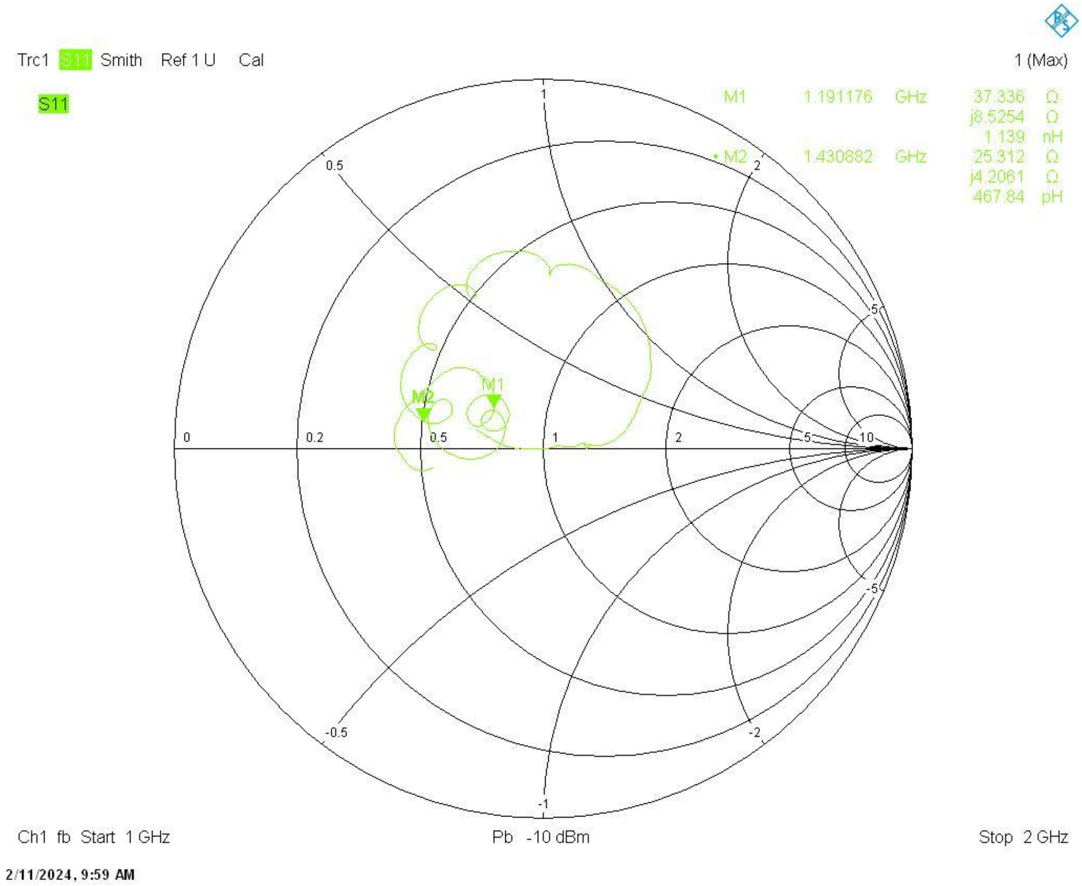


Figure 5.1.2(c): The Smith result 1195.192MHZ Antenna.

5.1.3 The Results of the *1455.1MHZ* Helix

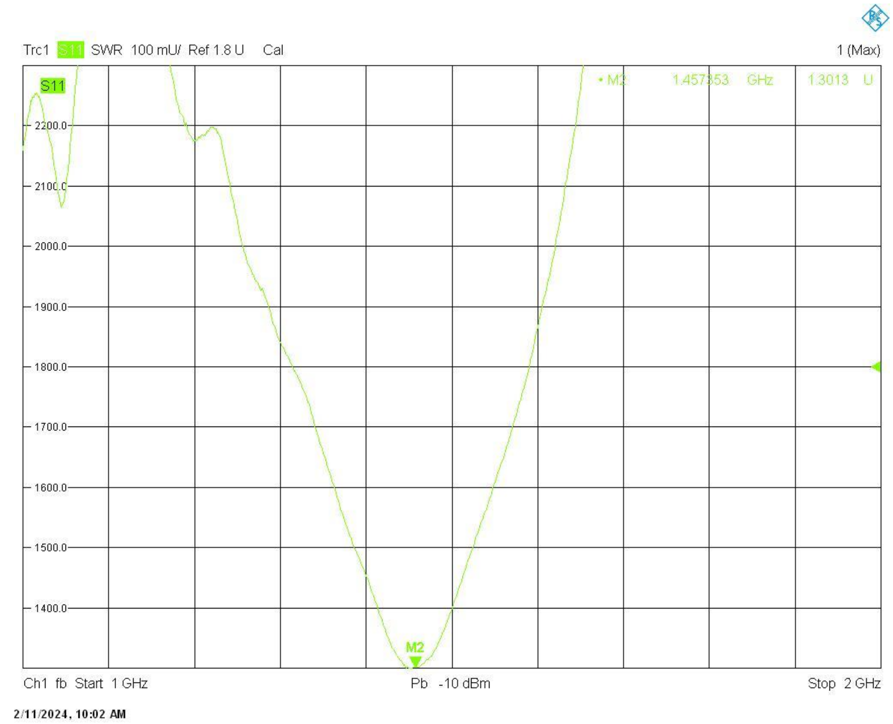


Figure 5.1.3(a): The SWR result 1455.1MHZ Antenna.

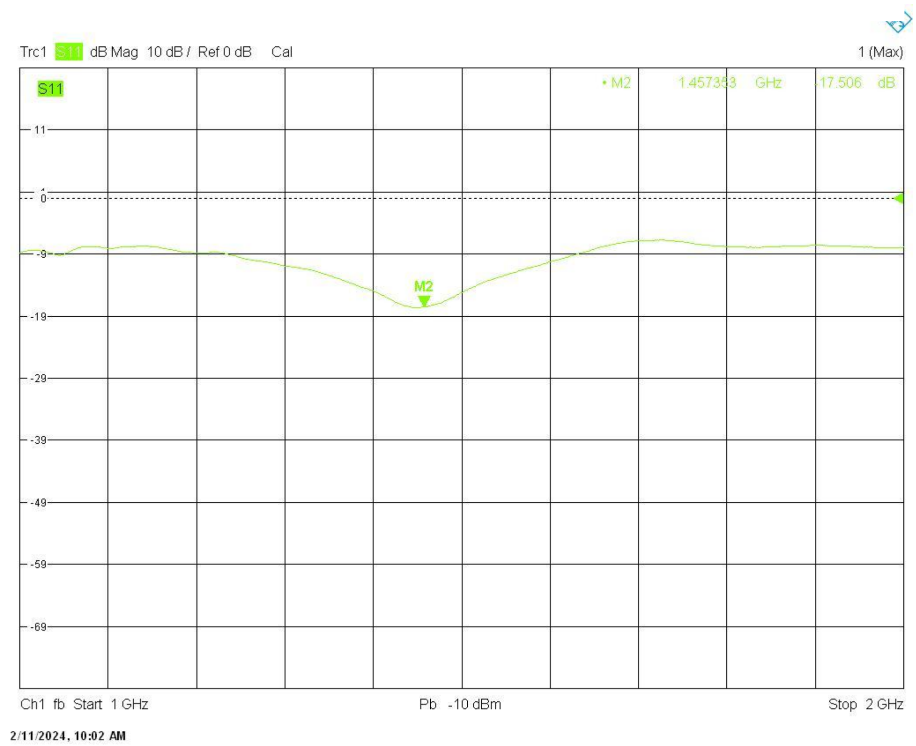


Figure 5.1.3(b): The S11 result 1455.1MHZ Antenna.

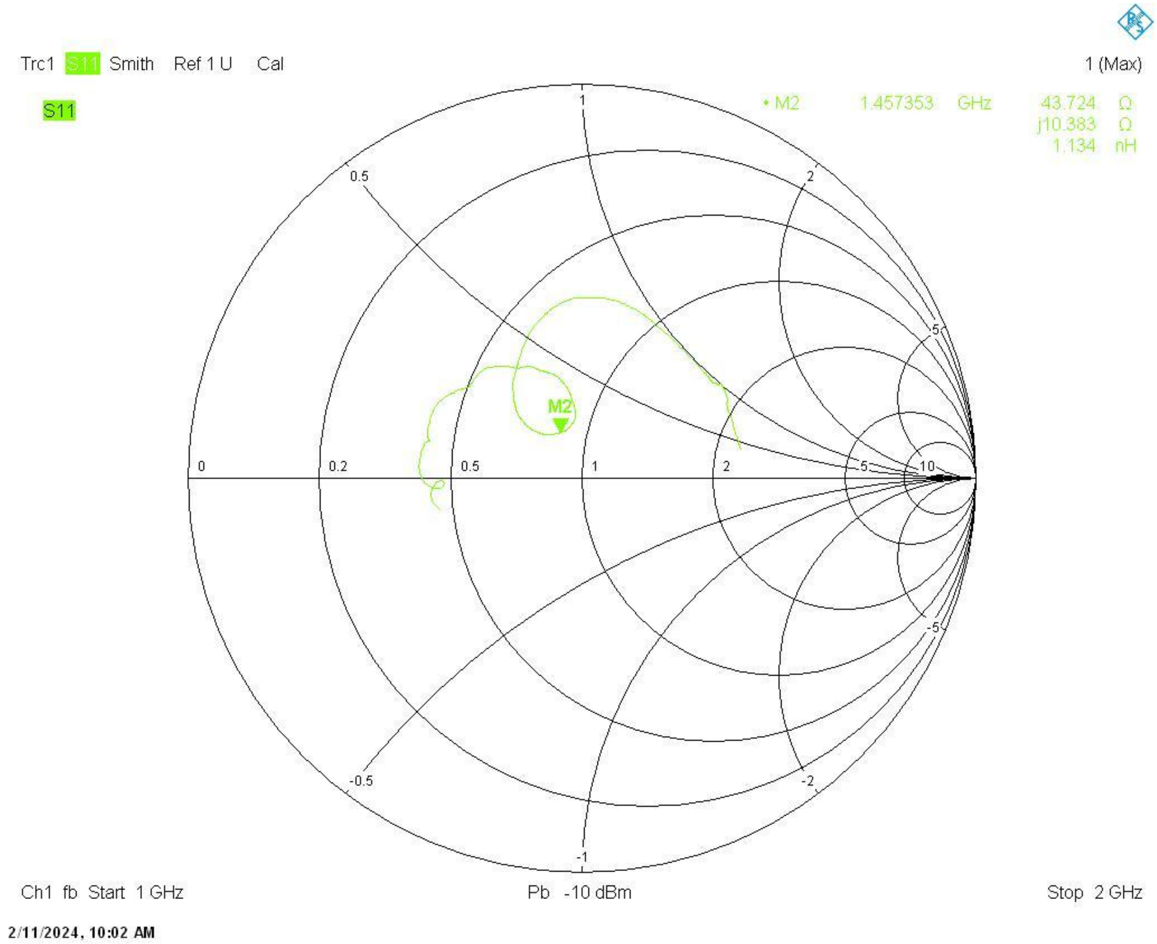


Figure 5.1.3(c): The Smith result 1455.1MHZ Antenna.

5.1.4 The Results of the *1249.3375MHZ* Helix

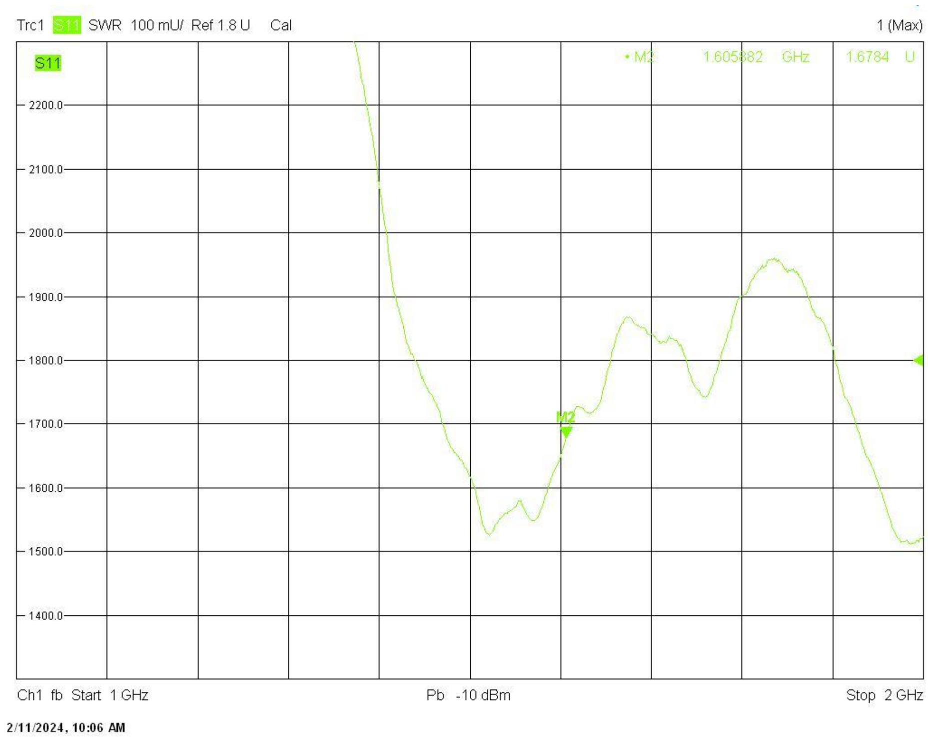


Figure 5.1.4(a): The SWR result 1249.3375 MHZ Antenna.

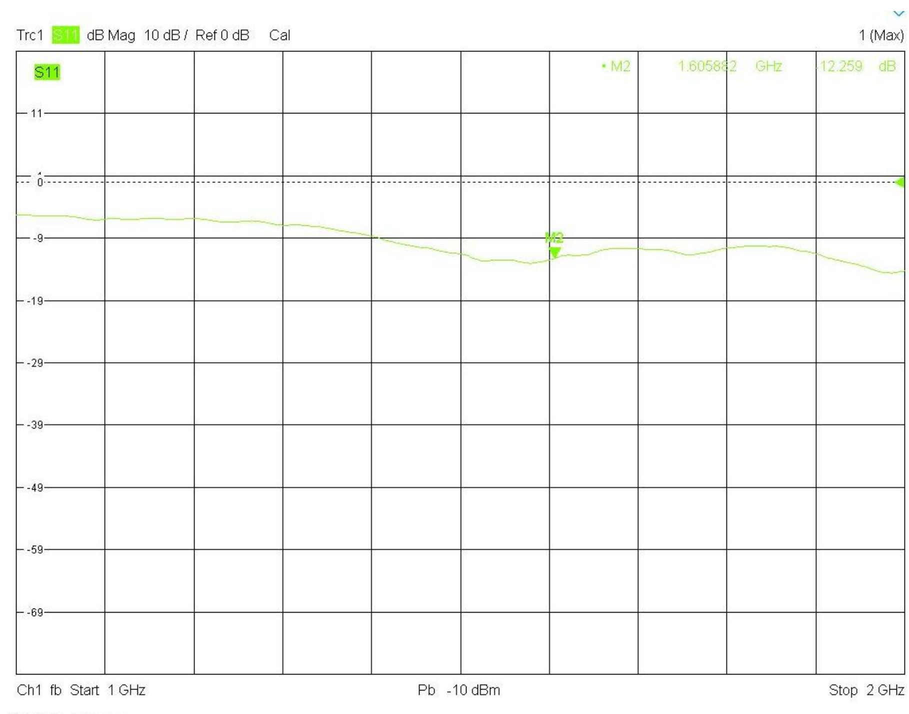
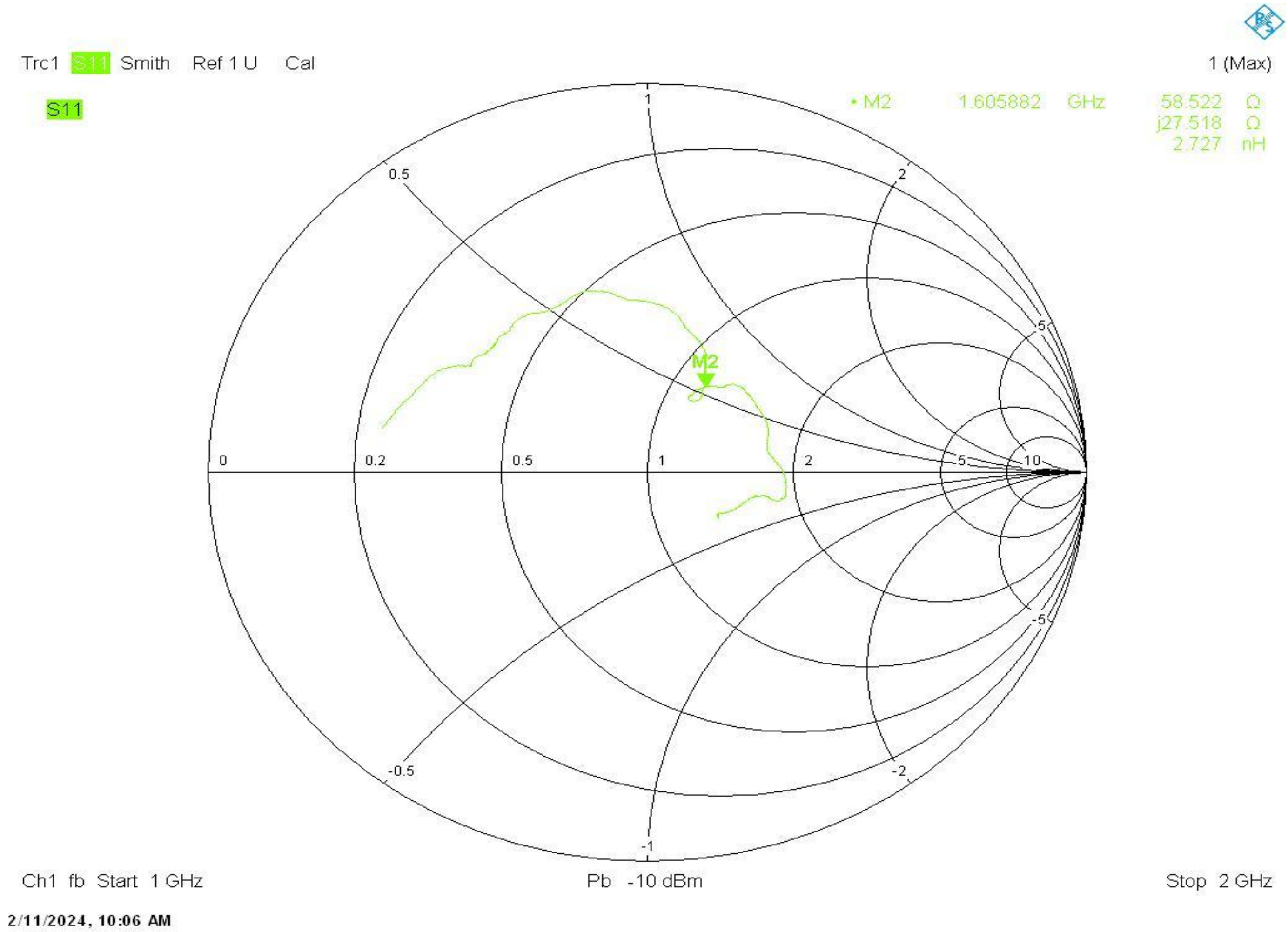


Figure 5.1.4(b): The S11 result 1249.3375 MHZ Antenna.



5.1.4(c): The smith results 1249.3375 MHZ Antenna.

5.2 The solar panel Readings

Solar Panel Calculation:

Power = VI = 18V x 1.11A = 19.98W ≈ 20W

Total Power = power x No. of motors = 20 x 1 = 20W

Battery Capacity (A/hr) = 7Ah

Charging Current (Amps)= Charging Power (Watt) / Charging Voltage (Volt) $=\frac{20W}{18V} = 1.111A$

Charging time (Hours) = Battery Capacity (A/h) / Charging Current(Amps) $=\frac{7Ah}{1.111A} = 6\ hr$

Discharging time (Hours) = Battery Capacity/ Total Load Current $=\frac{7Ah}{3.05} = 2.29hr$

Charger Controller Sizing:

Power of solar panel = 20W

Voltage = 18V

Max Current= P/V $=\frac{20}{18} = 1.11A$

5.2 Tracker System Power Calculation

$$Input\ Power\ of\ Stepper\ motor\ = I\ x\ V\ =\ 2.16\ x\ 15.35 = 33.2\text{W}$$
$$Power\ needed\ for\ Arduino\ Uno\ =\ I\ x\ V\ =\ 5\ x\ 60\ x\ 10^{-3}\ =\ 0.3W$$

Power needed for Camera = 6.5W

Total Power needed for Tracker System = P(Stepper Motor) + P(Arduino Uno) +P(Camera) = 33.2+0.3+6.5 = 40W

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