# Faculty of Electronics & Computer Technology And Engineering

## Development of an SDR-based Ground Station System for Receiving Signals from NOAA Satellites

**MUHAMMAD FAIZ BIN BAHARUDDIN**

**Bachelor of Electronics Engineering Technology (Telecommunications) with Honours**

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# Development of an SDR-based Ground Station System for Receiving Signals from NOAA Satellites

**MUHAMMAD FAIZ BIN BAHARUDDIN**

**A project report submitted**
**in partial fulfillment of the requirements for the degree of**
**Bachelor of Electronics Engineering Technology (Telecommunications) with Honours**

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**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

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**DEDICATION**

*special dedication to my beloved parent,*

BAHARUDDIN BIN ABDULLAH

*And*

NORRIZAN BINTI MOHD

*My lovely Siblings*

MOHD SHAFEZ BIN BAHARUDDIN

MUHAMAD FAHMI BIN BAHARUDDIN

NURSYAHIRA BINTI BAHARUDDIN

*My supportive and kind hearted Supervisor*

DR. NOR AZLAN BIN MOHD ARIS

**ABSTRACT**

This project developed a cost-effective and adaptable ground station using Software-Defined Radio (SDR) technology to receive and analyze NOAA (National Oceanic and Atmospheric Administration) satellite signals. NOAA satellites are essential for various sectors, including agriculture, aviation, disaster management, and climate research. Traditional satellite reception systems are costly and less accessible. By leveraging SDR technology, this project aimed to provide a user-friendly solution for NOAA signal reception and processing.The methodology involved a review of SDR systems and weather satellite signal processing techniques to identify improvements. Hardware and software components, including SDR hardware, antennas, and open-source software SatDump, were carefully selected and configured. Signal acquisition, demodulation, error correction, and data decoding were key steps. The project also created an intuitive user interface for data visualization and analysis. Results demonstrated the ground station's automation capabilities, ensuring uninterrupted image capture during satellite passes. The system improved signal-to-noise ratios when receiving signals from different locations. In conclusion, the project achieved its goal by delivering an efficient, reliable, and user-friendly ground station for NOAA satellite signal reception and analysis.

## *ABSTRAK*

Projek ini membangunkan stesen darat yang kos efektif dan mudah disesuaikan menggunakan teknologi Radio Berkomputer (SDR) untuk menerima dan menganalisis isyarat satelit NOAA (Pentadbiran Oseanografi dan Atmosfera Kebangsaan). Satelit NOAA adalah penting dalam pelbagai sektor, termasuk pertanian, penerbangan, pengurusan bencana, dan penyelidikan iklim. Sistem penerimaan satelit tradisional mahal dan kurang boleh capai. Dengan memanfaatkan teknologi SDR, projek ini bertujuan untuk menyediakan penyelesaian yang mesra pengguna untuk penerimaan dan pemprosesan isyarat NOAA.Methodologi melibatkan semakan sistem SDR dan teknik pemprosesan isyarat satelit cuaca untuk mengenal pasti penambahbaikan. Komponen perkakasan dan perisian, termasuk perkakasan SDR, antena, dan perisian sumber terbuka SatDump, dipilih dan disusun dengan teliti. Perolehan isyarat, pemodulasi, pembetulan ralat, dan pengekodan data adalah langkah utama. Projek ini juga mencipta antara muka pengguna yang intuitif untuk visualisasi data dan analisis.Keputusan menunjukkan keupayaan automasi stesen darat untuk memastikan penangkapan imej satelit NOAA yang tidak terganggu semasa laluan satelit. Sistem ini meningkatkan nisbah isyarat-ke-bising semasa menerima isyarat dari lokasi yang berbeza. Kesimpulannya, projek ini mencapai matlamatnya dengan menyampaikan stesen darat yang cekap, boleh dipercayai, dan mesra pengguna untuk penerimaan dan analisis isyarat satelit NOAA.

## ACKNOWLEDGEMENTS

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| RTL-SDR | - | Realtek Software defined radio |
| NOAA | - | National Oceanic and Atmospheric Administration |
| GOES | - | Geostationary Operational Environmental Satellite |
| POES | - | Polar Operational Environmental Satellites |
| QFH Antenna | - | Quadrifilar helicoidal antenna |
| APT | - | Automatic Picture Transmission |
| AVHRR | - | Advanced Very High-Resolution Radiometer |
| SNR | - | Signal to Noise Ratio |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Development of an SDR-based Ground Station System for Receiving Signals from NOAA Satellites represents a significant innovation in the field of weather data acquisition. The conventional satellite ground stations are prohibitively expensive and require specialized hardware, rendering them inaccessible to many organizations and individuals. However, the SDR technology allows for the reception of signals using general-purpose hardware, such as a personal computer and a low-cost SDR device, providing a more accessible and cost-effective alternative. The system development process entails identifying the appropriate NOAA satellites and frequencies, selecting the most suitable hardware, developing software that incorporates a decoder and user interface, testing, and optimizing for performance. An SDR-based weather information system has the potential to make critical weather data more accessible to a broader range of users, facilitating better-informed decision-making across multiple domains.

## 1.2 Addressing Weather Information Issue Through the Development of an SDR-based Ground Station System for Receiving Signals from NOAA Satellites

Developing an SDR-based ground station system capable of receiving signals from NOAA satellites is crucial in reducing the effects of climate change and extreme weather on rural communities. Rural areas require accurate and timely weather information to prepare for and reduce the effects of extreme weather phenomena such as cyclones, floods, and droughts. By utilizing the SDR-based system to receive signals directly from NOAA satellites, rural communities can gain access to accurate meteorological data. It allows them to develop effective early warning systems, increasing their preparedness for imminent severe weather events. Communities can take proactive measures to safeguard lives and property, make informed decisions about agricultural practices, and evacuate, if necessary, when they can access timely information. Farmers can optimize their irrigation schedules, modify their planting and harvesting times, and make informed crop selection decisions when accessing detailed weather data. Enables them to mitigate the effects of droughts, floods, and other extreme weather conditions on their agricultural activities, protecting their means of subsistence. In addition, the SDR-based system facilitates resource allocation and utilization by providing local authorities and relief organizations with accurate meteorological information. It allows them to allocate resources effectively, deploy emergency response teams to the most affected areas, and coordinate relief efforts. Ultimately, by increasing the availability of accurate weather information, the SDR-based Ground Station System contributes to the well-being and sustainability of rural communities by fostering resilience, facilitating adaptation to climate change, and mitigating the harmful effects of extreme weather events.



## 1.3 Problem Statement

Availability and precision of meteorological data can be problematic for weather monitoring systems, particularly in remote or rural areas. These restrictions may severely affect industries such as agriculture, transportation, and outdoor recreation, leading to potential financial losses and safety concerns. Existing weather monitoring systems are frequently prohibitively expensive, necessitating specialized hardware and software many users need help to afford. Consequently, there is a need for a cost-effective and accessible weather monitoring system that can acquire and process weather data in real time, utilizing software-defined radio technology to receive and decode NOAA satellite signals. By utilizing SDR technology, the proposed system can provide more flexible and adaptable weather monitoring, even in remote areas where conventional monitoring systems do not exist. It will give users access to accurate and up-to-date weather information, allowing for enhanced preparedness for potential natural disasters and more precise forecasts of changing weather conditions. Overall, the development of an SDR-based Ground Station System has the potential to revolutionize weather monitoring by providing a practical and dependable method for acquiring real-time weather data.

Based on the aforementioned information, the problem statements can be summarized as follows:

1. Meteorological data availability and precision are problematic, especially in remote areas.
2. Existing weather monitoring systems are expensive and inaccessible for many users.
3. A cost-effective and accessible solution is needed.



## 1.4 Project Objective

The objective of this project is to develop a low cost ground station for rural areas by implementing a NOAA receiver using RTL SDR technology. The specific objectives are as follows:

1. To design and implement a low-cost weather information system capable of receiving and extracting weather data from NOAA satellites, providing valuable information for targetting area.

2. To utilize software-defined radio (SDR) technology to receive and process signals from NOAA satellites, enabling the acquisition of NOAA Images.
3. To analyse performance of system through comparison various setup and location.

## 1.5 Scope of Project

Our project scope is broad, covering various areas of focus. This project aims to address critical issues, drive innovation, and develop impactful solutions through comprehensive problem-solving approaches:

1. Development and implementation of ground station sytem using Software-Defined Radio (SDR) technology.
2. Focus on receiving and processing meteorological data from NOAA satellites.
3. Selection and configuration of appropriate RTL-SDR .
4. Development of software modules for data acquisition and processing.
5. Integration of the system into a user-friendly interface.
6. Performance analysis will be conducted through testing and validation processes.
7. Deployed and operational ground station in the target environment.
8. Conduct antenna testing and calibration to ensure optimal performance in different environmental conditions.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Weather forecasting is crucial for numerous industries, including agriculture, aviation, marine transportation, and disaster management. Weather satellites play a critical role in providing real-time weather data to improve the accuracy of weather forecasts. However, receiving and processing signals from these satellites can be challenging and expensive, often requiring specialized equipment and expertise.

The introduction of software-defined radio (SDR) has transformed the way signals from weather satellites can be received and processed. SDR-based systems offer a flexible and cost-effective approach to receiving and processing signals from satellites. Unlike traditional radios, SDRs are software-based, which enables users to reconfigure the radio's parameters, including frequency, modulation scheme, and signal processing algorithms. This flexibility makes SDR-based systems ideal for weather information systems as the signal processing algorithms can be adapted to receive signals from various weather satellites, including those operated by NOAA.

This literature review aims to examine the development of an SDR-based weather information system for receiving signals from NOAA satellites. The review will provide an overview of SDR-based systems, NOAA satellites, and research studies that have focused on developing SDR-based weather information systems for receiving signals from NOAA satellites. The review will also emphasize the significance of antenna design in the success of the system and how SDR-based weather information systems can improve weather forecasting and provide critical information for various industries.

## 2.2 Chronology of polar meteorological satellites include NOAA satellites

### 2.2.1 First generation: TIROS Series (1960 - 1966)

On April 1, 1960, the first meteorological satellite was successfully sent into orbit, collecting photographs of Earth from space and transmitting them through radio to Earth stations (Figure 2.1).


Figure 2.1: First earth image captured by the TIROS-1 satellite, extracted from [1]

It is essential to note that the TIROS-1 satellite rotated at a rate of 12 RPM using a spin stabilization mechanism. Consequently, there were occasions when the satellite and its cameras were not aimed at the Earth (Figure 2.2). The acquired images and telemetry data were transmitted back to Earth via a 235 MHz FM downlink employing a circularly polarized cross-dipole antenna or Turnstile at the satellite's bottom (Figure 2.2). In addition, the satellite could receive Earth's commands via an antenna atop its dome. Different ground stations across the United States were responsible for receiving this information. In addition, the satellite was equipped with radio beacons that made its location and tracking easier, thanks to receiving stations dispersed across the North American continent.

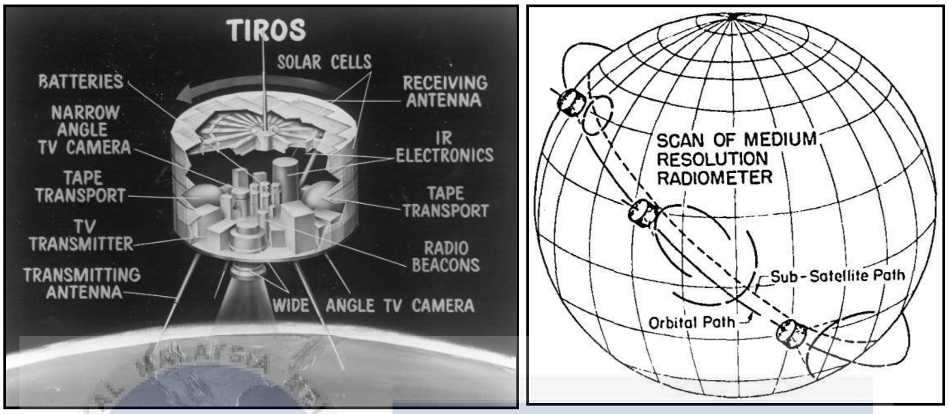



Figure 2.2: Image regarding the TIROS-1 satellite and its various parts from [1]

### 2.2.2 Second generation: TOS series (1966 – 1969)



The first satellites of the TOS (TIROS Operational System) series, ESSA-1 and ESSA-2 (Environmental Science Services Administration satellites), were launched in February 1966. These were the first satellites to work together in the same polar sun orbit. They weighed 304 kilograms and had a similar design to the previous TIROS series. One satellite captured daytime images while the other satellite captured nighttime images.

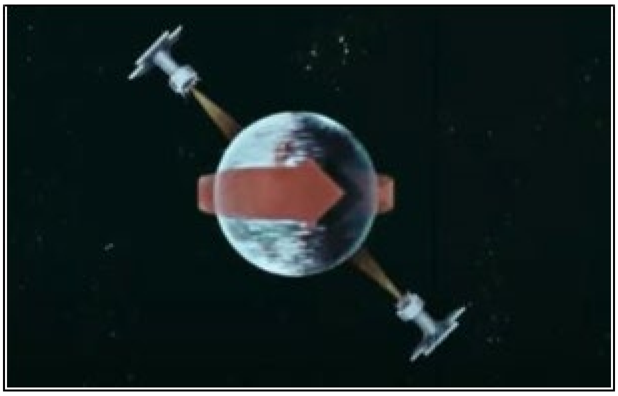


Figure 2.3: Examples of a pair of sun-synchronous polar satellites that orbit coordinating using [1]

### 2.2.3 Third Generation: ITOS Series (1970-1976)

The ITOS (Improved Shots Operational System) series of satellites, finally called NOAA (because the agency was created on October 3, 1970), started with NOAA-1, launched on December 11, 1970, and weighed 307 kg. In addition to the new name, author said that essential changes were made to this satellite. The most noticeable difference is that the TIROS-1's signature 18-sided prism-shaped chassis was replaced with a nearly cubic chassis 1m by 1m by 1.2m. Satellites were no longer stabilized by spinning. Instead, they used 3-axis stabilization based on moment wheels connected to electric motors. This made moving the satellite easier and controlling its position more precisely. This meant that I could take better pictures for longer.

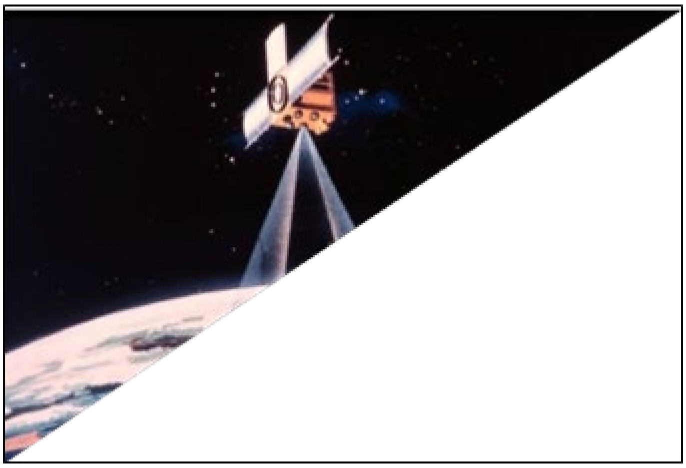


Figure 2.4: The illustration of NOAA-1 was a significant change in how the satellite was made.[1]

### 2.2.4 Fourth Generation: ATN Series (1978-1994)

The TIROS-N is part of the ATN (Advanced TIROS-N) line. It was launched on October 13, 1978, weighing 589kg. It started to have the AVHRR (Advanced Very High-Resolution Radiometer) sensor, an improvement on the VHRR, as its name suggests. There were four radiometers (4 bands) in the sensor (Figure 2.5):



- Channel 1: Light that can be seen between 0.55 and 0.9 m. Used to map landscapes and clouds during the day.
- Channel 2: near-infrared, ranging from 0.725 to 1.1 m. Making maps of surface water and plants.
- Channel 3: Atmospheric infrared window between 3.55 and 3.93 m. Sea surface temperature (SST) and finding fires.
- Channel 4: Atmospheric infrared window between 10.5 and 11.5 m. The temperature of the sea's surface and maps of clouds at night.

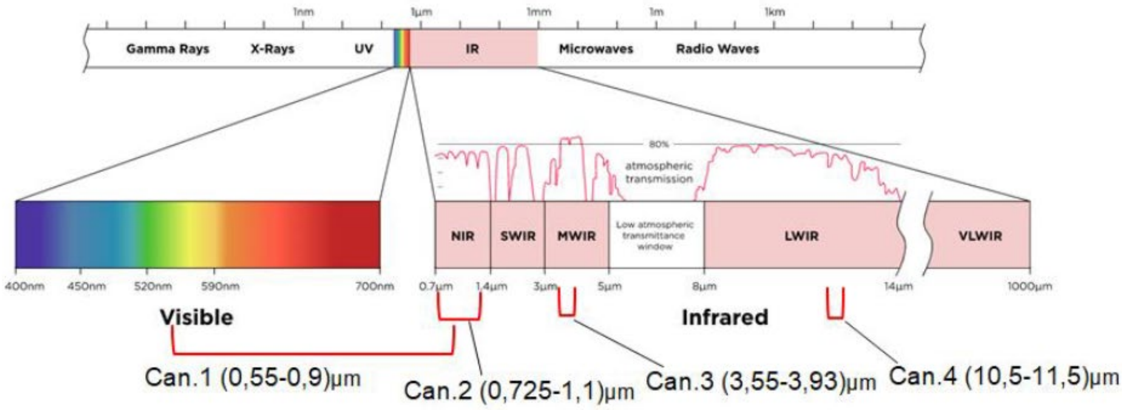



Figure 2.5: Visible and electromagnetic bands, as well as information about the AVHRR/1 channels, were taken from[1]

### 2.2.5 Fifth Generation: NOAA-POES Series (1998-2009)

NOAA-15, the first satellite of the fifth generation, was deployed on May 13, 1998, and is still in use. It weighs 1457 kg and is in an orbit around the sun that is 870 km high. It comes with the AVHRR/3 sensor. Compared to AVHRR/2, the AVHRR/3 has an extra infrared channel called 3A from 1.58 to 1.64m. The old channel 3 is now called 3B, with 6 channels [2].



NOAA-15 has been in service for 23 years, much longer than the 2 to 5 years that was thought to be the length of its duty. But some tools or systems no longer work or need help to do what they used to. The motor that turns the AHRR scanning mirror fails sometimes. Since 2002, there have been a few times when current peaks in the engine caused pictures to be messed up (Figure 2.6).

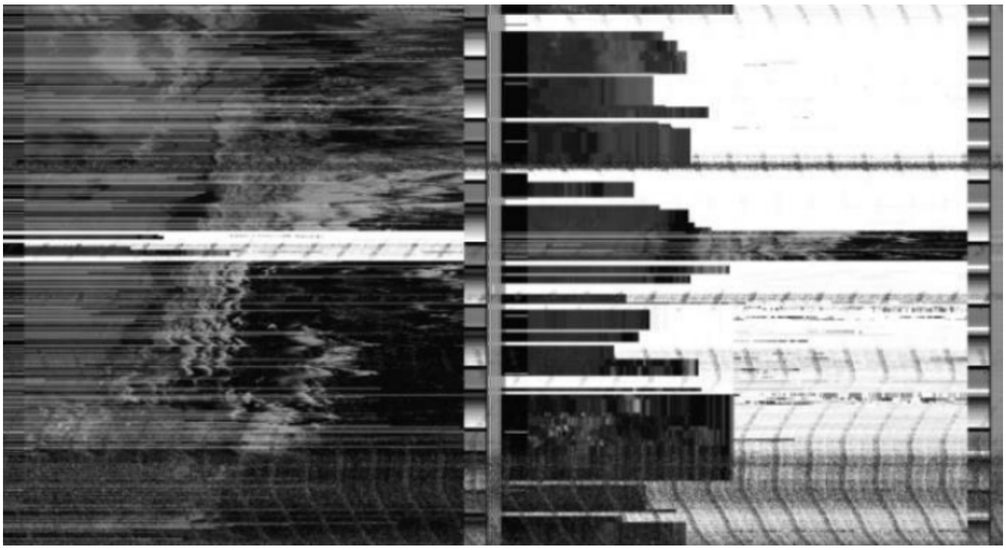


Figure 2.6: Images from NOAA-15 APT that were mixed up and sent to an user during an AVHRR engine trouble event [1]

The NOAA-18 satellite, launched on May 20, 2005, with instrumentation and characteristics (weight, orbit, etc.) like those of NOAA-15. It is still in service today. The NOAA-19 satellite, launched on February 6, 2009, with similar instrumentation and characteristics (weight, orbit, etc.) as its predecessors in the series. It is the last satellite of the fifth generation and continues in service today.[1]



Figure 2.7: Illustration of a fourth-generation satellite that use from [1]

## 2.3 SDR-Based Weather Information System

SDR-based weather information systems are a type of software-defined radio system that has been designed to receive and process signals from weather satellites. These systems use off-the-shelf hardware components such as antennas and digital signal processors, along with specialized software to process the received signals.

One of the main benefits of SDR-based weather information systems is their flexibility. They can be configured to receive signals from a variety of satellites, including those operated by NOAA, making them a valuable tool for meteorologists, weather enthusiasts, and organizations that rely on weather information [3].

Another advantage of SDR-based weather information systems is their ability to process multiple signals simultaneously. This means that users can receive and process data from several weather satellites at the same time, which enhances the accuracy and completeness of the captured weather information.



SDR-based weather information systems are also cost-effective when compared to traditional hardware-based systems. They use off-the-shelf components and general-purpose computing platforms, which makes them accessible to a wider range of users, including amateur weather enthusiasts and hobbyists [3].

Functionally, SDR-based weather information systems typically include software that can decode and interpret the signals received from weather satellites [3]. This software extracts data on various weather parameters such as temperature, humidity, air pressure, wind speed, and precipitation, which can then be displayed on a computer screen or other output device.

In summary, SDR-based weather information systems are a powerful tool for receiving and processing weather data. Their flexibility, ability to process multiple signals simultaneously, and cost-effectiveness make them an attractive option for meteorologists, weather enthusiasts, and organizations that rely on weather information for their operations.

## 2.4 Satellite Data's Impact in Environmental Weather Monitoring and Forecasting

Due to impressive improvements in satellite technology, satellite data is becoming increasingly crucial for weather tracking and forecasting. Because of these changes, scientists and meteorologists have more knowledge than ever. It was made easier to understand and predict weather patterns. With the help of geostationary and polar-orbiting satellites, we can now take high-resolution pictures, measure the parameters of the atmosphere, and keep an eye on many natural factors. This real-time data has changed the way we keep track of weather conditions. It lets us track weather systems, find trends, and closely monitor how storms and hurricanes form and move [4].



One of the most essential benefits of satellite data is that it helps improve weather-predicting models. By adding data from satellites to these models, analysts can improve the accuracy of their predictions. Satellite observations are a vital way to learn about weather factors like temperature, precipitation, wind patterns, and many more. Putting this information into forecasting models helps reduce uncertainty and makes weather estimates more accurate over a wide range of time scales, from short-term to seasonal.

Satellite remote sensing is a key part of monitoring different environmental parameters needed for weather research and forecasting. Satellites with special sensors can measure the temperature of sea and land surfaces, the plant index, the amount of aerosols in the air, the properties of clouds, and other parts of the atmosphere. These measurements are important for studying climate change, air quality, drought tracking, and spotting wildfires, all of which affect how the weather behaves. Satellites' long-term data records also make it possible to find trends and changes in these environmental factors, which helps study climate and make policy.

In addition to weather tracking and forecasting, satellite data has been very helpful in managing disasters and helping people in emergencies. By giving authorities real-time information about where natural disasters are, how bad they are, and how they are moving, satellites help them make good choices and use their resources well. Satellite imagery enables you to figure out how bad the damage is, plan how to manage for stand on your feet, it also find fragile places to protect yourself in the future. When combined with Geographic Information Systems (GIS), satellite data improves the ability to analyze and make decisions about space during emergencies. It makes it more efficient and focused way [4].



As satellite technology keeps improving and techniques for analyzing data improve, satellite data's value in weather monitoring, and forecasting will only keep growing. These improvements promise to make weather forecasts even more accurate and timely, better prepared for natural events, and better decisions in weather-related applications. Using satellite data, we can learn more about complicated weather trends, how climates affect each other, and how environmental changes affect people. Ultimately, this information will help us reduce risks, keep people and property safe, and make better decisions about weather-related events [4].

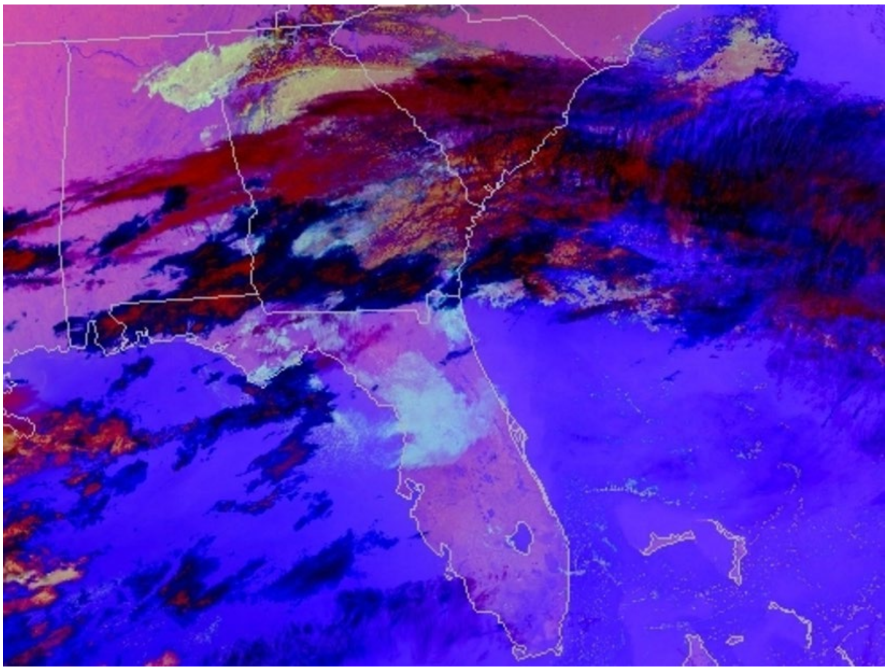


Figure 2.8: Images from Visible Infrared Imaging Radiometer Suite (VIIRS) extracted from [4]

## 2.5 Hardware

### 2.5.1 Antenna

To capture incoming signals, an antenna is securely connected to the input of the RTL-SDR dongle or any other compatible receiver device. It is important to note that there is no specific antenna requirement for the software-defined radio (SDR) system, as it can effectively function with antennas designed for various communication systems.

Once the antenna is properly attached, the RTL-SDR dongle processes the incoming signals. The dongle utilizes an analog to digital converter within its hardware to convert the analog signal into a digital format. Subsequently, the digitized data is transmitted to a computer through a USB connection.

Once the signal is received by the corresponding software on the computer, the user can then engage in radio listening activities, such as tuning in to a desired radio station.

<u>**Types of antenna for receiving NOAA satellite images**</u>

When capturing NOAA satellite images transmitted in APT mode, it is crucial to employ a high-quality antenna to ensure optimal signal reception with a favorable Signal-to-Noise Ratio (SNR). This, in turn, guarantees the receipt of images of superior quality.

While various antenna designs can meet the requirements, several factors should be carefully think about during the selection process. These factors encompass performance, economic viability, physical dimensions, durability, portability, weight, and complexity. Each aspect determines the most suitable antenna solution for the intended application.

**a. V-Dipole**



The V-dipole antenna, also known as the folded dipole antenna, is a popular and widely used design due to its simplicity and favorable radiation characteristics. This review aims to provide an overview of the existing literature on the V-dipole antenna, focusing on its properties, applications, and performance evaluations.

Researchers have extensively investigated the design and construction of V-dipole antennas. Conducted a comprehensive analysis of the electrical properties and radiation pattern of V-dipole antennas. They emphasized the advantages of the folded dipole structure, which offers wider bandwidth and improved radiation efficiency compared to a simple dipole [5].

The applications of V-dipole antennas span various fields, with notable contributions in radio astronomy. Demonstrated the effectiveness of V-dipole antennas in receiving and analyzing radio waves from celestial sources. The folded dipole design was found to provide good sensitivity and low noise characteristics, making it suitable for astrophysical observations .

Additionally, V-dipole antennas have shown promise in wireless communication systems. Investigated the performance of a V-dipole antenna in the context of wireless local area networks (WLANs). Their study highlighted the antenna's ability to achieve good impedance matching, high gain, and enhanced signal coverage, making it suitable for WLAN applications.

To evaluate the performance of V-dipole antennas, researchers have employed theoretical simulations and experimental measurements. Conducted a numerical analysis of the radiation pattern and impedance characteristics of a V-dipole antenna using electromagnetic simulation software. Their findings confirmed the wide bandwidth and favorable radiation properties of the V-dipole design [6].



Experimental studies have also focused on optimizing the performance of V-dipole antennas.  Investigated the effects of various design parameters, such as the length and spacing of the folded arms, on the antenna's resonant frequency and impedance matching. Their research emphasized the importance of precise parameter tuning to achieve optimal antenna performance [6].

In conclusion, the V-dipole antenna is a widely studied and applied design in various fields, including radio astronomy and wireless communications. Its folded dipole structure offers advantages such as wider bandwidth, improved radiation efficiency, and good impedance matching.

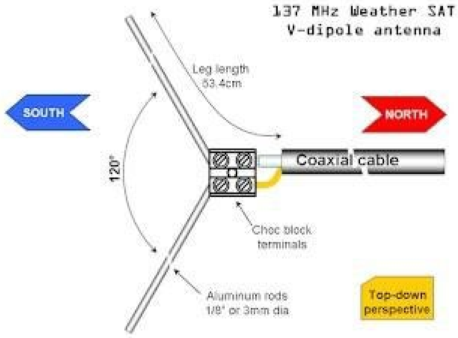



Figure 2.9: Schematic of V-dipole antenna extracted from [3]

**b. Crossed Dipole**

The crossed dipole antenna is a popular and widely used design known for its omnidirectional radiation pattern and broad bandwidth. It provides an overview of existing research on the crossed dipole antenna, including its properties, applications, and performance evaluations.

Numerous studies have focused on the design and characteristics of crossed dipole antennas. They comprehensively analyzed the crossed dipole's radiation pattern, impedance characteristics, and polarization properties. They emphasized the symmetrical radiation pattern and the ability to achieve circular polarization, making the crossed dipole antenna suitable for various applications [7].

Crossed dipole antennas have found extensive use in satellite communications. The use of crossed dipole antennas for satellite ground stations. It demonstrated that crossed dipole antennas offer desirable characteristics such as wide bandwidth, high gain, and low sidelobe levels, making them well-suited for receiving signals from satellites in different orbits.

In the field of radio astronomy, crossed dipole antennas have been widely employed. It investigated the use of crossed dipole arrays for low-frequency radio astronomy observations. They highlighted the advantages of crossed dipole antennas in terms of sensitivity, beamforming capability, and radio frequency interference mitigation (RFI) in astronomical observations.

Performance evaluations of crossed dipole antennas have been conducted through various methods. It evaluated the performance of a crossed dipole antenna for wireless communication applications. They analyzed parameters such as return loss, radiation pattern, and impedance bandwidth to assess the antenna's suitability for wireless systems.



Optimization techniques have been applied to enhance the performance of crossed dipole antennas. They employed genetic algorithms to optimize the design parameters of a crossed dipole antenna. Their study demonstrated the effectiveness of optimization methods in improving the antenna's performance [7].

In conclusion, the crossed dipole antenna is a widely studied and utilized design, offering advantages such as omnidirectional radiation, broad bandwidth, and circular polarization. Its applications range from satellite communications to radio astronomy. Ongoing research focuses on performance enhancements, optimization techniques, and exploring new applications for this versatile antenna configuration.

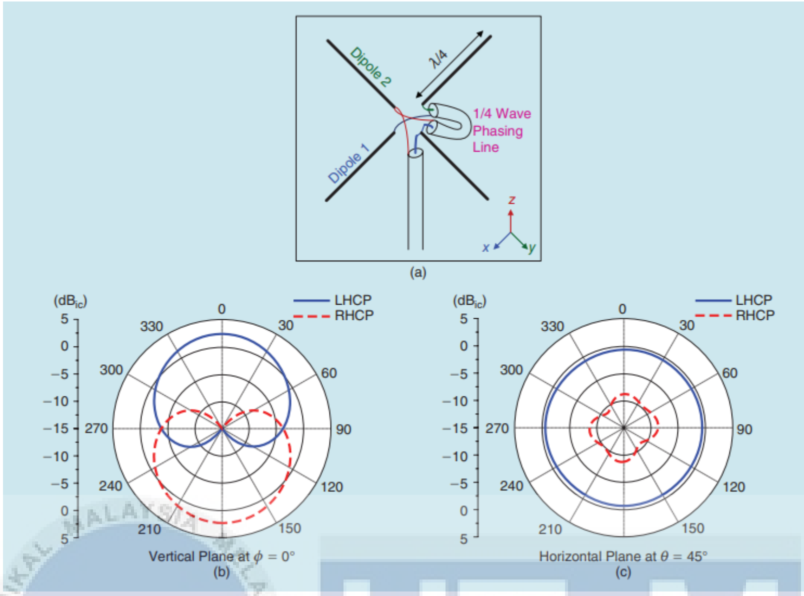



Figure 2.10: The 3-D view and its vertical-plane pattern and horizontal-plane pattern dipole antenna extracted from [7]

### c. Quadrifilar Helix Antenna

The quadrifilar helix antenna (QFH) has emerged as a popular choice for receiving signals from NOAA weather satellites. This literature review provides an overview of the existing research on the utilization of the quadrifilar helix antenna for NOAA satellite reception, encompassing its properties, applications, and performance evaluations.

Several studies have been dedicated to investigating the design and characteristics of quadrifilar helix antennas specifically tailored for capturing NOAA satellite signals. The utilization of the QHA for receiving transmissions from NOAA polar-orbiting satellites. Their research underscored the QHA's ability to achieve circular polarization and wide bandwidth, enabling effective reception of NOAA satellite data [3].

Practical implementations of the QHA for NOAA satellite reception have been demonstrated in various setups. There was an extensive analysis of a QHA-based system designed for receiving signals from NOAA weather satellites. It delved into important considerations such as antenna orientation, positioning, and preamplifier optimization to enhance reception quality and mitigate potential signal distortions.

Performance evaluations of quadrifilar helix antennas in the context of NOAA satellite reception have been conducted through both theoretical analyses and experimental measurements. The radiation pattern and gain of a QHA used for receiving NOAA satellite signals. Their findings emphasized the QHA's consistent and reliable signal reception capabilities, even in adverse weather conditions [3].



Additionally, researchers have explored optimization techniques aimed at enhancing the performance of quadrifilar helix antennas for NOAA satellite reception [3]. It employed a genetic algorithm to optimize the QHA's dimensions and helix pitch angle, resulting in improved signal reception from NOAA satellites. The study successfully demonstrated the efficacy of optimization in enhancing the antenna's performance and signal-to-noise ratio.

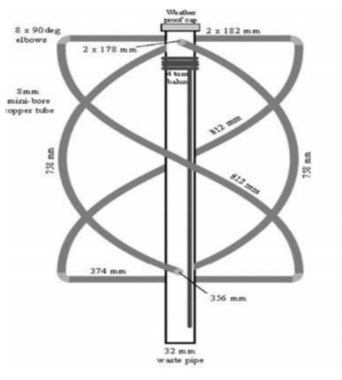



Figure 2.11: Schematic based on QFH Antenna extracted from [3]

### 2.5.2 Hack RF-One

HackRF One is an open-source software-defined radio platform that allows users to transmit or receive radio signals over a wide frequency range. It was created by Michael Ossmann and his company, Great Scott Gadgets, and is widely used by researchers, security professionals, and hobbyists.

What sets HackRF One apart from other SDR platforms is its ability to transmit and receive various modulation types, such as AM, FM, SSB, and CW. It used on many types of application, including wireless communication, signal analysis, and testing.

HackRF One has a frequency range of 1 MHz to 6 GHz, making it suitable for various applications. It is also compatible with multiple SDR software packages such as GNU Radio, SDR#, and GQRX, allowing it to be controlled for multiple tasks.

While HackRF One is a powerful tool, it should be used cautiously and in compliance with local laws and regulations. Transmitting on specific frequencies may require a license or authorization, so users should know of any legal restrictions in their area. Overall, HackRF One is a versatile and powerful tool for exploring the world of software-defined radio.


Figure 2.12: Hack RF-One hardware extracted from [8]

### 2.5.3 RTL-SDR

RTL-SDR is a type of software-defined radio that uses a low-cost digital TV tuner based on the Realtek RTL2832U chipset. RTL-SDR stands for "Realtek Software Defined Radio," it has gained familiarity in recent years due to its low cost and wide availability.

RTL-SDR can receive a wide range of frequencies, from a few megahertz to over 1 gigahertz, depending on the specific tuner and antenna used. It can receive FM radio, DAB radio, AM radio, aircraft communications, police and emergency services communications, digital television signals, and more.

RTL-SDR works by converting radio signals the antenna receives into a digital format that a computer can process. This is done using the RTL2832U chip's built-in analog-to-digital converter. The converted digital signal is then sent to the computer over USB, where it can be processed by software.



RTL-SDR is commonly used by hobbyists, radio enthusiasts, and security researchers for various applications, including listening to radio broadcasts, monitoring air traffic, tracking ships, decoding digital signals, and analyzing wireless communications. Its cheapness and versatility make it a popular choice for experimenting with radio technology and learning about the principles of software-defined radio.


Figure 2.13: RTL-SDR hardware extracted from [3]

### 2.5.4 Raspberry Pi

A Raspberry Pi in the SDR-based Weather Information System can provide several benefits. Firstly, the Raspberry Pi is a low-cost computer, which makes it a cost-effective option for building a weather information system. Additionally, its small form factor makes it easy to deploy in remote or rural areas where space may be limited. Moreover, the Raspberry Pi has low power consumption, making it a suitable choice that runs on solar or battery power.



One of the ways to utilize a Raspberry Pi in the SDR-based Weather Information System is to control the SDR device by connecting it to the Raspberry Pi and using the GPIO pins to control the device. Another way is to use Raspberry Pi to store and process the weather data received from the NOAA satellites, which can be done using Python or other programming languages. The Raspberry Pi can also host a web server to display weather information on a web page. Finally, a cellular modem or a USB dongle may be used with the Raspberry Pi to provide cellular connectivity to the system, enabling it to transmit weather information to remote or rural areas.

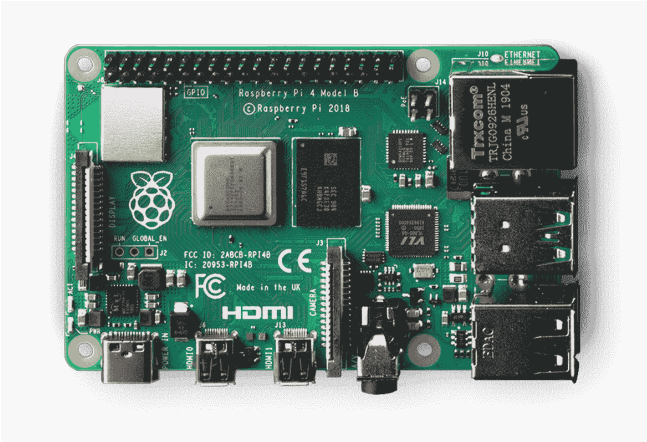



Figure 2.14: Raspberry Pi 4 hardware extracted from [8]

## 2.6 Software

### 2.6.1 SDR # AND SDR ++ For Receive

Software-defined radio (SDR) has become a popular technology for receiving and decoding signals from various sources, including weather satellites. In particular, SDR# and SDR++ are two widely used applications for receiving signals from NOAA weather satellites.



SDR# (SDRSharp) is a Windows-based SDR application that supports a wide range of SDR devices and provides a user-friendly interface. It has been used in various weather information systems, such as the Open Satellite Project (OSP), which is an open-source project that aims to provide free and open access to weather satellite data. SDR# has been used to receive and decode signals from NOAA satellites, allowing users to extract weather data from the received signals.

SDR++ is an open-source, cross-platform SDR application that provides a modern and customizable user interface. It supports various SDR devices and provides built-in decoders for different satellite weather protocols, including APT, LRPT, and HRPT. SDR++ has been used in multiple projects, such as the Meteor M-N2-2 Reception and Decoding project, which is a project that aims to receive and decode signals from the Russian Meteor M-N2-2 weather satellite.

In addition to SDR# and SDR++, other SDR applications have been used for receiving signals from NOAA satellites, such as GQRX, which is a Linux-based SDR application that supports various SDR devices and provides a user-friendly interface. GQRX has been used in multiple projects, such as the NOAA Weather Satellite Reception with RTL-SDR and GQRX project, which is a project that aims to receive and decode signals from NOAA weather satellites using a low-cost RTL-SDR dongle and GQRX.

Overall, SDR# and SDR++ are two popular SDR applications for receiving signals from NOAA weather satellites. They provide a user-friendly interface and support various SDR devices, allowing users to extract weather data from the received signals. Other SDR applications, such as GQRX, have also been used for receiving signals from NOAA satellites and provide similar functionalities.



### 2.6.2 WXTOIMG For Decode the Signal

WXtoImg is a software tool widely used for decoding weather satellite signals, particularly those from the National Oceanic and Atmospheric Administration (NOAA). To receive and decode these signals, specialized equipment, such as a receiver and antenna, can be connected to a computer running the WXtoImg software. Once the software receives the signals, it can decode them into images of weather patterns and data such as sea surface temperatures, cloud cover, and atmospheric conditions.

Several studies have evaluated the performance of WXtoImg in decoding satellite signals and generating high-quality images. One study evaluated the software's ability to process Automatic Picture Transmission (APT) signals from NOAA polar-orbiting satellites. It produced high-quality images with minimal errors, even in noisy environments. Another study proposed a new approach to processing weather satellite data using image processing algorithms and machine learning techniques, enhancing the decoded images' quality [3].

WXtoImg has also been used to generate sea surface temperature maps and analyze historical NOAA satellite images for climate research. These studies demonstrate that WXtoImg is a reliable and effective tool for decoding weather satellite signals and generating accurate and reliable data for various weather forecasting, oceanography, and climate research applications.

The studies reviewed in this report suggest that WXtoImg is a valuable tool for decoding weather satellite signals and generating high-quality images and data [3]. The software's ability to process signals from NOAA polar-orbiting satellites, generate sea surface temperature maps, and analyze historical NOAA satellite images for climate research makes it a tool for many applications. Overall, WXtoImg is a reliable and effective tool for weather forecasting, oceanography, and climate research.

### 2.6.3 GRLEVEL3 For Display Weather

GRLevel3 is a software that is widely used to display weather radar data, and it is used by meteorologists, storm chasers, and other weather enthusiasts to track and analyze weather patterns. Developed by Gibson Ridge Software, LLC, this software provides a variety of features that allow users to visualize and analyze weather radar data in different formats.

One of the key features of GRLevel3 is its ability to display radar data in various formats, including reflectivity, velocity, and spectrum width. These formats can be used to identify different types of precipitation, such as rain, snow, and hail, as well as to identify areas of turbulence and wind shear. This makes it a valuable tool for analyzing weather patterns and making predictions about upcoming weather events.

GRLevel3 also provides users with the ability to display storm tracks and warnings, and users can set up alerts to notify them when a storm is approaching. This feature is particularly useful for meteorologists and emergency management officials who need to make quick decisions about issuing warnings and evacuations.



Moreover, GRLevel3 provides users with a range of tools for analyzing radar data, including the ability to create cross-sections of radar data, view storm structures in three dimensions, and plot storm attributes such as storm height and precipitation intensity. These tools allow users to gain a deeper understanding of weather patterns and make more accurate predictions.

Overall, GRLevel3 is a powerful tool for visualizing and analyzing weather radar data, and its range of features and ease of use make it a popular choice among meteorologists and weather enthusiasts alike.

## 2.7 APT Signal

Receiving data from NOAA (National Oceanic and Atmospheric Administration) satellites plays a crucial role in weather monitoring and forecasting. APT signals are utilized to enhance the reception of NOAA satellite data, ensuring a reliable and continuous stream of information. APT signals are specifically designed to capture and decode the transmissions from NOAA satellites, and they are generated using software-defined radios (SDRs) and specialized antenna systems. By optimizing the APT signal reception system, which includes selecting the appropriate antenna, adjusting its position and orientation, and optimizing the SDR settings, high-quality data reception can be achieved [9]. Specialized software is used to decode the received APT signals, resulting in usable weather information for various applications. However, challenges such as atmospheric conditions, antenna positioning, and radio frequency interference need to be considered for effective reception [10]. Continuous advancements in signal optimization and decoding technologies will further improve the efficiency and reliability of receiving NOAA satellite data through APT signals.

## 2.8 Comparison of GOES and POES, Frequencies of NOAA Satellites

Table 2.1: Comparison of GOES and POES characteristics derived from [11]

| | GOES | POES |
|---|---|---|
| Orbit | Geostationary orbit | Polar orbit |
| Coverage Area | Full disk view of Earth from fixed position. | Global coverage with multiple passes. |
| Weather Monitoring | Continuous observation of weather patterns and over specific region. | Observation of weather systems and data and collection multiple times per day. |
| Severe Weather Monitoring | Rapid updates on storms and severe weather. | Monitoring of storms and severe weather. |
| Atmospheric Composition | Limited monitoring. | Measures ozone and pollutants. |
| Environmental Monitoring | Limited capabilities for environmental monitoring. | Measures environmental parameters such as land surface temperature, ice extent, and vegetation health. |
| Applications | Weather forecasting, storm tracking and disaster management | Weather forecasting, climate monitoring and environmental research. |

Table 2.2: Frequencies of NOAA Satellites derived from [12]

| Satellite | Receiving frequency (MHz) | Wavelength (m) |
|---|---|---|
| NOAA 15 | 137.620 | 2.18 |
| NOAA 18 | 137.9125 | 2.175 |
| NOAA 19 | 137.100 | 2.188 |

## 2.9 Comparison of Previous Research Paper

In this subtopic, research title regarding their component, features and remark will be discuss. Each feature of previous research paper reflects the uniqueness of their project in develop weather monitoring system using SDR based.

Table 2.3: Comparison within previous Research Papers

| Num | Research Title | Component | Features | Remark |
|---|---|---|---|---|
| 1 | Estación de tierra autónoma para la recepción de imágenes de satélites NOAA (Autonomous ground station for receiving images from NOAA satellites) [1] | • Hardware: raspberry pi 4 and RTL-SDR.<br>• Antenna: Turnstile Antenna<br>• Software: WXtoImg, Gpredict | Provide details regarding the antenna model and antenna assembly. | The project has a few problems such as limited coverage, reliance on specific satellites, technical complexity, protocol compatibility issues, trouble getting to remote places, and worries about cost and long-term viability. |

| Num | Research Title | Component | Features | Remark |
|---|---|---|---|---|
| 2 | Low-Cost and Portable Ground Station for the Reception of NOAA Satellite Images [12] | • Hardware: raspberry pi 3b+, and RTL-SDR<br>• Antenna: double cross antenna<br>• Software: Raspbian OS for raspberry pi 3b+, SOX for set audio tools, predict, and WXtoImg | This result covers 1793km x 3200km and includes images of cloudy and clear skies. | This project's narrow focus on local climatic patterns could limit its applicability for regional or global climate analysis. The emphasis on affordability and portability may also result in limited functionality, such as the absence of a dependable orientation system for receiving high-resolution images. |
| 3 | NOAA Satellite Weather Stations: State of the Art, Perspective and Future Projection [13] | • Hardware: Icom PCR-1500,USRP 2920, RTL-SDR 2832U,<br>• Antenna: crossed dipole and QFH antenna | It shows the impact of ground satellite stations that link to NOAA and give difference between NOAA and GOES. | This project's dependence on open-access meteorological data from NOAA satellites, which could be disrupted or altered, is a potential disadvantage. Moreover, reliance on third-party infrastructure-as-a-service providers may impose restrictions and potential costs, affecting the project's long-term viability and access to essential resources. |

| No | Research Title | Component | Features | Remark |
|---|---|---|---|---|
| 4 | SDR Based Ground Station for Image Reception from Weather Satellites [3] | • Hardware: RTL-SDR<br>• Antenna: quadrifilar helicoidal antennas and v-dipole<br>• Software: SDR#, WxToImg, Orbitron, LRPT Decoder. | Displays the result of comparing NOAA 19 and Meteor M2. The paper presents thermal and fundamental images. | This project initial limitations in area coverage and image quality with the antenna setup, which affected the effectiveness of the system. While improvements were made, there may still be limitations in capturing comprehensive and high-quality images from weather satellites. The rough weather predictions based on these images may have limited accuracy compared to more advanced methods. |

| No | Research Title | Component | Features | Remark |
|---|---|---|---|---|
| 5 | Real-time Decoding of Satellite Signals Autonomous Metro-A step towards Automation View project Ultrasonic based Bone Densitometer View project Real-time Decoding of Satellite Signals [14] | • Hardware: RTL2832U, R820T2<br>• Antenna: V-shaped Antenna<br>• Software: GNU Radio, SDRsharp, WXTOIMG and MMSSTV | It describes a low-cost, customisable system for decoding UHF and VHF satellite transmissions. USRP B200, RTL SDR, and a self-designed V-shape antenna acquired clear signals from the ISS and NOAA-18 satellites, resulting in ideal experimental findings. | This project's limited satellite signal decoding capability is a disadvantage. It catches signals from the International Space Station (ISS) and NOAA-18 satellites but may not decode messages from other satellites. This may limit the mini-ground station's satellite signal reception and decoding capabilities. |

| No | Research Title | Component | Features | Remark |
|---|---|---|---|---|
| 6 | Design and Development of Dipole Antenna for NOAA Satellite Image Acquisition System and Processing [15] | • Hardware: RTL-SDR<br>• Antenna: double v double dipole and double cross double dipole<br>• Software: SDRSharp software, WxtoImg, and Gpredict. | It shows comparrison between VSWR, gain, and return loss of V and double cross double dipoles. | This project have limited frequency range of the designed antenna. While it is optimized for receiving NOAA satellite signals at specific frequencies (137.1 MHz, 137.62 MHz, and 137.912 MHz), its performance outside these frequencies may be compromised. This could restrict the versatility and applicability of the antenna for receiving signals from other satellites or satellite systems operating at different frequencies. |

| No | Research Title | Component | Features | Remark |
| --- | --- | --- | --- | --- |
| 7 | A low cost solution for NOAA remote sensing [16] | • Hardware: RTL-SDR, FUNcube Dongle Pro+ or HackRF<br>• Antenna: QFH antenna<br>• Software: MATLAB Simulink | It show the simulation using block diagram from Simulink in MATLAB. | This project's low-cost hardware and components may limit its performance compared to more expensive options. Low-cost components may compromise signal quality, sensitivity, and noise suppression. The indicated system's ability to forecast atmospheric phenomena and generate heat maps from infrared photos is still in development. |

| No | Research Title | Component | Features | Remark |
|---|---|---|---|---|
| 8 | Image Data Acquisition for NOAA 18 and NOAA19 Weather Satellites Using QFH Antenna and RTL-SDR [17] | • Hardware: RTL-SDR<br>• Antenna: Quadrifilar Helical Antenna (QHA)<br>• Software: WXtoImg, CubicSD | It show developed a low-cost NOAA satellite ground station. The designed QFH antenna performed well at different frequencies, and the RTL-SDR effectively received information from NOAA 18 and NOAA 19 satellites, despite slight frequency offsets during signal reception. | This project could be impacted by frequency offsets when receiving Automatic Picture Transmission signals from NOAA 18 and NOAA 19 satellites. Although minor at 0.0685% and 0.0686%, the frequency offsets potentially affect received data. This may affect satellite ground station data accuracy. |
| 9 | Implementation of NOAA Weather Satellite Receiver using HackRF-One SDR [18] | • Hardware: Raspberry Pi 4, HackRF-One<br>• Antenna: VHF-Band Antenna<br>• Software: OpenCv, SDR# | Implements an SDR-based weather station. The technology reliably obtains real-time satellite forecast gray-scale images in varied weather circumstances. This technology helps in disasters without internet or cellular signals. | This project is that it requires low computational power compared to other similar systems. While this may be seen as an advantage in terms of resource efficiency, it could also limit the processing capabilities of the weather station. The lower computational power may restrict the system's ability to handle complex weather data analysis or support additional features and functionalities. |

| No | Research Title | Component | Features | Remark |
| --- | --- | --- | --- | --- |
| 10 | Economical Antenna Reception Design for Software Defined Radio using RTL-SDR [19] | • Hardware: RTL-SDR<br>• Antenna: Quadrifilar Helical Antenna<br>• Software: GNU radio, HDSDR, WXtoImg | It show about using Quadrifilar Helical Antenna for SDR purpose. | The project aims to provide a cost-effective solution using SDR, but the affordability of hardware components can still be a limitation. Additionally, the performance and efficiency of the self-constructed antenna should be carefully considered compared to commercially available options. |
| 11 | Meteorological Picture Reception System using Software Defined Radio (SDR)[20] | • Hardware:RTL-SDR<br>• Antenna:QHA antenna<br>• Software:GNUradio, WXtoImg. | The RTL-SDR module used in this article tuned correctly each of the three transmission frequencies (137.1 MHz, 137.9125 MHz, and 137.62 MHz) in the APT format of the NOAA satellites and the GNU Radio Companion (GRC) application, allowing a satisfactory visualisation of the signal in frequency-modulated APT format. | This project have limited frequency tuning and signal reception quality with the RTL-SDR module, potential error detection due to automation, and limited advanced functionality and customization options with the GNU Radio Companion interface and WXtoImg software. |

## 2.10 Summary of Chapter 2

Based on previous research papers, it can be concluded that various ground station setups, and technologies are used for receiving images from NOAA weather satellites. The hardware components include Raspberry Pi boards, RTL-SDR devices, and radio receivers. Antenna types such as turnstile, cross dipole, quadrifillar helical antenna, and V-dipole antenna are employed for signal reception. Software applications like WXtoImg, Gpredict, SDR#, and GNU Radio are utilized for decoding and processing received signals. The studies showcase the successful acquisition of NOAA satellite images and highlight these ground station solutions' low-cost and portable nature. They also discuss the performance, comparisons, and prospects of different antenna and reception systems, emphasizing the importance of reliable weather data for various applications.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

Developing a ground station using Software-Defined Radio (SDR) technology for receiving signals from NOAA (National Oceanic and Atmospheric Administration) satellites is an important project to improve the acquisition and analysis of weather data. Before this, there has been a growing demand for accurate and timely weather information across various sectors, including agriculture, aviation, disaster management, and climate research. NOAA satellites are renowned for their extensive coverage and high-quality data, making them a valuable source of weather observations.

This methodology focuses on designing and implementing a software-defined radio system that can receive and decode the signals transmitted by NOAA satellites. Traditional weather satellite receivers often rely on specialized hardware and proprietary software, which can be expensive and limiting. By utilizing SDR technology, we can use its flexibility and versatility to develop a cost-effective and customizable solution for receiving satellite signals.

The main reason is to establish a reliable and efficient system capable of capturing, demodulating, and decoding the data transmitted by NOAA satellites. The received data typically includes essential meteorological information such as cloud cover, sea surface temperatures, precipitation, and atmospheric profiles. By capturing this data, we can generate accurate weather reports and predictions, facilitating informed decision-making processes across various sectors.

The proposed methodology involves several key stages. An extensive literature review and research on software-defined radio systems and weather satellite signal processing techniques will be conducted. This is understanding the current state-of-the-art methodologies and identifying potential areas for improvement.

Next, we will design and configure the SDR system's necessary hardware and software components for satellite signal reception. This includes selecting suitable SDR hardware, such as receiver modules and antennas, and configuring them to operate within the frequency bands used by NOAA satellites. Additionally, open-source SDR software frameworks like SatDump will be employed to develop signal-processing blocks and implement the required decoding algorithms.



Once the hardware and software components are set up, the focus will shift to signal acquisition and demodulation. This stage involves capturing the satellite signals using the SDR receiver, applying appropriate demodulation techniques to extract the data, and implementing error correction mechanisms to improve the dependability and accuracy of received information.

Following successful signal acquisition and demodulation, the next step is to decode the received data. NOAA satellites transmit data in specific formats, typically utilizing protocols like Automatic Picture Transmission (APT) or High-Resolution Picture Transmission

(HRPT). Our methodology will involve designing and implementing algorithms to decode these protocols and extract the meteorological data contained within them.

Lastly, a user-friendly interface will be developed to enable users to interact with the system, view the received weather data, and perform analysis and visualization tasks. This interface will provide a seamless experience, allowing users to efficiently access and utilize weather information.

## 3.2 Study Design

The main objective of this development is to create a ground base using the NOAA satellite data retriever and raspberry pi. In this system, the principal device used is an RTL-SDR. The RTL-SDR selected for this system is the RTL-SDR 2832U. WXtoImg generates images for this project, while SDRsharp is integrated with RTL-SDR to process data from a cross-dipole antenna. Based on the flowchart below, the first flowchart depicts the development process for this writing. The second is a flowchart depicting the system's operation in this pursuit.

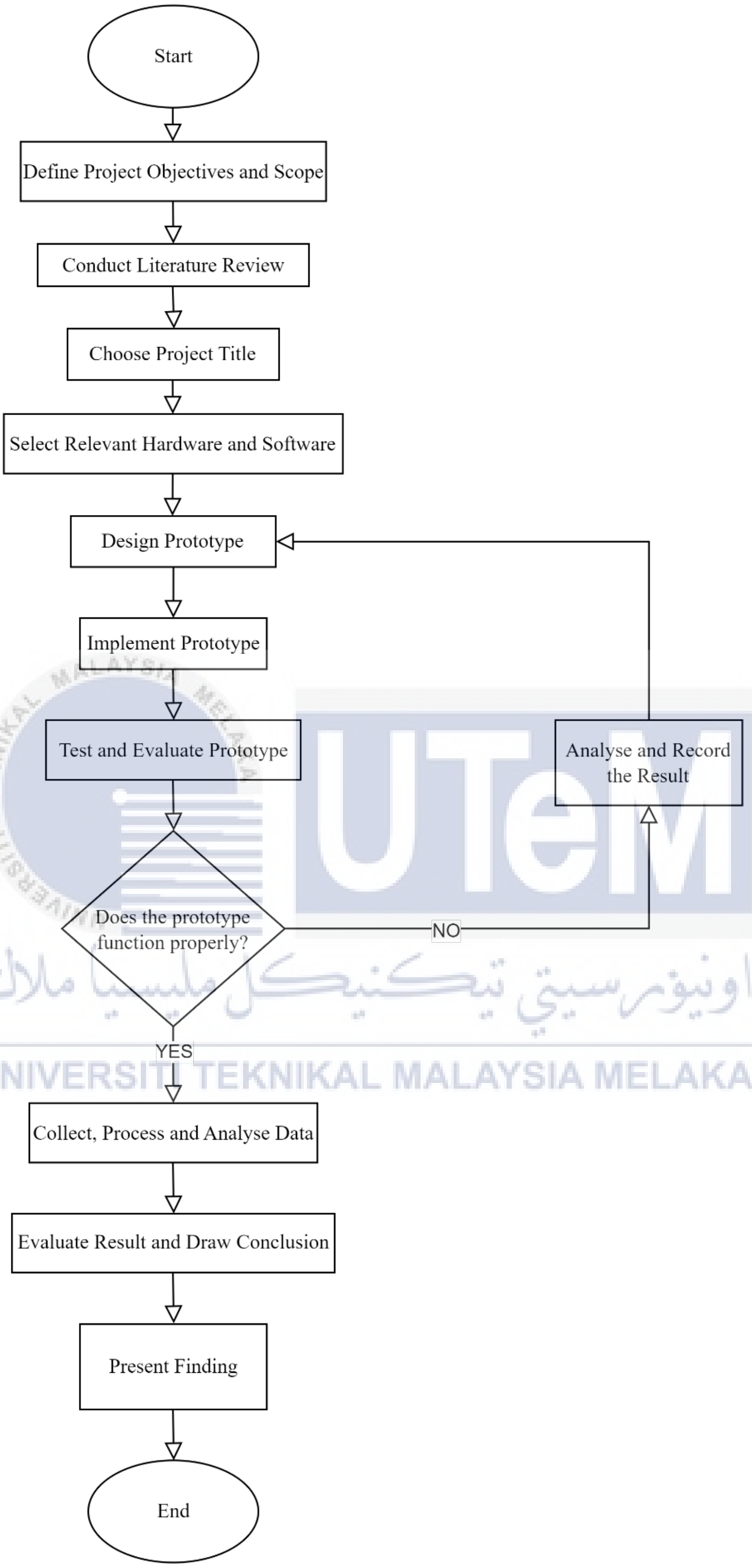



Figure 3.1 : Flowchart of the project

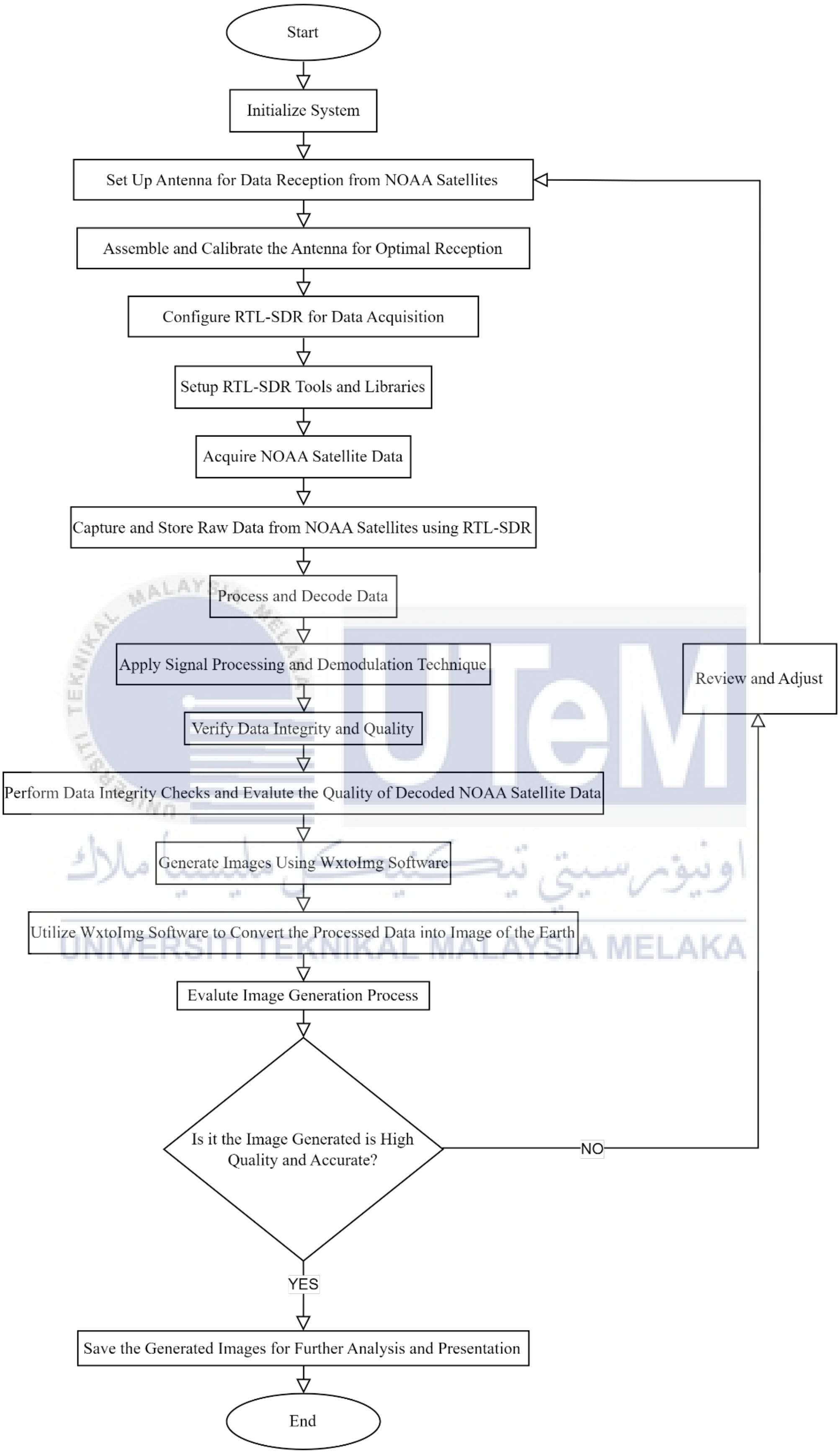



Figure 3.2 : Flowchart of the system in this project

## 3.3 Elaboration of process flow

This project is designed to develop a weather satellite receiver. The process begins by gathering all the components and equipment, including a Raspberry Pi, an RTL-SDR dongle, an antenna, and a microSD card. Next, the Raspberry Pi is set up by installing the Raspbian operating system, configuring network settings, and updating the system. Then it focuses on installing and configuring the RTL-SDR software, which involves downloading dependencies, obtaining the RTL-SDR software package, compiling it, and configuring the device.

A testing phase to ensure the RTL-SDR dongle is functioning correctly, where the device is verified, tuned to an FM radio station, and tested for reception. The subsequent step involves installing and configuring WXtoImg, a software for decoding and processing the received satellite images. Once the software is already set up, it should set up the antenna for optimal signal reception. This includes selecting a suitable location, positioning the antenna, and adjusting the gain settings. With the antenna in place, The antenna will receive the data from satellite National Oceanic and Atmospheric Administration (NOAA), NOAA 15, NOAA 18, NOAA 19 on frequency 137.620 MHz, 137.9125 MHz and 137.100 MHz, the process of receiving and decoding satellite images using WXtoImg. This includes scheduling passes, initiating recording, and processing the recorded data to generate ideas.

Finally, the post-processing and enhancement of the captured satellite images using various editing tools and techniques. It should get a successful setup and get pictures of NOAA satellites.

### 3.4 Hardware Specification

In this project, specific hardware components and equipment should be used. Firstly, a Raspberry Pi single-board computer is required, and it should use one of the latest models available at the time of implementation, such as Raspberry Pi 3 or Raspberry Pi 4. An RTL-SDR dongle is essential for capturing the radio frequency signals from the NOAA weather satellites, and it also should choose a dongle that utilizes the Realtek RTL2832U chipset. For effective signal reception, a suitable antenna is necessary. By constructing a QFH (Quadrifilar Helix Antenna) antenna using copper wire or coaxial cable, providing dimensions and specifications for optimal performance.

Additionally, a microSD card with at least 8GB capacity is needed to install the Raspbian operating system and other software packages. A 5V micro USB power adapter with a suitable current rating ensures a stable power supply to the Raspberry Pi. Lastly, a computer or laptop is required for software downloads, writing the operating system image to the microSD card, configuring the Raspberry Pi, and processing the received satellite images.



#### 3.4.1 Bill of Material

Table 3.1: Bill of Material (B.O.M)

| No. | Components Name | Description | Quantity |
|---|---|---|---|
| 1 | RTL-SDR | RTL-SDR 2832u | 1 |
| 2 | Raspberry Pi | Raspberry Pi 4 | 1 |
| 3 | Antenna | Cross-Dipole Antenna | 1 |
| 4 | MicroSD card | Capacity 8GB | 1 |
| 5 | Tuner | Tuning frequency | 1 |
| 6 | Coaxial cable | 50 Ω coaxial cable | 1 |
| 7 | SMA Connector | Female / Male connector | 1 |

### 3.4.2 RTL-SDR 2832U


Figure 3.3 : RTL-SDR 2832U

For the Weather Satellite Receiver project, the RTL-SDR chip is a popular choice for many reasons. First, cost is an important issue. RTL-SDR dongles are cheaper than other software-defined radio devices, which makes easy for users to get. The RTL-SDR dongle also has a wide range of bands, including those used by NOAA weather satellites. This makes sure that their correspondence can be picked up well. The RTL-SDR dongles use the Realtek RTL2832U processor, which works well with the software. This is another benefit. This makes it easy to integrate with Raspberry Pi and other platforms because many software programmes and tools work with the Realtek chipset. Also, the RTL-SDR community is big, active, and helpful. It has a lot of online tools, tutorials, and forums to help people get started and fix problems. This community-driven method ensures that RTL-SDR keeps improving and more people use it. Lastly, it's important to mention how versatile RTL-SDR is. It can be used for many different things besides receiving NOAA weather satellites, like amateur radio, FM radio, air traffic control, and ADS-B aeroplane tracking. The RTL-SDR chip is a cheap, flexible, and well-supported way to pick up radio signals. This makes it a popular choice for the Weather Satellite Receiver project.

### 3.4.3 Cross-Dipole Antenna

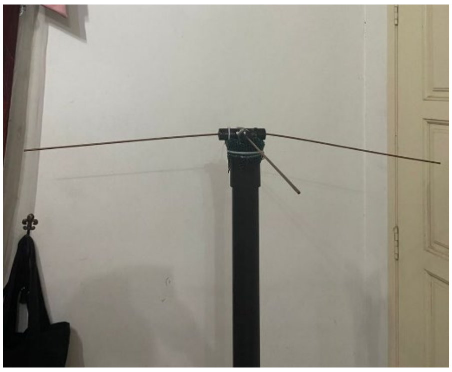


Figure 3.4 : Cross-Dipole Antenna

The choice of the cross-dipole antenna for this project was driven by several key considerations. Much like the Quadrifilar Helix (QFH) antenna, the cross-dipole antenna excels in its capacity to receive circularly polarized signals, which is paramount for accurately capturing NOAA weather satellite signals. Circular polarization helps mitigate signal distortion stemming from satellite positioning, ultimately leading to improved signal reception and decoding accuracy. Furthermore, cross-dipole antennas, like to their QFH counterparts, demonstrate wideband performance, enabling them to intercept signals across a broad frequency spectrum without necessitating frequent adjustments. This characteristic proves to be indispensable when intercepting NOAA weather satellite signals that operate within specific frequency bands. Cross-dipole antennas also share the advantageous attributes of low noise and high gain with QFH antennas. This means they are adept at receiving weak signals with minimal interference and are capable of enhancing the quality of the received signals.



In addition, the cross-dipole antenna boasts omnidirectional reception capabilities, enabling it to capture signals from all directions without the need for precise alignment with the satellite. This omnidirectional characteristic enhances its versatility in scenarios where signals may emanate from various angles.

Lastly, like to QFH antennas, cross-dipole antennas are relatively straightforward to construct, rendering them a practical choice. They can be fabricated using common materials such as copper wire or coaxial cable, affording the flexibility to tailor the antenna's size and shape to align with the specific project requirements. In summary, the selection of the cross-dipole antenna for this project was grounded in its effectiveness in receiving circularly polarized signals, wideband performance, low noise, high gain, omnidirectional reception capabilities, and the convenience of customization.

### 3.4.4 Raspberry Pi

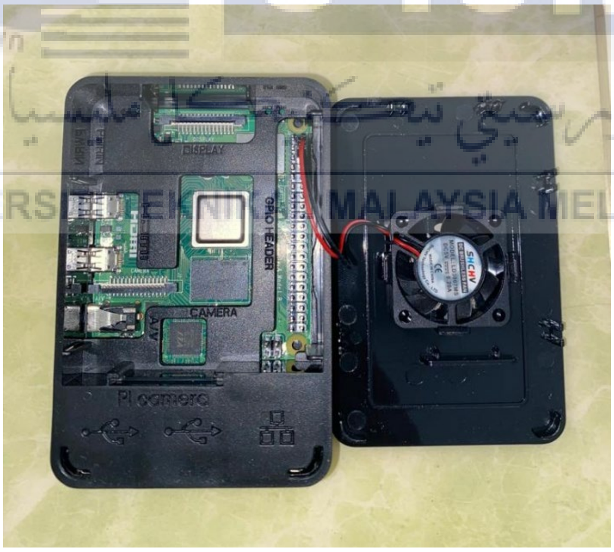



Figure 3.5 : Raspberry Pi 4



The Raspberry Pi has been picked as the central part of this project for several good reasons. One of the best things about the Raspberry Pi is its cheapness. Because of its low price, it can be used by many people, such as students, hobbyists, and enthusiasts. Even though the Raspberry Pi is cheap, it doesn't skimp on usefulness and needs more processing power to meet the project's needs. The Raspberry Pi is also small and easy to carry, which makes it great choice for projects that need to be moved or set up in different places. Its small size makes it easy to put the receiver into separate enclosures or outside to get the best signal receiving. The Raspberry Pi uses very little power, which is another critical benefit. It is made to be energy-efficient, so the receiver can work for a long time without using too much power.

Also, the Raspberry Pi's GPIO (General Purpose Input/Output) pins allow users to connect and handle external devices like the RTL-SDR dongle, antenna, and other peripherals. This makes it easier to make changes and add more gear. The Raspberry Pi also has a large and active group of users and developers who work on it. This dynamic group ensures lots of online resources, forums, and tutorials, making it easier to find support, guidance, and help with problems. Linux-based operating systems like Raspbian are available for the Raspberry Pi. This allows to load and run different programmes and tools to capture, decode, and process satellite signals. The Raspberry Pi is a great choice for this project because it is cheap, minor, uses little power, can be expanded, has community support, and can run different software.



### 3.5 Enabling Sustainable Development through Component Selection

In pursuing sustainable development, it is crucial to integrate environmental, social, and economic considerations to meet the needs of the present while safeguarding future generations. Regarding weather information systems, the combination of RTL-SDR (Software-Defined Radio), Raspberry Pi, and cross-dipole antenna offers a powerful and sustainable solution. It details how these parts work together to develop an SDR-based weather information system that receives signals from NOAA (National Oceanic and Atmospheric Administration) satellites.

RTL-SDR is the base of this system. It is an inexpensive and flexible piece of hardware that can receive and process a wide range of radio bands. With its accessibility and affordability, RTL-SDR enables a broader reach for weather information systems, particularly in resource-constrained environments. Its low cost empowers communities with valuable weather data, facilitating informed agricultural decision-making, disaster preparedness, and climate monitoring. Also, because RTL-SDR is software-defined, it can be customized and adapted to meet the requirements of different areas and communities. It helps build local resilience and promotes sustainable practices.

The Raspberry Pi, a compact and low-power single-board computer, complements RTL-SDR in developing weather information systems. Its energy-efficient design reduces environmental impact, aligning with sustainable development goals. Additionally, Raspberry Pi's data processing and storage capability allows for on-device handling of weather data received from RTL-SDR. This local processing reduces the reliance on extensive cloud infrastructure, promoting more efficient and sustainable data management practices. Furthermore, the Raspberry Pi community's collaborative and open-source nature fosters innovation and knowledge sharing, driving the continuous improvement of weather information systems for sustainable development worldwide.

A key component in receiving satellite signals is the cross-dipole antenna, renowned for its effectiveness in capturing data from NOAA weather satellites. The unique design of the cross-dipole antenna provides excellent coverage in all directions and circular polarization, making it an ideal choice for weather data reception. Using cross-dipole antennas, sustainable development initiatives access vital weather information transmitted by NOAA satellites. This real-time data is pivotal in sustainable agriculture, disaster management, and climate research. With up-to-date weather information, communities can make informed decisions, enhance resilience, and improve overall well-being. Additionally, cross-dipole antennas are durable and require fewer replacements, constructed using robust materials like PVC. This characteristic reduces environmental impact while providing reliable and long-lasting performance.

In conclusion, the RTL-SDR, Raspberry Pi, and cross-dipole antenna combination offers a sustainable approach to developing an SDR-based weather information system. These components bring affordability, adaptability, and efficiency to weather data solutions, empowering communities with the knowledge needed for sustainable decision-making. Embracing this technology enables sustainable development efforts to make informed choices, drive resilience, and ensure a better future for future generations.



## 3.6 Software Specification

In this project, the way the software is specified is done orderly. First, a Linux-based operating system like Raspbian is chosen because it works well with Raspberry Pi and has an interface that is easy to use. The operating system gives the necessary software a safe place to run. Next, the needed software programmed are put in place. One crucial piece of software is SatDump, which works with the RTL-SDR dongle to record radio signals from NOAA weather satellites and figure out what they mean. WXtoImg is another essential tool.

It takes the received signals and turns them into high-resolution weather satellite images. It can also be used to improve and handle images. Also, the project may require the installation of specific libraries and utilities for signal processing, data analysis, and picture manipulation. These extra parts improve the software and improve how the satellite data is received, decoded, and shown. By using this method, the software requirements for this project will be successfully met. This means NOAA weather satellite signals can be captured, decoded, and processed efficiently.

### 3.6.1 Raspbian


Figure 3.6 : User Interface of Rapsbian

Raspbian was chosen for this project's operating system for several good reasons. Raspbian is first and foremost made for and optimised for Raspberry Pi devices. This makes it easy to use and makes sure it works well. Its interface makes it easy for people of all skill levels, even newbies, to use. Users can easily set up and set up their Raspberry Pi for the project because it has a desktop experience that they are used to. Raspbian also has a large software repository made just for the Raspberry Pi. It comes with many software packages, libraries, and tools that meet the project's needs, such as capturing, decoding, and processing radio signals. Raspbian is also known for being stable and reliable. It goes through much testing and development to ensure it works without problems. This is important for projects that may need to run for a long time. The active community around Raspbian has a lot of online tools, forums, and tutorials that users can use to get help, solve problems, and share what they know. Raspbian supports programming languages like Scratch and Python, which fits well with the Raspberry Pi. Considering all these things, Raspbian is the best choice for this project because it is compatible, easy to use, has a lot of software support, is stable, and has community support.

### 3.6.2 SatDump

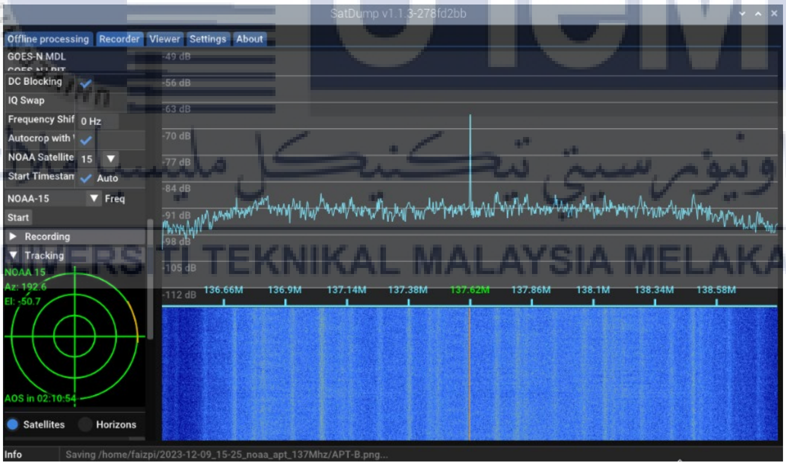



Figure 3.7 : User interface of Satdump

SatDump is currently serving as a general-purpose satellite data processing software. It provides all the necessary stages to transition from the satellite transmission to actual products. SatDump is being used by users of RTL-SDRs and other software-defined radios for decoding images from a wide array of weather imaging satellites including GOES, GK-

2A, NOAA APT, NOAA HRPT, FengYun, Electro-L, and Meteor M2 LRPT + HRPT, among many others.

The software is enabling users to download, process, and visualize satellite data from various sources. It allows the creation of automated stations, the use of projections, and access to the latest updates and features of the software. It is being regularly updated with new features and bug fixes, with the latest release being 1.1.3 as of June 29, 2023.

Overall, SatDump is serving as a robust tool for anyone interested in satellite data processing, offering a wide range of features and supporting a variety of satellites.

### 3.6.3 WxtoImg



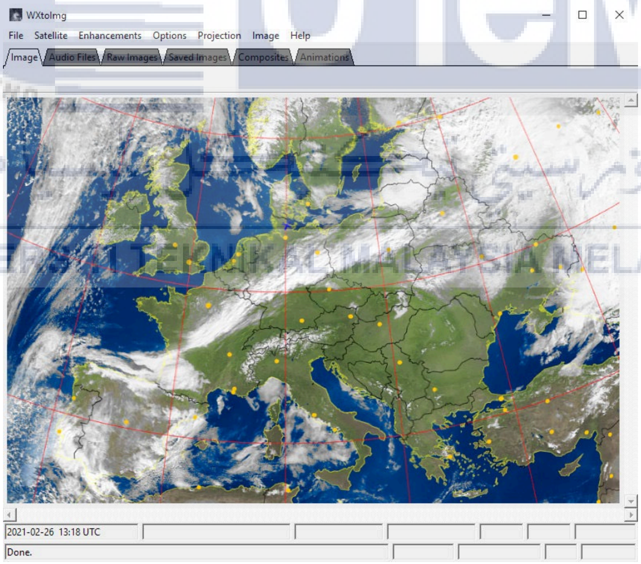



Figure 3.8 : User interface of WxtoImg

For many reasons, this project prefers WXtoImg. First, WXtoImg is designed to analyse weather satellite signals and generate high-resolution images, making it perfect for weather data analysis. Its image processing capabilities improve satellite photos and enable reliable weather pattern interpretation. WXtoImg works with various satellite reception systems, including the project's RTL-SDR dongles, for easy integration and efficient radio signal processing. The software's straightforward controls and displays make configuration easy for all technical levels. WXtoImg lets users modify weather satellite photos using contrast correction and histogram equalisation. Image overlay and map integration allow users to add data to pictures for better analysis. Drives WXtoImg development, upgrades, and support. Comprehensive documentation and resources help users start, debug, and explore advanced features. WXtoImg, with its powerful image processing, interoperability, user-friendliness, advanced functionality, and strong community support, is a good choice for the project.

## 3.7 Block Diagram of the project

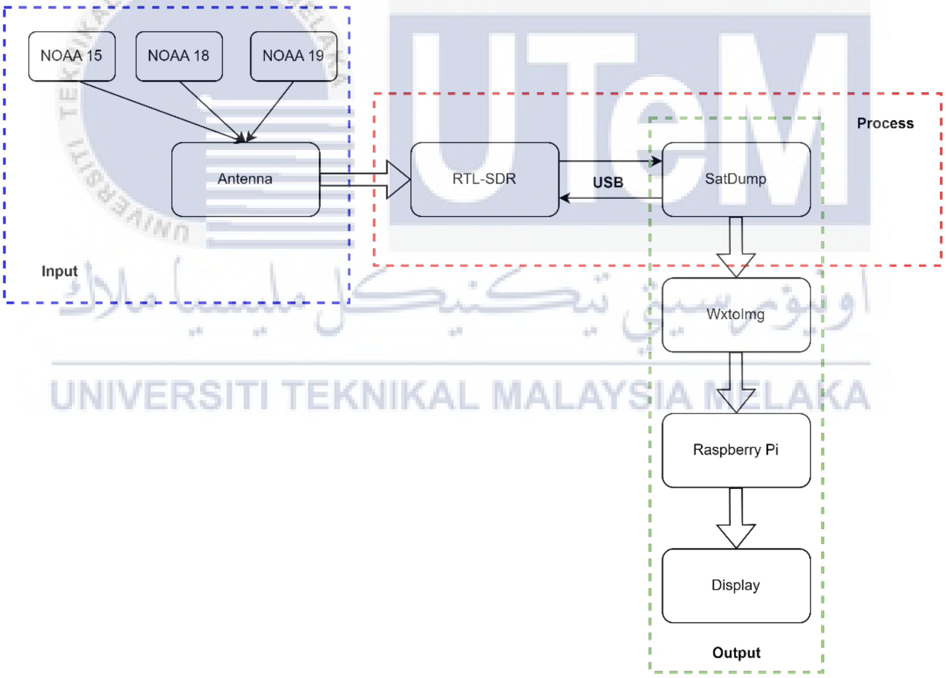



Figure 3.9 : Block Diagram of Development of an SDR-based Ground Station System for Receiving Signals from NOAA Satellites

This block diagram shows how the project's data and processes move. The radio receiver is the RTL-SDR dongle, which picks up the signal from NOAA satellite using QFH antenna. The RTL-SDR programme talks to the dongle, which lets the Raspberry Pi get radio signals and decode it. The Raspberry Pi is the main computer, which runs different pieces of software, including WXtoImg. WXtoImg software takes the received signals and does picture processing and decoding to make high-resolution satellite images of the weather. The results of WXtoImg are then shown on a monitor or screen so they can be seen and analysed.

## 3.8 Summary of Chapter 3

This chapter represents the proposed methodology to enhance the acquisition and analysis of weather data. NOAA satellites are known for their extensive coverage and high-quality data, making them a valuable source of weather observations. This project focuses on designing a cost-effective and customizable solution by utilizing SDR technology instead of traditional specialized hardware and proprietary software. The aim is to establish a reliable and efficient system capable of capturing, demodulating, and decoding the data transmitted by NOAA satellites, including meteorological information like cloud cover, sea surface temperatures and atmospheric profiles. The proposed methodology involves designing and configuring the necessary hardware and software components, signal acquisition and demodulation, decoding of received data, and the development of a user-friendly interface for data visualization and analysis. Overall, this project aims to create a comprehensive weather monitoring system using SDR technology and open-source software, enabling users to access accurate weather data for informed decision-making.

# CHAPTER 4

# RESULT AND DISCUSSIONS

## 4.1 Introduction

One of the objectives of this project was to design and construct a ground station capable of automatically capturing NOAA satellite images without the need for manual intervention. The goal was to create a system that could receive and save the images transmitted by the satellites during each pass, enabling users to access and download them locally or remotely. By automating the image capture process, the ground station provided a convenient and efficient solution for receiving NOAA satellite images. Users can rely on the ground station to continuously capture images without the need for constant monitoring. This feature enabled them to build a comprehensive archive of satellite imagery, which could be further analyzed, compared, and utilized for various purposes.



## 4.2 Configuration and Setup

### 4.2.1 Selection for Cross-Dipole Antenna

The project's hardware assembly began with the careful selection of a cross-dipole antenna. This choice was pivotal in ensuring optimal signal reception from NOAA weather satellites. The cross-dipole antenna was preferred for its unique design, which offers improved gain and radiation patterns for VHF signals. Its dual-element configuration is known to enhance signal capture, making it well-suited for receiving satellite signals in the VHF frequency range.

The connection scheme described involves the arrangement of coaxial cables and their connections between the primary coaxial cable and individual dipole antennas. This configuration is crucial for the efficient reception of satellite signals. In Figure 4.1, it observe the connection layout where each dipole antenna corresponds to a specific port on the main coaxial cable. This connection system is carefully labeled, denoting that each dipole antenna (S1, S2, S3, and S4) is connected to its respective port (S1, S2, S3, and S4) on the main coaxial cable.

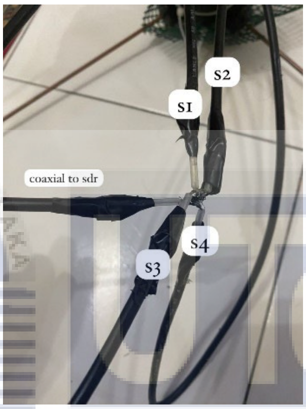



Figure 4.1 : Connection Between Antenna and Main Coaxial to SDR

Figure 4.2 provides a detailed depiction of the connections between the dipole antennas and the main coaxial cable. This visual representation aids in understanding how each dipole antenna is integrated into the system, ensuring that the signals received by each antenna are efficiently transmitted through the main coaxial cable for further processing by the SDR (Software-Defined Radio) device. The clarity and organization of this connection scheme are vital for maintaining signal integrity and optimizing the reception capabilities of the entire system.

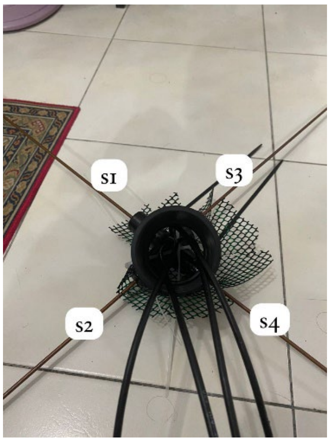



Figure 4.2 : Connection Between Dipole Antenna and Main Coaxial

### 4.2.2 Antenna Testing with SatDump Application

Before integrating the cross-dipole antenna into the complete setup with the Raspberry Pi and the raspberry-noaa-v2 setup, a thorough testing phase was conducted. This involved utilizing the SatDump application, a tool designed for capturing and analyzing satellite signals. The purpose of this testing was for two thing which is to verify the performance and functionality of the antenna in isolation and second to gain insights into its capabilities.



During the testing phase with SatDump, various aspects of the antenna performance were assessed. Signal reception quality, signal strength, and the ability to track satellite passes were closely monitored. This evaluation allowed us to gauge the antenna's effectiveness in capturing NOAA satellite signals under real-world conditions. Any potential challenges or limitations of the antenna were identified and documented during this phase.

Figure 4.3 : Testing Phase Using SatDump

In Figure 4.4, a detailed configuration for signal reception is presented, outlining key parameters essential for optimizing the reception of NOAA weather satellite signals. The gain setting is prominently specified as 40, indicating that the incoming signals, transmitted by the NOAA-18 satellite, undergo amplification by a gain is 40 dB. This choice of gain strikes a delicate balance, effectively boosting the signal's strength while keeping noise to a minimum.



Furthermore, the specific frequency setting of 137.912 MHz corresponds precisely to NOAA-18, ensuring that the system is finely tuned to receive signals from this particular satellite. This precise frequency alignment is pivotal in capturing NOAA-18's data accurately.

The signal-to-noise ratio (SNR) is denoted at 8 dB. This SNR value signifies that the strength of the received NOAA satellite signal surpasses the background noise level by 8 dB. A higher SNR is indicative of a cleaner and more dependable signal, thereby enhancing the quality and reliability of the received meteorological data. In summary, the configuration settings depicted in Figure 4.4 exemplify a meticulous approach to signal reception, enabling the system to capture and process NOAA-18 signals effectively, ultimately contributing to the acquisition of precise meteorological information.

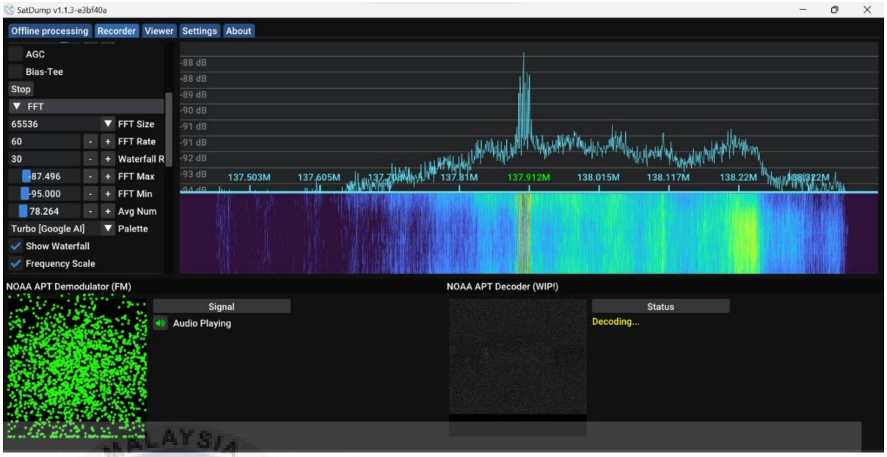



Figure 4.4 : The Signal Receive When NOAA 19 Satellite Through the Antenna

To enhance the signal-to-noise ratio, several factors come into play, with antenna placement being a significant contributor. As depicted in Figure 4.5, the strategic placement of the antenna in an open field setting was implemented. This placement decision proved pivotal, as illustrated in Figure 4.6, where the resulting output demonstrated a notable increase in the signal-to-noise ratio, elevating it from 8 dB to an impressive 13 dB. The shift in antenna location to an open field environment significantly improved signal reception, reducing the impact of noise and interference. This optimization underscores the importance of thoughtful antenna placement in achieving superior signal quality and overall system performance.

Figure 4.5 : Cross-Dipole Antenna on the Field

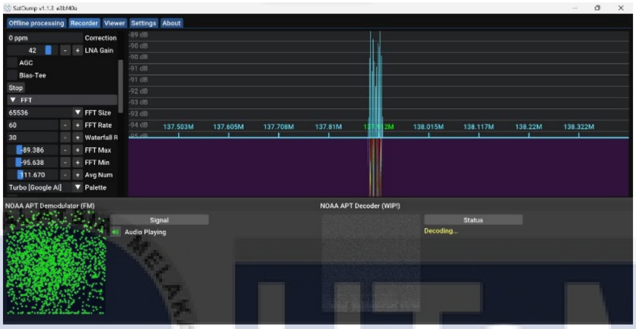



Figure 4.6 : The Signal of NOAA 19 on the Field



### 4.2.3 Raspberry Pi Model Selection

Figure 4.7 showcases the central component of our project, wherein the Raspberry Pi 4 Model B interfaces seamlessly with the RTL-SDR (Software-Defined Radio) device. This configuration was meticulously chosen for its pivotal role in achieving efficient signal reception and processing. The Raspberry Pi 4 Model B, recognized for its substantial computational prowess, was the optimal choice for managing the complexities of NOAA weather satellite signals. Its compatibility with the RTL-SDR device and the robust community support surrounding it streamlined our project's implementation, simplifying hardware integration and software compatibility. This figure encapsulates the heart of our setup, emphasizing the synergy between the Raspberry Pi 4 Model B and the RTL-SDR, which underpins the success of our satellite signal reception system.

Figure 4.7 : RTL-SDR Connected with Raspberry Pi 4

### 4.2.4 Software Installation and Enviroment Setup

The software installation and environment setup were pivotal stages in configuring our system for NOAA weather satellite signal reception. We initiated this comprehensive process by carefully selecting the Raspberry Pi 32-bit Lite OS as the operating system for our Raspberry Pi 4 Model B, emphasizing its resource efficiency to optimize performance. Subsequently, we installed the "raspberry-noaa-v2" software package, sourced from its GitHub repository. Following meticulous installation steps, including resolving dependencies and configuring the software to suit our project's unique requirements, we tuned it to precise geographical coordinates for accurate satellite pass predictions.

Additionally, we fine-tuned frequency settings to match NOAA satellite frequencies and programmed the software for pass scheduling. Image processing configurations were also meticulously adjusted to enhance image quality, encompassing contrast, brightness, and filtering. Rigorous testing and calibration procedures were conducted, and robust error handling and monitoring mechanisms were put in place. Comprehensive documentation and regular backups were ensured to maintain system integrity. As seen in Figure 4.8, the successful installation and configuration of the "raspberry-noaa-v2" software within our

Raspberry Pi 4 Model B solidified our system's readiness to receive and process NOAA weather satellite signals with precision and efficiency.

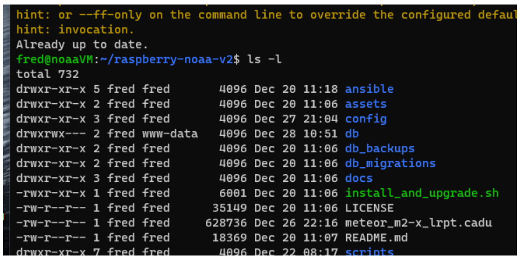



Figure 4.8 : "Raspberry-NOAA-v2" Was Succesfully Plug in on 32 bit OS Lite

## 4.3 Interface of the System

The Raspberry NOAA V2 system, hosted on GitHub, is a comprehensive tool designed for capturing satellite imagery using a Raspberry Pi or a regular 32-bit computer running a Debian Bullseye-based distro. The interface of the system is well-structured and user-friendly. It includes a clear directory structure with folders such as ansible, assets, config, db, db_backups, db_migrations, docs, scripts, software, templates, tmp, and webpanel, each serving a specific purpose. A key component of the interface is the web panel, which provides a user-friendly way to interact with the system and view the captured satellite imagery. The system also uses a "settings.yml" file for configuration, allowing users to customize the system according to their needs. Various scripts are used for different tasks, enhancing the functionality of the system. Overall, the interface of the Raspberry NOAA V2 system, as shown in Figure 4.9, Figure 4.10 and Figure 4.11 is designed for ease of use, flexibility, and extensibility, making it a robust and versatile tool for capturing satellite imagery.

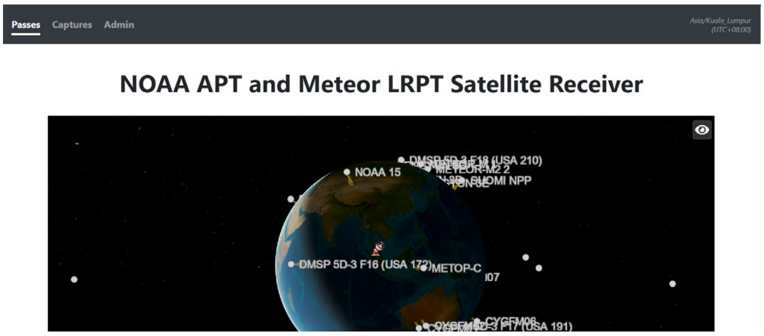



Figure 4.9: Automatic Ground Station Interface

| Status | Satellite | Pass Start | Pass End | Max Elevation | Azimuth | Direction |
|---|---|---|---|---|---|---|
| | | | 11/01/2024 | | | |
| ✓ | NOAA 18 | 00:12:33 | 00:27:41 | 36° W | 184° | Northbound |
| ✓ | NOAA 15 | 08:42:56 | 08:57:55 | 63° W | 6° | Southbound |
| ✓ | NOAA 19 | 09:33:36 | 09:48:52 | 39° E | 27° | Southbound |
| ✓ | NOAA 18 | 11:14:51 | 11:30:04 | 44° E | 25° | Southbound |
| ✕ | NOAA 19 | 22:18:56 | 22:34:21 | 57° W | 175° | Northbound |
| | | | 12/01/2024 | | | |
| ⌛ | NOAA 18 | 00:00:00 | 00:15:32 | 51° W | 178° | Northbound |
| ⌛ | NOAA 15 | 08:17:23 | 08:32:31 | 64° E | 18° | Southbound |
| ⌛ | NOAA 18 | 11:02:43 | 11:17:26 | 31° E | 31° | Southbound |
| ⌛ | NOAA 15 | 20:55:55 | 21:10:34 | 40° W | 182° | Northbound |
| ⌛ | NOAA 19 | 22:06:41 | 22:22:15 | 79° W | 170° | Northbound |
| ⌛ | NOAA 18 | 23:47:32 | 00:03:24 | 70° W | 172° | Northbound |
| | | | 13/01/2024 | | | |
| ⌛ | NOAA 15 | 20:30:08 | 20:45:16 | 83° W | 169° | Northbound |

Figure 4.10 : The Schedule of NOAA Satellite


Figure 4.11 : List of all Satellite Passes Recorded

### 4.4 Result and Analysis

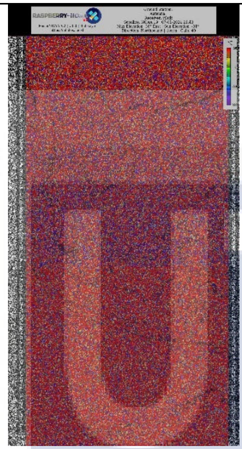
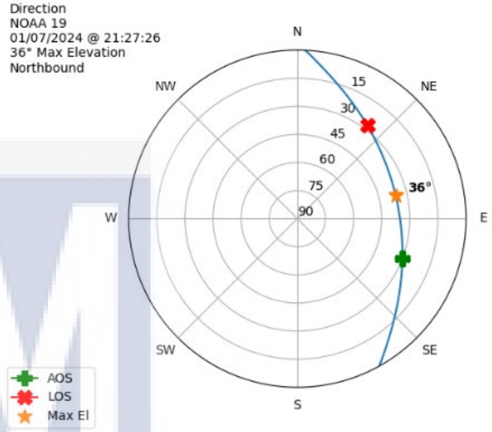
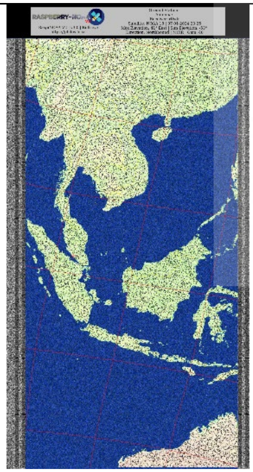
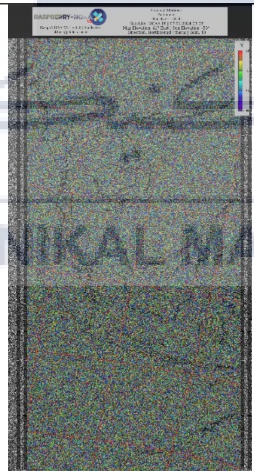
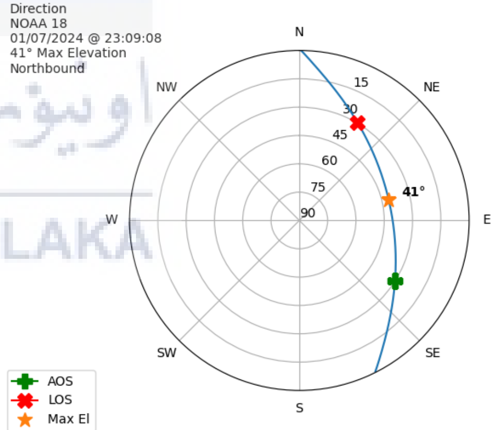
A cross-dipole antenna, constructed from aluminium tubes, is positioned on the terrace for the purpose of signal reception. The antenna gain is crucial for the successful reception of satellite signals. Once the antenna probe is connected to the RTL-SDR dongle and the correct frequency is chosen in SatDump, a spike frequency diagram of the received signal is generated. This allows for the analysis of a signal's parameters. The system also utilizes SatDump for further processing and analysis of the received signals.

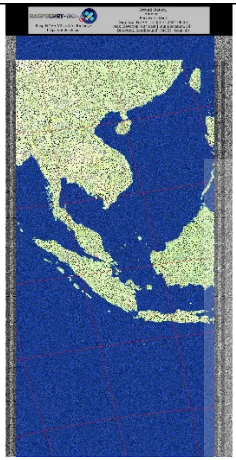
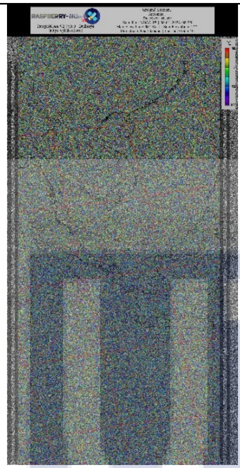
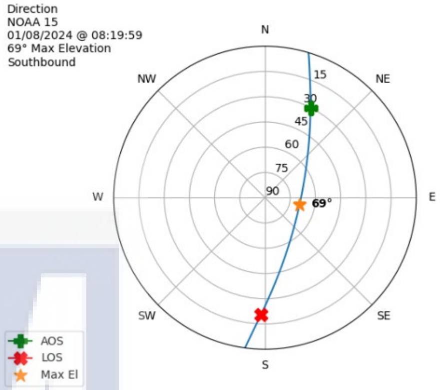
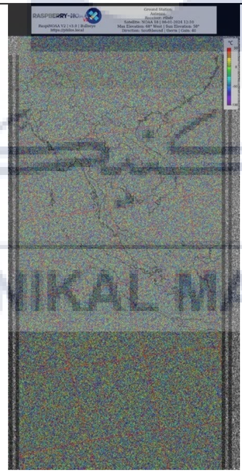
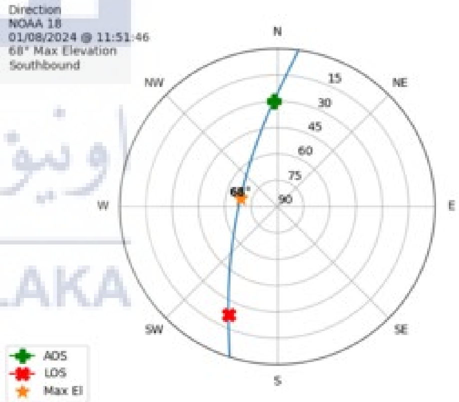
Referring to the provided tables, Table 4.1 documents Record of NOAA Satellite Passes. Meanwhile, Table 4.2 presents the outcomes derived from the recorded NOAA satellite passes. These recorded passes occurred between January 7th and January 10th, encompassing observations made at three distinct locations: Taman Tasik Utama, Kampus Teknologi Utama, and Ayer Keroh in Melaka. The enhancements applied to the observations include Map Color Infrared (MCIR), Thermal data, and information regarding polar directions.

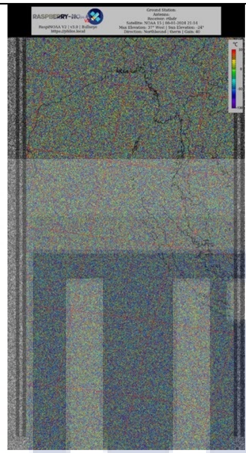
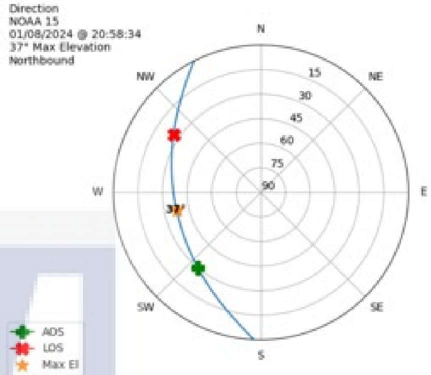
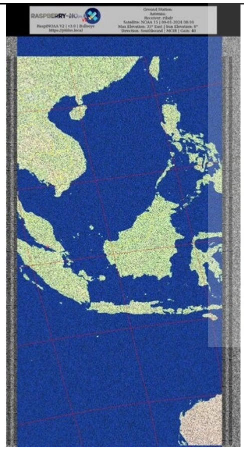
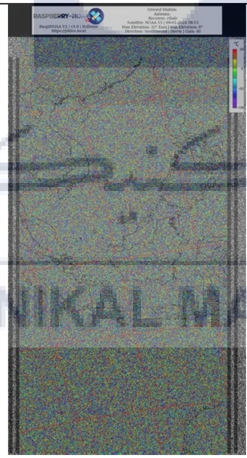
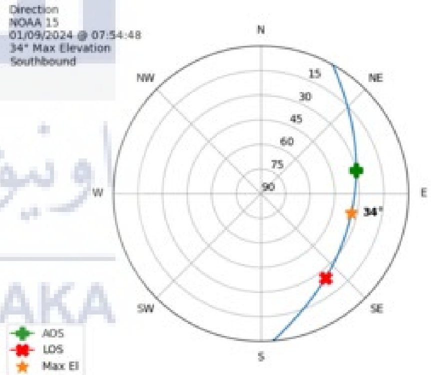
Table 4.1: Record of NOAA Satellite Passes for January 2024

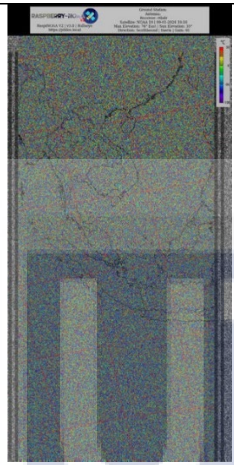
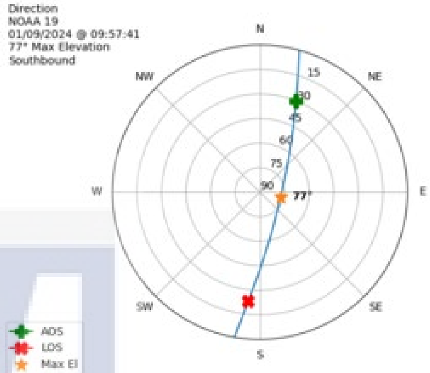
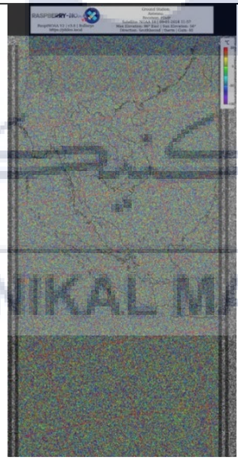
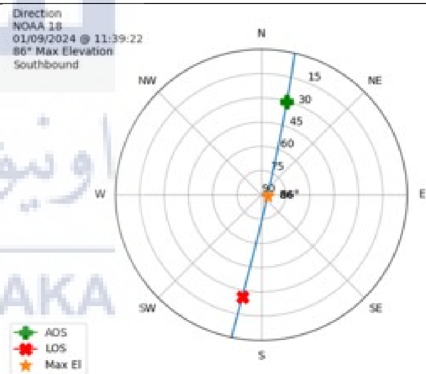
| No | NOAA Satellite | Date & Time | Elevation | Azimuth | Direction |
|---|---|---|---|---|---|
| 1 | NOAA 19 | 07/01/2024 21:27:26 | 36° E | 151° | Northbound |
| 2 | NOAA 18 | 07/01/2024 23:09:08 | 41° E | 153° | Northbound |
| 3 | NOAA 15 | 08/01/2024 08:19:59 | 68° E | 17° | Southbound |
| 4 | NOAA 18 | 08/01/2024 11:51:46 | 68° W | 8° | Southbound |
| 5 | NOAA 15 | 08/01/2024 20:58:34 | 37° W | 183° | Northbound |
| 6 | NOAA 15 | 09/01/2024 07:54:48 | 33° E | 29° | Southbound |
| 7 | NOAA 19 | 09/01/2024 09:57:41 | 76° E | 16° | Southbound |
| 8 | NOAA 18 | 09/01/2024 11:39:22 | 86° E | 13° | Southbound |
| 9 | NOAA 15 | 09/01/2024 20:32:45 | 76° W | 170° | Northbound |
| 10 | NOAA 19 | 10/01/2024 09:45:35 | 55° E | 21° | Southbound |

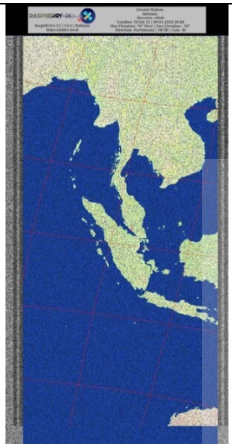
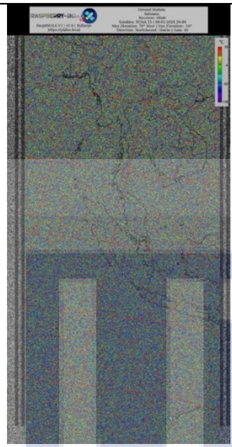
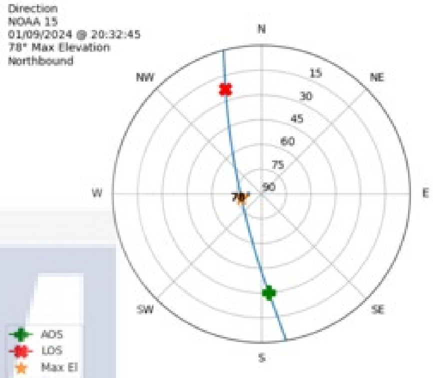
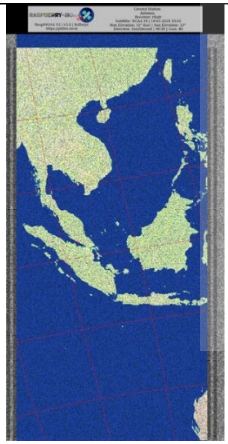
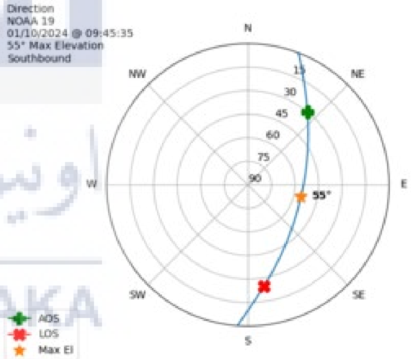
Table 4.2: Result from Record of NOAA Satellite Passes for January 2024

| No | Enhancement | | |
|---|---|---|---|
| | MCIR | Thermal | Polar-Direction |
| 1 |  |  |  |
| 2 |  |  |  |

| No | Enhancement | | |
|---|---|---|---|
| | MCIR | Thermal | Polar-Direction |
| 3 |  |  |  |
| 4 |  |  |  |

<table>
<tr><th rowspan="2">No</th><th colspan="3">Enhancement</th></tr>
<tr><th>MCIR</th><th>Thermal</th><th>Polar-Direction</th></tr>
<tr><td>5</td><td></td><td></td><td>
</td></tr>
<tr><td>6</td><td></td><td></td><td>
</td></tr>
</table>

| No | Enhancement | | |
|---|---|---|---|
| | MCIR | Thermal | Polar-Direction |
| 7 |  |  |  |
| 8 |  |  |  |

| No | Enhancement | | |
|---|---|---|---|
| | MCIR | Thermal | Polar-Direction |
| 9 |  |  |  |
| 10 |  |  |  |

In pictures 1 to 3, refer to table 4.1 and table 4.2, the ground station was located at Taman Tasik Utama, as indicated in figure 4.15. In picture 1, we captured NOAA 19 on January 7, 2024, at 21:27:26 with an elevation of 36 degrees to the east, an azimuth of 151 degrees, and the antenna facing north. Unfortunately, the image quality was not optimal when applying MCIR and thermal enhancements. Picture 2 shows NOAA 18 on the same day at 23:09:08, with an elevation of 41 degrees to the east, an azimuth of 153 degrees, and the antenna also facing north. The image was slightly clearer but not as clear as desired. In picture 3, we captured NOAA 15 on January 8, 2024, at 08:19:59, with an elevation of 68 degrees to the east, an azimuth of 17 degrees, and the antenna facing south. The image quality resembled that of picture 2. For all these pictures, a gain of approximately 30 to 34 dB was used to improve the signal-to-noise ratio (SNR).

Moving on to pictures 4 to 6, the ground station was positioned on the rooftop of Kampus Teknologi UTEM, as seen in figure 4.16. Picture 4 captured NOAA 18 on January 8, 2024, at 11:51:46, with an elevation of approximately 68 degrees to the west, an azimuth of 8 degrees, and the antenna facing south. The image was very clear when MCIR and thermal enhancements were applied. Picture 5 also exhibited a clear image, capturing NOAA 15 on January 8, 2024, at 20:58:34, with an elevation of 37 degrees to the west, an azimuth of 183 degrees, and the antenna facing north. Picture 6 captured NOAA 15 on January 9, 2024, at 7:54:48, with an elevation of 33 degrees to the east, an azimuth of 29 degrees, and the antenna facing south. A gain of 35 to 38 dB was used for these pictures to achieve a better SNR.

Finally, pictures 7 to 10 were taken at the Ayer Keroh location. In picture 7, NOAA 19 was captured on January 9, 2024, at 9:57:41, with an elevation of 76 degrees to the east, an azimuth of 16 degrees, and the antenna facing south. Although slightly clearer with MCIR, the image quality improved significantly when thermal enhancement was applied. Picture 8 featured NOAA 18 on the same day but at 11:39:22, with an elevation of 86 degrees to the east, an azimuth of 13 degrees, and the antenna facing south. Picture 9 captured NOAA 15 on January 9, 2024, at 20:32:45, with an elevation of 76 degrees to the west, an azimuth of 170 degrees, and the antenna facing north. Lastly, picture 10 showed NOAA 19 on January 10, 2024, at 9:45:35, with an elevation of 55 degrees to the east, an azimuth of 21 degrees, and the antenna facing south. A gain of 39 to 40 dB was applied at this location to optimize the SNR.

These observations provide insights into the varying image quality achieved at different locations and times, demonstrating the impact of antenna positioning and signal gain on signal reception and image clarity.



Utilizing MCIR enhancement, a color image is generated that closely mirrors the real-time view from the satellite. A formation of clouds is being observed over the southern part of Malaysia as shown in Figure 4.12, specifically surrounding the area of Ayer Keroh, Melaka.

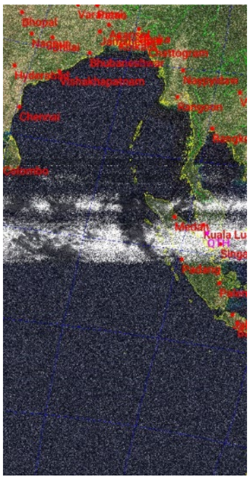


Figure 4.12 : MCIR Enhancement with location applied to raw image

The thermal images depicted in Figure 4.13 showcased temperature variations across the Ayer Keroh region in Melaka. These images were generated using a frequency of 137.620 GHz. Furthermore, the thermal image displayed was received during a NOAA-15 satellite pass, as illustrated in Figure 4.14. This pass occurred on the 8th of January 2024 at 20:58:34, with the satellite reaching a maximum elevation of 37° while heading northbound.



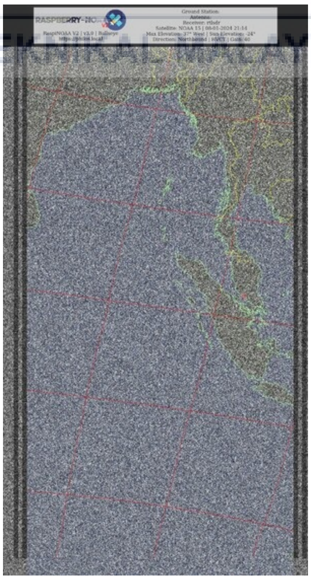


Figure 4.13 : NOAA Colour IR Contrast Enhancement Option


Figure 4.14 : Satellite NOAA-15 Heading Northbound at Ayer Keroh, Melaka

The thermal images depicted in Figure 4.13 showcased temperature variations across the Ayer Keroh region in Melaka. These images were generated using a frequency of 137.620 GHz. Furthermore, the thermal image displayed was received during a NOAA-15 satellite pass, as illustrated in Figure 4.14. This pass occurred on the 8th of January 2024 at 20:58:34, with the satellite reaching a maximum elevation of 37° while heading northbound.



Figure 4.15 : The Portable Ground Station at Taman Tasik Utama, Ayer Keroh, Melaka

Figure 4.16 : The Portable Ground Station at Kampus Teknologi UTeM

Figure 4.17 : The Portable Ground Station at Ayer Keroh, Melaka



The implementation of the portable ground station had a total cost of 500 Malaysian Ringgit, proving its economy compared to other ground stations. Its small size, as seen in Figure 4.15, facilitated installation.

The results obtained with this system provided us with an average of three satellite images per day automatically, including those from NOAA 15, NOAA 18, and NOAA 19. The system demonstrated its ability to emulate a ground station, and it did not present difficulties for users in operating the equipment. The altitude at which the ground station was situated played a crucial role in signal reception, contributing to the system's effectiveness in receiving satellite images.

## 4.5 Experimenting with Low Noise Amplifier (LNA)

The RTL-SDR can currently receive frequencies ranging from 22 to 2200 MHz. The Low Noise Amplifier (LNA) H14-03, as shown in Figure 4.18, is capable of amplifying the signal by approximately 84 dB, as demonstrated in Figure 4.19. However, it's important to note that the bandwidth is limited to 6 kHz and cannot be further expanded as it's already at its maximum. In terms of results, it consistently produces improved output images, as evidenced by Figure 4.20.

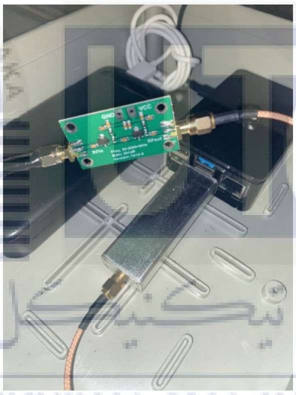




Figure 4.18 : Low Noise Amplifier (LNA) Connected With RTL-SDR

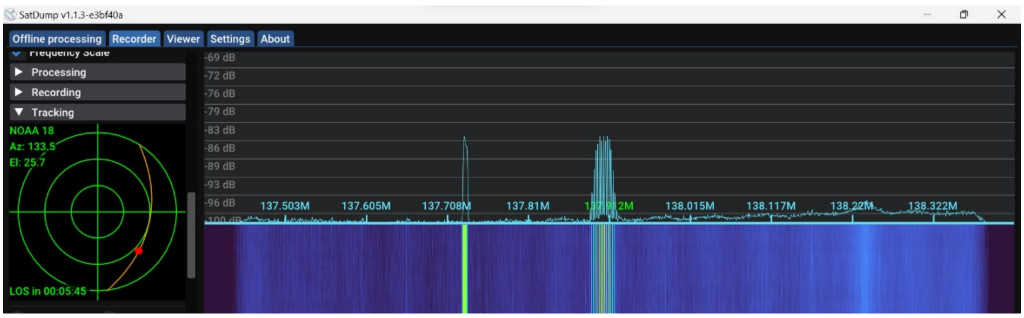



Figure 4.19 : Bandwith from Low Noise Amplifier (LNA)

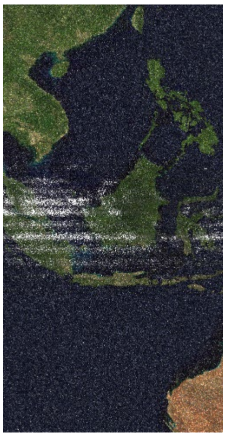


Figure 4.20 : Image that generated from LNA connected with RTL-SDR

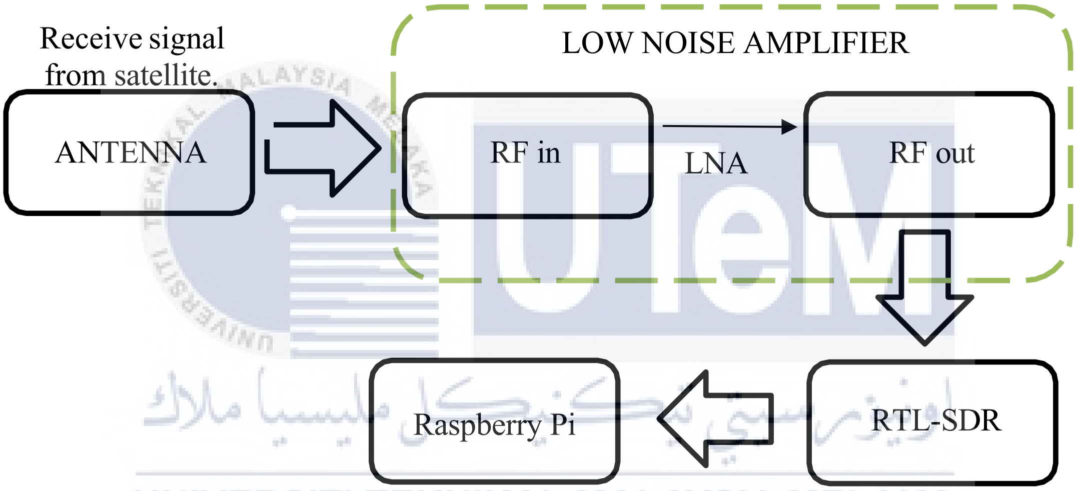





Figure 4.21 : Block Diagram for Low Noise Amplifier (LNA)

### 4.6 Discussion

The primary objective of this project is to introduce a cost-effective and portable ground station system for the automatic acquisition of satellite images. The system aims to engage in the analysis of local climatic trends, with a particular focus on addressing climate change concerns.

One notable advantage of this portable ground station is its autonomy, eliminating the need for users to wait for satellite passes over their location. This autonomy allows for the continuous reception of satellite images, making it a valuable tool for both real-time image processing and data collection. When not actively running specific applications for receiving and decoding satellite images, the system can be employed for other tasks, enhancing its versatility.

To further the educational objectives of this project, future endeavors will focus on promoting climate analysis and forecasting studies among students, particularly in academic institutions. By leveraging the capabilities of this portable ground station, students can gain practical experience in working with NOAA polar orbit and geostationary satellite systems. Additionally, the affordability and accessibility of this system make it an ideal choice for training exercises and laboratory experiments in institutions, including those in underdeveloped regions where resources are limited.

In upcoming developments, we plan to incorporate an orientation system to facilitate the reception of high-resolution images (HRPT). This enhancement will enable even more reliable image processing and expand the system's capabilities, ensuring its continued relevance and utility in the field of climate analysis and satellite image acquisition.

## 4.7 Summary of Chapter 4

This chapter presents the ongoing development of the project, with a strong emphasis on achieving a fully functional system. This comprehensive chapter currently focuses on signal reception, encompassing hardware, software, and system interface components. It provides a detailed overview of the current state of the project, showcasing ongoing experimental activities that are currently resulting in the generation of high-quality images from various locations.

A notable accomplishment in the current phase is the significant improvement in the signal-to-noise ratio, which highlights the continuous refinement and optimization of the reception system. This chapter underscores the iterative nature of the project's development, where hardware and software components are currently working seamlessly to ensure successful signal reception and the production of high-quality images. It also reflects the dynamic and evolving nature of the project as it is currently advancing towards its objectives.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

This project aims to create an ground station system utilizing the NOAA Satellite Data Retriever system with RTL-SDR 2832U. The project is currently a success in terms of developing a portable weather monitoring solution through the integration of specific technologies to enhance the monitoring device. Furthermore, the project has effectively transformed into a portable device with diverse measurement capabilities.

Upon analyzing the results, we can confidently conclude that our objectives are currently being met. The system developed in this project surpasses the utility of conventional methods. Notable improvements include the system's ability to gather information from remote and secluded locations, as well as the device's enhanced portability compared to existing alternatives. Comparative analysis with contemporary solutions consistently yields positive outcomes.

## 5.2 Future work

These devices have the potential for future modifications to enhance their design for improved user comfort. Furthermore, the images obtained through these devices can serve as valuable resources for in-depth research and more accurate weather forecasting, ultimately contributing to the advancement of a nation. Additionally, with the inclusion of a suitable antenna, the same project can extend its capabilities to receive signals from geostationary satellites like GOES-16. These signals can then be decoded to generate images with significantly broader coverage, spanning approximately half of the globe.

Moreover, this Software-Defined Radio (SDR) can also be utilized for monitoring Ham (amateur radio) bands when paired with an appropriate antenna. There are prospects for transforming the traditional method of receiving weather data into a more portable device. This would enable the device to receive information at any time and from any location, provided it is equipped with the necessary components. Unlike the current system, which is limited to receiving signals in specific locations, this project has the potential to facilitate weather information retrieval from virtually anywhere.

## 5.3 Project Potential

Weather monitoring services play a pivotal role across various sectors, encompassing agriculture, transportation, aviation, disaster management, and public safety. The provision of precise and timely weather information is instrumental in enabling informed decision-making, proactive preparation for severe weather events, and the mitigation of potential risks. However, in numerous regions, particularly in remote or rural areas, reliable access to comprehensive weather data faces challenges stemming from infrastructure limitations and cost constraints.

The proposed project endeavors to tackle these challenges through the creation of a weather information system, leveraging NOAA satellite data retrieval technology in conjunction with RTL-SDR (Software Defined Radio). This cost-effective solution empowers the reception of satellite signals and the generation of weather imagery, thereby facilitating real-time monitoring of weather patterns and conditions.



Furthermore, the system serves as a valuable tool for the study of weather patterns and their environmental repercussions. Climate change research and environmental monitoring benefit significantly from the availability of precise weather data. By affording researchers the capability to access real-time weather insights, this prototype contributes to a deeper comprehension of climate dynamics and bolsters endeavors to address and adapt to environmental shifts.

The system's affordability renders it particularly well-suited for deployment in resource-constrained or signal-challenged areas, including rural regions. By delivering a portable and accessible weather monitoring solution, the project ensures that individuals and organizations in such locales gain access to dependable and timely weather information. Consequently, this facilitates the development of effective response strategies, enhances agricultural practices, improves transportation safety, and augments overall disaster preparedness.

In conclusion, the development of a weather information system utilizing NOAA satellite data retrieval technology in tandem with RTL-SDR holds immense promise for the realm of weather monitoring services. The project's potential lies in its capacity to furnish real-time weather data, issue early warnings, support climate change research, and provide cost-effective solutions readily embraced by educational institutions, weather enthusiasts, and amateur radio operators. In mitigating the environmental impact associated with weather-related disasters and accidents, this initiative plays a vital role in building more resilient and sustainable communities.

# REFERENCES


[1] A. : David and P. Serrano, "TRABAJO DE FIN DE GRADO TÍTULO DEL TFG: Estación de tierra autónoma para la recepción de imágenes de satélites NOAA TITULACIÓN: Ingeniería de Sistemas Aeroespaciales."

[2] G. K. Davis, "History of the NOAA satellite program," *J Appl Remote Sens*, vol. 1, no. 1, p. 12504, 2007, doi: 10.1117/1.2642347.

[3] A. Kumar, P. Y. Kalyan Reddy, C. Yadav Np, A. T. Kumar Joel, and C. N. Yadav, "SDR Based Ground Station for Image Reception from Weather Satellites SDR based ground station for image reception from weather satellites View project Establishment of Ground Station for two-way Communication via Geostationary Amateur Radio Satellite View project SDR Based Ground Station for Image Reception from Weather Satellites," *International Journal of Advance Science and Technology*, vol. 29, no. 10S, pp. 7694–7705, 2020, [Online]. Available: https://www.researchgate.net/publication/342199345

[4] E. Berndt, A. Molthan, W. Vaughan, and K. Fuell, "Transforming Satellite Data into Weather Forecasts," *Eos (Washington DC)*, Jan. 2017, doi: 10.1029/2017EO064449.

[5] S. W. Ellingson, "Antennas for the next generation of low-frequency radio telescopes," *IEEE Trans Antennas Propag*, vol. 53, no. 8, pp. 2480–2489, 2005, doi: 10.1109/TAP.2005.852281.

[6] M. J. Chashmi, P. Rezaei, and N. Kiani, "Reconfigurable graphene-based V-shaped dipole antenna: From quasi-isotropic to directional radiation pattern," *Optik (Stuttg)*, vol. 184, pp. 421–427, 2019, doi: https://doi.org/10.1016/j.ijleo.2019.04.125.

[7] S. X. Ta, I. Park, and R. W. Ziolkowski, "Crossed Dipole Antennas: A review," *IEEE Antennas Propag Mag*, vol. 57, no. 5, pp. 107–122, 2015, doi: 10.1109/MAP.2015.2470680.

[8] M. Sugadev, M. Kaushik, V. Vijaykumar, and T. Ravi, "Implementation of NOAA Weather Satellite Receiver using HackRF-One SDR," in *2022 International Conference on Computer Communication and Informatics (ICCCI)*, IEEE, Jan. 2022, pp. 1–4. doi: 10.1109/ICCCI54379.2022.9741043.

[9] S.-S. Lin and Y.-Z. Song, "A Doppler Effect Correction Method for APT Weather Satellite Image Reception," in *2021 International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS)*, IEEE, Nov. 2021, pp. 1–2. doi: 10.1109/ISPACS51563.2021.9651104.

[10] H. Sharma and G. Sujediya, "A REVIEW: WEATHER SATELLITE RECEPTION BY APT DECODING," || *ISO*, vol. 4, 2019.

[11] GISGeography, "GOES vs POES (Geostationary and Polar Operational Environmental Satellites)." https://gisgeography.com/goes-poes-geostationary-polar-operational-environmental-satellites/ (accessed Jun. 07, 2023).

[12] A. E. Quiroz-Olivares, N. I. Vargas-Cuentas, G. W. Z. Segura, and A. Roman-Gonzalez, "Low-Cost and Portable Ground Station for the Reception of NOAA Satellite Images," 2019. [Online]. Available: www.ijacsa.thesai.org

[13] J. Peña-Becerra, E. P. Estupiñán-Cuesta, J. Carlos Martínez-Quintero, and E. Paola Estupiñán-Cuesta, "State of the Art, Perspective and Future Projection," vol. 15, no. 1, 2020, doi: 10.14483/issn.2248-4728.

[14] A. Dattatraya, K. Dr, V. Karad, R. S. Bhadade, A. D. Kulkarni, and A. A. Naik, "Real-time Decoding of Satellite Signals Autonomous Metro-A step towards Automation View project Ultrasonic based Bone Densitometer View project Real-time Decoding of Satellite Signals." [Online]. Available: https://www.researchgate.net/publication/365130286

[15] M. Fathurahman, Zulhelman, A. Maulana, and M. Widyawati, "Design and Development of Dipole Antenna for NOAA Satellite Image Acquisition System and Processing," in *Journal of Physics: Conference Series*, Institute of Physics Publishing, Dec. 2019. doi: 10.1088/1742-6596/1364/1/012025.
[16] E. Ardizzone, A. Bruno, F. Gugliuzza, and R. Pirrone, "A Low Cost Solution for NOAA Remote Sensing," in *Proceedings of the 7th International Conference on Sensor Networks*, SCITEPRESS - Science and Technology Publications, 2018, pp. 128–134. doi: 10.5220/0006639101280134.
[17] R. Wiryadinata, M. Khoirussolih, N. Rohanah, I. Muttakin, and T. Firmansyah, "Image Data Acquisition for NOAA 18 and NOAA 19 Weather Satellites Using QFH Antenna and RTL-SDR," in *MATEC Web of Conferences*, EDP Sciences, Oct. 2018. doi: 10.1051/matecconf/201821802002.
[18] M. Sugadev, M. Kaushik, V. Vijaykumar, and T. Ravi, "Implementation of NOAA Weather Satellite Receiver using HackRF-One SDR," in *2022 International Conference on Computer Communication and Informatics (ICCCI)*, 2022, pp. 1–4. doi: 10.1109/ICCCI54379.2022.9741043.
[19] K. S. Govarthanam and A. M. Kaushik, *Economical Antenna Reception Design for Software Defined Radio using RTL-SDR*. [Online]. Available: www.icieca.in
[20] C. Velasco and C. Tipantuña, "Meteorological picture reception system using software defined radio (SDR)," in *2017 IEEE Second Ecuador Technical Chapters Meeting (ETCM)*, 2017, pp. 1–6. doi: 10.1109/ETCM.2017.8247551.

# APPENDICES

## Appendix A   Raspberry Pi command

```
latitude: 2.269900
longitude: 102.294500
altitude: 24.310000



noaa_receiver: 'gnuradio'
meteor_receiver: 'gnuradio'

test_gain: 40
test_sdr_device_id: 0
test_enable_bias_tee: false
test_freq_offset: 0


noaa_memory_threshold: 100
meteor_m2_memory_threshold: 200

select_best_overlapping_passes: true
select_meteor_pass_over_noaa: true

noaa_15_schedule: true
noaa_15_sdr_device_id: 0
noaa_15_freq_offset: 0
noaa_15_enable_bias_tee: false
noaa_15_gain: 29.7
noaa_15_sun_min_elevation: 6
noaa_15_sat_min_elevation: 30

noaa_18_schedule: true
noaa_18_sdr_device_id: 0
noaa_18_freq_offset: 0
noaa_18_enable_bias_tee: false
noaa_18_gain: 29.7
noaa_18_sun_min_elevation: 6
noaa_18_sat_min_elevation: 30

noaa_19_schedule: true
noaa_19_sdr_device_id: 0
noaa_19_freq_offset: 0
noaa_19_enable_bias_tee: false
noaa_19_gain: 29.7
noaa_19_sun_min_elevation: 6
```

noaa_19_sat_min_elevation: 30

meteor_m2_3_schedule: true
meteor_m2_3_sdr_device_id: 0
meteor_m2_3_freq_offset: 0
meteor_m2_3_enable_bias_tee: false
meteor_m2_3_gain: 29.7
meteor_m2_3_schedule_sun_min_elevation: -90
meteor_m2_3_sun_min_elevation: 6
meteor_m2_3_sat_min_elevation: 30
meteor_m2_3_80k_interleaving: false

days_to_schedule_passes: 7

delete_oldest_n: 0
delete_older_than_n: 30

in delete_files_older_than_days (default is 3 days)
delete_noaa_audio: true
delete_meteor_audio: true
delete_files_older_than_days: 3

extend_for_annotation: true
image_annotation_location: 'North'
produce_polar_az_el_graph: false
produce_polar_direction_graph: true
ground_station_location: ''
antenna_information: ''
show_sun_elevation: true
show_pass_direction: true
produce_spectrogram: true

noaa_crop_telemetry: false
produce_noaa_pristine_image: false
produce_noaa_pristine_histogram: false
noaa_daytime_enhancements: 'MSA MSA-precip MCIR MCIR-precip HVC-precip HVCT-precip HVC HVCT ZA therm sea CC HE HF MD BD MB JF JJ LC TA WV NO histeq'
noaa_nighttime_enhancements: 'MCIR MCIR-precip HVCT ZA therm NO TA sea histeq'
noaa_crop_toptobottom: false
noaa_interpolate: false
noaa_jpg_image_quality: 90
noaa_thermal_temp_overlay: true
noaa_thermal_temp_overlay_location: 'NorthEast'
noaa_map_crosshair_enable: true
noaa_map_crosshair_color: "0xcc3030"
noaa_map_grid_degrees: 10.0
noaa_map_grid_color: "0xff0000"
noaa_map_country_border_enable: true

```
noaa_map_country_border_color: "0xffff00"
noaa_map_state_border_enable: true
noaa_map_state_border_color: "0xffff00"
wxtoimg_map_offset: 10.5                    #Change this value only if you see map offsets
from the ground on WXtoImg NOAA images

flip_meteor_image: true
meteor_jpg_image_quality: 90
satdump_image_scaling_factor: 1
meteor_draw_map_overlay: true
meteor_draw_cities: true
meteor_map_crosshair_enable: true
meteor_map_crosshair_color: "#CC3030"
meteor_map_country_border_color: "#FFFF00"
meteor_create_rain_probability_overlay: true
meteor_create_equidistant_projection: true
meteor_create_mercator_projection: false
meteor_create_spreaded_images_without_overlay: true

web_server_name: philos.local
enable_non_tls: false
web_port: 80
enable_tls: true
web_tls_port: 443
lock_admin_page: true
admin_username: 'admin'
admin_password: 'admin'
web_passes_date_format: 'd/m/Y'
web_datetime_format: 'd/m/Y H:i:s'

log_level: DEBUG

disable_wifi_power_mgmt: false
disable_at_mail: false
```

# Appendix B Gant Charts

| No | PSM 2 Project Activity | Expected | Week | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Actual | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | Meeting with supervisor | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 2 | Meeting with JK PSM | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 3 | Design the suitable antenna | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 4 | Study Related Research | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 5 | Complete Chapter 1: Introduction | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 6 | Progress Update to supervisor | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 7 | Complete Chapter 2: Literature Review | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 8 | Complete Chapter 3: Methodology | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 9 | Submit 1st draft report | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 10 | Review report with supervisor | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 11 | Submit report | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 12 | Preparation for presentation | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |
| 13 | PSM 2 presentation | Expected | | | | | | | | | | | | | | |
| | | Actual | | | | | | | | | | | | | | |

# Development of an SDR-based Ground Station System for Receiving Signals from NOAA Satellites

*by* MUHAMMAD FAIZ BIN BAHARUDDIN



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